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How Much Do Consumers Value Fuel Cost Savings? Evidence from Passenger Vehicle Leasing

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Working Paper 21-27
August 2021
Updated April 2023

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Acknowledgments

The authors would like to thank Rachel Feldman, David Greene, Arik Levinson, Mark Jacobsen, and Lutz Sager for helpful comments.

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How much do consumers value fuel cost savings? Evidence from passenger vehicle leasing*

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April 2023

Abstract

Vehicle leasing involves a consumer renting a car for about three years. Given the typical lease length, we show that estimating valuation of leased vehicle fuel cost savings is fundamentally different from estimating valuation of purchased vehicle fuel cost savings. We find that new vehicle lessees and buyers undervalue lifetime fuel cost savings. But because leasing periods last around three years, new vehicle lessees fully value lease-specific fuel cost savings. Our estimates also imply that leasing companies set residual values, defined as a vehicle's post-lease expected value, with the expectation that used vehicle buyers undervalue post-lease fuel cost savings.

JEL codes: D12, L11, L62, Q41

Key words: Consumer demand, vehicle leasing, valuation of fuel cost savings

*The authors would like to thank Rachel Feldman, David Greene, Arik Levinson, Mark Jacobsen, and Lutz Sager for helpful comments.

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1 Introduction

In 2017, the US transportation sector became the largest source of greenhouse gas (GHG) emissions and has maintained this title since then.[1] To address the growing share of GHG emissions from transportation and to reduce the country's energy dependence, the US Environmental Protection Agency (EPA) and the National Highway Traffic and Safety Administration (NHTSA) currently set standards for new passenger vehicle GHG emissions and fuel economy.[2] Over the past decade, the standards have been revised several times, with the most recent revision from the Biden administration requiring significant increases in fuel economy for model years 2024 through 2026.[3] By law, each revision requires the federal agencies to perform a regulatory impact analysis (RIA) of the new standards, which involves a comprehensive calculation of costs and benefits associated with the policy change.

A large component of welfare in recent RIAs accruing to new vehicle consumers is in the form of fuel cost savings. The standards, by requiring increases in fuel economy, reduce vehicle fuel costs, saving drivers money. Recent RIAs show that the fuel cost savings exceed the technology costs associated with increasing fuel economy.[4] Therefore, tightening the standards increases private welfare in addition to lowering gasoline consumption and GHG emissions. This creates the following puzzle: If tightening the standards increases private welfare, why does the new vehicle market need regulation to adopt fuel-saving technology? The economics literature has identified this puzzle as an example of the energy efficiency gap: the situation where a market fails to adopt energy efficient technologies even when the associated lifetime energy cost savings exceed the upfront adoption costs. Identifying whether a gap exists and understanding where it comes from has significant implications for evaluating the standards.[5]

[1] For more details, see https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

[2] Passenger vehicles include different types of light-duty vehicles, including cars, SUVs, passenger vans, and pickup trucks.

[3] The NHTSA standards require year-over-year eight percent increases in fuel economy for model years 2024 and 2025 and a 10 percent increase in 2026. This represents an increase in new vehicle vehicle economy of 10 miles per gallon for model year 2026, relative to model year 2021. For more details, see https://www.nhtsa.gov/press-releases/usdot-announces-new-vehicle-fuel-economy-standards-model-year-2024-2026.

[4] The RIA performed for the Obama 2012-2025 standards and the Biden administration standards document that the associated fuel cost savings are expected to exceed the technology costs.

[5] The presence of an energy efficiency gap has broad implications that go beyond evaluating changes to fuel economy and GHG standards. In theory, the energy efficiency gap justifies combining multiple instruments if energy

In the passenger vehicle market, one common explanation for the gap is that consumers undervalue fuel costs when making a purchase decision. Undervaluation is generally defined as when consumers are willing to pay less than $1 for $1 of fuel cost savings over the lifetime of a vehicle. Recent economics literature has shown mixed results as to whether consumers undervalue fuel costs. Busse et al. (2013) and Sallee et al. (2016) find that new and used vehicle consumers fully value fuel cost savings. Allcott and Wozny (2014) find moderate undervaluation among used vehicle buyers, while Gillingham et al. (2021) and Leard et al. (2023b) find that new vehicle buyers substantially undervalue fuel cost savings. We contribute to this literature by exploring this issue in the context of three different groups: buyers, lessees, and leasing companies. Our empirical findings are consistent with conclusions drawn from more recent studies, that lessees and buyers undervalue vehicle lifetime fuel cost savings.

We provide insights about how consumers value fuel cost savings by using data on new vehicle leases during 2010-2018. A vehicle lease involves a consumer renting a vehicle from leasing company for a fixed period of time; the modal lease length in our data is three years.[6] Those that lease vehicles, denoted as lessees, pay a leasing company a fixed monthly rate until the lease ends. Leases represent a significant share of new vehicle transactions. In 2018, about a quarter of all new vehicle transactions were leases. Unlike vehicle purchases, vehicle leases have a relatively short usage period by the lessee—generally about three years.[7] As a result, a vehicle's fuel costs over the leasing period are substantially smaller than a new vehicle's expected lifetime fuel costs (see Figure 3). Furthermore, a leased vehicle's fuel costs over the leasing period occur relatively soon after the lease transaction takes place—that is, lessees pay the fuel costs during the three to four year leasing period. This is in sharp contrast to the fuel costs of a newly purchased vehicle, which occur for many years after the purchase takes place. These characteristics of leases reduce uncertainty surrounding expected miles

use produces an externality. In the context of the new vehicle market, the presence of a gap motivates combining a standard or an energy efficient product subsidy with a carbon tax (Allcott et al., 2014).

[6]In our data, about 85 percent of leases are 3 or 4 years. Only 10 percent are 1 or 2 years. See Appendix Figure A.1 for the distribution of lease length in our data.

[7]We find that most lessees plan on returning their vehicles at the end of the lease rather than purchasing them. We discuss this frequency further in section 4.2.3.

driven and gasoline prices, thereby simplifying the calculation of fuel costs expected to occur during the lease.[8]

In our analysis, we estimate how new vehicle lessees value fuel cost savings, and compare this valuation with a separate estimate of how new vehicle buyers value fuel cost savings. We find that new vehicle lessees and buyers both undervalue *lifetime* fuel cost savings, meaning fuel cost savings that occur over the vehicle's useful life. Importantly, however, since new vehicle lessees only pay fuel costs over their leasing period that is much shorter than a typical vehicle lifetime, our results suggest that new vehicle lessees fully value lease-specific fuel cost savings.[9]

Disaggregating our fuel cost valuation analysis by buyers and lessees sheds light on the source of undervaluation.[10] We find that the time dimension of vehicle fuel costs—which occur each year for many years over the life of a vehicle—could explain undervaluation. While our results are consistent with models of bounded rationality or loss aversion, they are not supported by models of rational inattention or hyperbolic discounting.

To motivate our empirical model, we present a conceptual framework to show how to measure consumer valuation of fuel cost savings for leased vehicles. Prior literature has treated new vehicle leases the same as new vehicle purchases (Busse et al., 2013; Leard et al., 2023b). These studies identify consumer valuation based on an estimated relationship between vehicle price, whether it be a buyer purchase price or a lessee purchase price, and

[8] Most leases have total or annual mileage limits, and the fees associated with exceeding these limits can be substantial.

[9] We illustrate this result with an example. Suppose we have two identical consumers, with the only difference being that one leases a 2018 Toyota Corolla and the other buys a 2018 Toyota Corolla. Suppose the per mile fuel cost of the Corolla falls permanently by 10 percent (due to either a fall in gasoline prices or an increase in the Corolla's fuel economy), which reduces the Corolla's present value of lifetime fuel costs by $1,000 and the present value of the first three years of fuel costs by $300. Further suppose that both consumers are willing to pay $300 for this reduction. The calculation to determine whether a consumer undervalues fuel cost savings depends on the timeframe assumed. Traditional analysis estimates whether buyers value lifetime fuel cost savings, which are $1,000 in our example. Therefore, the buyer undervalues fuel costs with an implied valuation ratio of $300/$1,000 = 0.3. Lessees, on the other hand, only incur fuel cost savings over the leasing period and relinquish the vehicle after the lease ends. The appropriate comparison for lessees is therefore lease-specific fuel costs, which are $300. As a result, the lessee fully values lease-specific fuel costs, with a lease-specific fuel cost valuation ratio of $300/$300 = 1.

[10] The literature has identified several possible reasons that could explain undervaluation of vehicle fuel cost savings, including loss aversion (Greene, 2011), inattention (Sallee, 2014), hyperbolic discounting (Heutel, 2015), or credit constraints (Gillingham and Palmer, 2014). Prior studies lack comprehensive empirical evidence on the source of undervaluation. The source of undervaluation is important for designing efficient policy. For example, if inattention is the source of undervaluation, then lowering the cost of information acquisition—such as providing simple and clear fuel cost comparisons—would be efficient.

vehicle fuel costs. We show that doing so can bias estimates of fuel cost savings valuation toward full valuation. This is because of a fundamental difference between a vehicle purchase and a vehicle lease. Consumers that purchase a vehicle pay the full agreed upon price (either with cash or with a loan). Consumers that lease a vehicle, on the other hand, do not pay the full agreed upon price; instead, they pay a monthly amount, which is calculated based on the agreed upon price minus a residual value. The residual value is defined as the expected value of the vehicle once the lease ends. It is set by the leasing company and is generally not negotiable. Ignoring the residual value biases fuel cost savings valuation toward full valuation. This occurs because post-lease fuel cost savings should be capitalized in the residual value and not the purchase price. To obtain an unbiased estimate of fuel cost savings valuation for vehicle leases, the vehicle residual value must be taken into account.

Our data also allow us to estimate leasing companies' perception of how used vehicle buyers value fuel cost savings. When a vehicle is leased, a leasing company purchases the vehicle and sets the residual value for the vehicle. At the end of a lease, leasing companies sell the vehicle on the used vehicle market.[11] Since post-lease fuel costs occur once the lease ends, this residual value should incorporate expected post-lease fuel costs, given that prior literature has shown that the fuel costs are capitalized in used vehicle prices (Busse et al., 2013; Allcott and Wozny, 2014; Sallee et al., 2016). We show that the relationship between residual value and fuel costs provides an estimate for how leasing companies expect the used vehicle market to value post-lease fuel cost savings. In our benchmark specification, we find that leasing companies expect the used vehicle market to value 53 percent of post-lease fuel cost savings when setting residual values, suggesting undervaluation. To the best of

[11] Unlike new vehicles where a fraction are leased, nearly all used vehicles are purchased.

our knowledge, this is the first documented empirical estimate of companies' perceptions of consumer fuel cost valuation.

2 Background on the Leasing Market

Figure 1 illustrates that leases have steadily grown in popularity over the past decade and represent a significant portion US new vehicle transactions.[12] While the processes for leasing or buying a vehicle both start with a consumer negotiating a price for the vehicle they want to drive off the lot—usually some deviation from manufacturer's suggested retail price (MSRP)—the similarities end there. There are two main differences between buying a vehicle and leasing one. First, when leasing a vehicle, the consumer uses the vehicle for an agreed upon period of time (about three years on average) but does not own the vehicle; at the end of the lease term, the car is returned to the leasing company, which is often the captive financing arm of the manufacturer. Thus, a leased vehicle is essentially a rental. When the lease expires, the lessee typically has the option to return the vehicle to the leasing company or to purchase it at a prespecified price known as the residual value. We summarize key differences between leasing and buying a vehicle in Appendix Table A.1.

Second, a lessee only pays for the depreciation (plus interest, taxes, and fees) of the vehicle over the life of the lease rather than paying the full negotiated sale price of the vehicle. The amount of depreciation is determined by taking the difference between the negotiated price and the residual value of the vehicle at the end of the lease.[13] The residual value is set by the leasing company at the time the lease is signed and is generally not negotiable—it represents an estimate of the resale value of the vehicle on the used vehicle market at the end of the lease. Factors such as age, mileage, expected demand, and even gasoline price forecasts can affect a leasing company's residual value calculation. Residual value is usually expressed as a percentage of MSRP. For example, if a vehicle is leased for 36 months with a negotiated

[12]Data from the Bureau of Transportation Statistics (BTS) show lease rates of around 17 percent in 2010, which is moderately higher than the 2010 rate in the InMoment data. However, BTS data show a similar pattern of lease rate growth between 2010 and 2018, with lease rates reaching nearly a quarter of all new vehicle transactions in 2018, which is consistent with our data. For more details, see https://www.bts.gov/content/new-and-used-passenger-car-sales-and-leases-thousands-vehicles.

[13]This transaction structure is why leases typically cost much less per month than financed purchases: the lessee pays for only a portion of the vehicle's value rather than the entire purchase price.

price equal to its MSRP of $30,000 and the vehicle has a residual value equal to 60 percent of MSRP ($18,000), then the lease price to the consumer will be $\$30,000 - \$18,000 = \$12,000$. The consumer will pay $12,000 plus interest, taxes, and fees, over the 36-month period.[14]

The residual value is an important component of the lease transaction and our analysis. Residual value affects both the cost of the lease to the consumer and the expected resale value of the vehicle for the company post-lease. If the residual value is set higher than what the vehicle is worth at the end of the lease, the leasing company will lose money. The company will be forced to sell the vehicle at a lower price than the residual value, effectively meaning it paid for some of the vehicle's depreciation during the lease instead of the lessee. If the residual value is set too low, the leasing company could potentially make money on a sale in the used market. However, usually the lessee has the option to buy the vehicle at the residual value post-lease. This generally does not happen, and we discuss lease return frequency further in Section 4.2.3. But if the residual value is substantially different from the market price, then the lessee might purchase the vehicle at the end of the lease and resell it for a profit. Thus, even market movements in a favorable direction for the leasing company may not result in much financial gain.

While individual leasing companies have their own internal processes for setting residual value, many use a benchmark known as the *Automotive Leasing Guide* (ALG) to inform their decisions.[15] ALG publishes residual value forecasts six times per year and releases forecast values around 45 days prior to their effective date (e.g., January/February residual value forecasts are released in mid-November). This allows leasing companies time to adjust their internal forecasts and incorporate ALG's insights into leases that are signed during the effective period. ALG factors many elements into its residual value forecasts, including current used vehicle prices, economic outlook, and incentives forecasts. Importantly, ALG

[14] Given a $1,000 down payment, $150 in title/registration fees, and an average interest rate based on our sample, the monthly payment for this lease would be around $370.

[15] ALG told us that the company works with nearly every major auto manufacturer and captive leasing company, but that many of them also have their own residual value department. We also spoke to the head of the residual value department for a large auto manufacturer, who confirmed that ALG represents the industry benchmark for residual value setting.

also adjusts residual value forecasts in response to gasoline price changes.[16] Our paper is the first we are aware of to test whether these residual value adjustments fully reflect expected changes in post-lease fuel costs.

3 Data

We use several data sources for our analysis. Our main source is the New Vehicle Customer Survey (NVCS), a national survey of the US new vehicle market conducted annually by the market research firm, InMoment (formerly called MaritzCX). The NVCS is a large sample of new vehicle buyers and lessees each year from all 50 states and the District of Columbia.[17] A typical survey includes roughly 200,000 responses per year, which represents approximately one percent of the new vehicle market (Leard et al., 2023b). The responses include information about the transaction details, including the actual purchase or lease price paid by the respondent, as well as trade-in allowances and other financing details, such as loan interest rates. Following Busse et al. (2013) and Leard et al. (2023b), in our analysis we use actual purchase and lease transaction prices to reflect effects of negotiation on final agreed upon prices. The NVCS also includes vehicle details (e.g., make, model, drive type, fuel type, trim), customer demographic information (e.g., location, income, education level, age, household size, marital status), and many other details related to the purchase and shopping experience. The InMoment survey data span market years 2010 to 2018.[18]

We merge the InMoment data with detailed vehicle characteristics from Wards Automotive (e.g., miles per gallon (mpg), body style, weight, horsepower, wheelbase, MSRP) and national average retail gasoline prices from the US Energy Information Administration. We merge the Wards data to InMoment observations based on a detailed set of vehicle identifiers, including model year, make, model, trim/series (e.g., LE vs. LX) fuel type (e.g.,

[16] For example, an increase in gasoline prices could result in an increase in residual value for fuel-efficient vehicles and a decrease in residual value for gas guzzlers.

[17] The survey has a response rate of about 9 percent and a caveat of sampling method is that vehicles of a select portion of luxury and specialized brands are not sampled in a subset of states. BMW, Jaguar-Land Rover, Mercedes Benz, MINI, Porsche, Smart, and Tesla purchase or lease transactions are not sampled by InMoment in the following states: Alaska, Arizona, California, Hawaii, Illinois, Kansas, Maryland, Montana, Nevada, New Hampshire, New York, Oregon, Pennsylvania, South Dakota, and Washington. Given this limitation, we frame the paper in terms of a single national new vehicle market.

[18] A "market year" in the auto industry runs from October of one calendar year through September of the following year. For example, October 2017 through September 2018 would be considered market year 2018.

gasoline vs. hybrid), drive type (e.g., front wheel drive vs. all wheel drive), body style (e.g., sedan vs. hatchback), and engine size (e.g., 4 cylinder vs. 6 cylinder). This merge captures all variation in observed vehicle characteristics, in particular, miles per gallon, which is especially relevant for our analysis.[19] Dollar amounts (e.g., purchase prices, gasoline prices) are adjusted to 2017 US dollars using the historical Consumer Price Index for All Urban Consumers (CPI-U) from the Bureau of Labor Statistics.

We use a few other data sources to assist with constructing some of the key variables in our analysis. For expected lifetime fuel costs, we use separate vehicle miles traveled (VMT) and scrappage probability schedules for cars and light trucks that are derived from the 2017 National Household Travel Survey and R.L. Polk vehicle registration data, respectively; these schedules are also used by Leard et al. (2023a).[20] For imputing the residual value of leases, we use state sales tax rates—which factor into the monthly payment for a vehicle lease—from the Tax Policy Center and the Tax Foundation.[21]

We calculate expected discounted lifetime fuel costs using a scrappage probability-weighted sum of annual fuel costs:

$$FC_{ijt} = \sum_{n=1}^{T_{ij}} \frac{VMT_{ijn} \cdot prob_{jn}^{survive} \cdot cpm_{jt}}{(1+\delta_i)^{n-1}}. \tag{1}$$

Equation (1) shows expected discounted lifetime fuel cost (FC_{ijt}) calculations for consumer i who purchased/leased vehicle j in time period t (month and year). The term VMT_{ijn} represents consumer i's annual vehicle miles traveled in year n for vehicle j, which we base on the NHTS schedules. The term $prob_{jn}^{survive}$ is vehicle j's survival probability in year n based on scrappage rates (which gets closer to zero as the vehicle ages), and cpm_{jt} is vehicle $j's$ cost per mile, computed as the average gasoline price at the time the transaction occurred divided by vehicle j's fuel economy. The term δ_i is a discount factor, which we assume to be

[19] For example, the 2018 Toyota Camry has 8 different trims in our sample. All 8 trims are sedans with front wheel drive, but the trims differ based on engine size and fuel type. The 2.5-liter gasoline sedans all have fuel economy of 33 MPG, the 3.5-liter gasoline sedans all have fuel economy of 27 MPG, and the hybrid sedan has fuel economy of 48 MPG.

[20] The VMT schedules are broken down by consumer demographics based on income, age, and urban versus rural status. Both the VMT and scrappage schedules are disaggregated by car versus light truck.

[21] The Tax Policy Center data are available at https://www.taxpolicycenter.org/statistics/state-sales-tax-rates. The Tax Foundation data are available at https://taxfoundation.org/updated-state-and-local-option-sales-tax/.

4 percent for all consumers in our main specification. We use bimonthly national gasoline price averages (e.g., January/February, March/April) in our main specification to align with ALG's residual value forecast release schedule. Additionally, we disaggregate equation (1) into pre- and post-lease components to facilitate estimation of lessee valuation of lease-specific fuel cost savings and leasing company perception of used vehicle buyers' valuation of post-lease fuel cost savings.

In our main specification, we exclude any transactions (purchase or lease) whose sale price differs from MSRP by more than 25 percent in either direction.[22] We provide an example of how our sample is trimmed based on removal of outliers, missing data, and other factors in Appendix Table A.2.

3.1 Summary Statistics

We provide selected summary statistics across three groups—full sample, purchases, and leases—in Table 1. Average transaction prices for the full sample are similar to reported estimates from the Bureau of Transportation Statistics,[23] which reports average transaction prices of around $35,000 to $37,000 between 2010 and 2018.[24] Transaction prices tend to be slightly higher among leases relative to purchases, possibly due to high income households being more likely to lease and choose more expensive vehicles relative to choices made by low-income households.[25] Leased vehicles appear to be slightly more fuel-efficient as well, with an average fuel economy that is over 1-mpg higher than that of purchased vehicles. Other vehicle characteristics are similar across groups. Leases tend to be three years long,

[22]We believe differences bigger than this represent unrealistically large discounts or premiums relative to MSRP and consider these price outliers or data entry errors. In our robustness checks, we allow the 25 percent threshold to vary and also include a specification that keeps any transactions that have a sale price that is less than 100 percent of MSRP or greater than 50 percent of MSRP (e.g., for a vehicle with an MSRP of $20,000, we keep any transactions with prices ranging from $10,000 to $40,000). Even including what we believe to be extreme price outliers does not significantly alter our results.

[23]Source: https://www.bts.gov/content/new-and-used-passenger-car-sales-and-leases-thousands-vehicles.

[24]See further evidence from Edmunds.com, which reports average transaction prices of around $35,000 between 2016 and 2018 (Source: https://www.cnbc.com/2021/04/16/car-shoppers-should-buckle-up-for-high-prices-and-low-inventory-.html).

[25]Table 1 shows evidence of income-based sorting, where mean income is higher for people leasing new vehicles versus people buying new vehicles.

with residual values averaging around 58 percent of MSRP, which is in the middle of the range one would expect based on websites such as Edmunds.com.[26]

Gasoline prices average just over \$3 per gallon in our sample. Figure 2 shows the national bimonthly gasoline price variation over time, which affects lifetime fuel costs that factor into our analysis. Figure 3 shows average lease-specific, post-lease, and lifetime fuel costs by market year and vehicle type (car versus light truck). Lease-specific fuel costs represent around one third of lifetime fuel costs, and there is considerable variation in fuel costs during our sample period in a pattern consistent with the gasoline price movements illustrated in Figure 2. Across both cars and light trucks, we see 30 to 40 percent swings in expected fuel costs over the sample period. These are economically meaningful changes in operating costs that we expect to influence demand for fuel economy.

Finally, we turn to consumer demographics. Average household income is around \$120,000 in our sample, which is higher than the US average but is consistent with the fact that new vehicles tend to be purchased by higher income households. Additionally, lessees tend to have higher incomes than buyers, as well as a slightly higher likelihood of having a bachelor's degree.[27] A large percentage of our sample live in urban areas, with a slightly higher percentage of lessees living in urban areas than buyers.[28]

4 Theory and Empirical Strategy

Our goal is to estimate willingness to pay (WTP) for fuel cost savings by consumers and leasing companies' perceived WTP for fuel cost savings of used vehicle buyers. In the sections that follow, we first discuss an approach for estimating WTP with a pooled sample of leases and purchases, which we use as a benchmark to compare with the existing literature. We then extend this framework to examine the leasing market specifically. We introduce a simple theoretical framework that allows us to recover these estimates using exogenous

[26]We discuss the residual value variable imputation and distribution in more detail in the appendix.

[27]These features of the data are consistent with results reported in Mannering et al. (2002), which show that higher income and education are related to a greater likelihood of leasing a vehicle.

[28]These demographic differences could imply that buyers and lessees are not fully comparable sets of drivers and have different vehicle preferences. Both household income and urbanization tend to be correlated with higher demand for fuel efficiency (Leard et al., 2023a), so these demographic characteristics may lead us to expect to estimate a high marginal willingness to pay for fuel cost savings for lessees relative to buyers.

changes in gasoline prices. The framework we describe follows Leard et al. (2023b), and the reduced form estimation approach builds on Busse et al. (2013) and Leard et al. (2023b).[29]

4.1 Baseline Case: Willingness to Pay for Fuel Cost Savings in the New Vehicle Market

4.1.1 Model

Consider a market for a single new vehicle model. The equilibrium price of the vehicle is equal to WTP of the marginal consumer for that vehicle . WTP is a function of several factors, including expected lifetime fuel costs FC, and sales volumes Q.[30]

We are interested in estimating how WTP varies with changes in fuel costs. For example, if gasoline prices increase, all vehicles become more expensive to drive, but fuel-efficient vehicles become less expensive to drive relative to inefficient alternatives. As a result, we might expect demand for less efficient vehicles to fall and demand for more efficient vehicles to rise, or at least that demand for fuel-efficient vehicles would rise relative to less fuel-efficient model-variants (Busse et al., 2013).[31] One way this demand shift could manifest is in the equilibrium prices people pay for vehicles (i.e., prices of fuel-efficient vehicles may increase relative to inefficient vehicles). Some researchers (e.g., Espey and Nair, 2005) have used traditional hedonic methods to estimate this relationship directly and interpreted the price-fuel cost relationship as the change in WTP. However, suppliers and manufacturers could also respond to a change in demand by allocating more resources to producing fuel-efficient cars and allocating fewer resources to producing inefficient cars. As described in Busse et al. (2013), assuming that the supply of vehicles in the market is fixed may make

[29] The reduced form approach we follow has the benefit that our results do not depend on the underlying market structure. Our approach requires making an assumption about the average demand elasticity for consumers, which we vary in our robustness checks.

[30] We consider expected discounted lifetime fuel costs in our analysis as the primary fuel cost variable of interest. A rational consumer who fully values fuel cost savings should be indifferent between paying $1 more in purchase price and saving $1 more in discounted future fuel expenditures. Inherently baked into this variable are assumptions about future gasoline prices, annual miles driven and vehicle survival rates, and consumer discount rates.

[31] To illustrate further, consider demand for the Toyota Prius—a fuel-efficient car—versus demand for a less efficient Toyota Tacoma pickup truck. If gasoline prices go up, demand for both vehicles might decline because their operating costs increased. However, the Toyota Prius is more fuel-efficient, so demand for the Prius should fall by less than demand for the Tacoma. Thus, a gasoline price increase could lead to demand increases for Priuses relative to Tacomas.

sense for the used car market, but in the new car market manufacturers and dealers have some latitude to make supply-side adjustments over the short term of a few months to a couple of years.[32] Thus, the equilibrium response of consumer WTP to fuel cost changes has two components—a component we can directly measure via observed changes in prices, and an implied component based on the shift in equilibrium quantity supplied and consumers' price elasticity of demand. The sum of these two components represents the total change in willingness to pay due to a change in fuel costs. If the supply response to a shift in demand is nonzero, the hedonic approach alone may understate the total change in consumer WTP.

Formally, the relationship between the equilibrium price and WTP of the marginal consumer is as follows:[33]

$$P = WTP(FC, Q(FC)). \tag{2}$$

Differentiating equation (2) with respect to fuel costs and rearranging, we obtain:

$$\frac{\partial WTP}{\partial FC} = \frac{\partial P}{\partial FC} - \frac{\partial WTP}{\partial Q} \cdot \frac{\partial Q}{\partial FC}. \tag{3}$$

The left side of equation (3) is our empirical object of interest—the change in WTP due to changes in fuel costs. We next make some functional form assumptions to assist in estimating equation (3). Specifically, we assume a linear relationship between equilibrium prices and fuel costs $\left(\frac{\partial P}{\partial FC} = \alpha\right)$ and a log-linear relationship between sales and fuel costs $\left(\frac{\partial Q}{\partial FC} = \beta \cdot e^{\beta \cdot FC}\right)$.[34] Additionally, we assume a constant elasticity of demand, where $\frac{\partial WTP}{\partial Q} \cdot \frac{Q}{WTP} = \frac{1}{\mu}$ represents the average own price elasticity across all vehicle model variants. Substituting these assumptions into equation (3), we obtain:

[32] Continuing with the Prius-Tacoma example, Toyota manufacturing plants may have the short-term flexibility to convert some of their Tacoma production to Prius production in response to a gasoline price increase, since demand for Priuses might increase relative to demand for Tacomas.

[33] For ease of exposition, we do not explicitly state factors that are likely to affect equilibrium price and WTP, such as economic conditions and sociodeomographic characteristics. We control for these features in the empirical specification. Furthermore, for clarity here we omit variable subscripts differentiating different households, vehicle model variants, and time periods. We later introduce these when discussing our empirical strategy.

[34] The assumption of a linear relationship between equilibrium prices and fuel costs has been used by others in the literature (Allcott and Wozny, 2014; Sallee et al., 2016) and also facilitates a straightforward computation of changes to WTP.

$$\gamma \equiv \frac{\partial WTP}{\partial FC} = \alpha - \frac{\beta}{\mu} \cdot \frac{P}{Q} \cdot e^{\beta \cdot FC}. \tag{4}$$

The right hand side of equation (4) uses the fact that, in equilibrium, $\frac{\partial WTP}{\partial Q} = \frac{WTP}{\mu \cdot Q} = \frac{P}{\mu \cdot Q}$. We can estimate α and β from data, and can use vehicle stub-level average prices, quantities, and lifetime fuel costs, along with an assumed elasticity μ, to estimate γ. Note that if supply were fixed, we would have $\beta = 0$ and $\gamma = \alpha$.

Following Leard et al. (2023b), an underlying assumption we adopt to estimate changes in WTP is that the average change in WTP across all consumers is equal to the average change in WTP for marginal consumers purchasing or leasing vehicles. Busse et al. (2013) adopt and illustrate this assumption with a supply-demand diagram displaying a parallel demand curve shift in response to a gasoline price change.[35] For ease of exposition and for comparison with our leasing model, we reproduce this diagram in Panel (a) of Figure 4. In this Figure, we show how a shift in demand maps to a change in WTP: the change in WTP equals the sum of the change in price (represented by the estimate for α in equation (4)) and an adjustment for the change in quantity (represented by the second term in equation (4)). Insofar that shifts in demand due to changes in fuel costs are on average approximately parallel, this is a relatively weak assumption.[36]).

4.1.2 Empirical Approach

Our approach uses techniques similar to those of Busse et al. (2013) and Leard et al. (2023b) to account for both price and quantity-related equilibrium responses to fuel cost changes. We estimate separate reduced form relationships between prices and cost per mile and quantity and cost per mile, with cost per mile defined as the gasoline price divided by fuel economy (in mpg).[37] We then combine these estimates with an assumed average own

[35] Specifically, see Figure 5 in Busse et al. (2013).

[36] One way to avoid this assumption would be to estimate a structural model of vehicle demand, which would require assuming a logit, nested logit, or a more complex form for demand (Gillingham et al., 2021; Allcott and Wozny, 2014; Leard et al., 2023a). We adopt the reduced-form approach for ease of estimation, to facilitate straightforward interpretations of coefficient estimates, and to avoid structural assumptions.

[37] Though we are ultimately interested in changes in WTP per change in fuel costs, our reduced form estimates use cost per mile as the primary independent variable of interest rather than lifetime fuel costs. We do this for two reasons. First, using cost per mile makes our estimates easier to compare with prior work. Second, using cost per mile means our regression results do not rely on assumptions we make about VMT and discount factors when computing

price elasticity of demand across our vehicle model-variants to estimate an average change in WTP due to a change in fuel costs (γ).

We estimate γ in several steps. First, we estimate α using the following linear regression equation:

$$P_{ijt} = \alpha \cdot cpm_{jt} + Z_{ijt}\theta + \tau_t + \nu_j + \varepsilon_{ijt}. \tag{5}$$

where cpm_{jt} is the vehicle j's cost per mile in time period t; Z_{ijt} is a vector of vehicle and demographic characteristics and includes a constant; τ_t represents both a market year and bimonthly fixed effect;[38] ν_j is a vehicle stub fixed effect;[39] and ε_{ijt} is an error term. The estimation equation is indexed by household respondent i since we observe household-specific transaction prices and demographics data. Most typical vehicle controls (e.g., horsepower, weight, wheelbase) do not vary materially within a vehicle stub, so our price and quantity regressions include minimal vehicle controls aside from the stub fixed effect. The stub fixed effect also controls for many of the unobserved attributes (e.g., look and feel, interior, handling) that may be correlated with demand and purchase price. Consumer demographic controls include a bachelor's degree dummy, urban/rural dummy, household income, household size, and a race dummy equal to one if the buyer is white and zero otherwise.[40] Following Klier and Linn (2016) and Leard et al. (2023b), our regressions also control for stringency of federal fuel economy standards.[41]

lifetime fuel costs. We convert our cost per mile point estimates to be in terms of fuel costs prior to calculating WTP. The conversion is straightforward and is described in Appendix Section A.3.

[38] New models are generally released starting in October prior to the vehicle's model year, and InMoment uses the market year as the basis for its annual New Vehicle Customer Survey.

[39] We define a vehicle "stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. The same vehicle stub may exist across multiple model years.

[40] InMoment asks households to report their income using one of 19 bins. We take the midpoint of the reported bin and use this as a proxy for household income. The bins are in increments of \$5,000 or \$10,000 up to household incomes of \$85,000 and are in larger increments beyond this amount. We use the American Community Survey to impute missing education, income and race demographic information at the zip code level. For the dummy variables, the imputed data are reported as a percentage rather than a binary variable (e.g., if 63 percent of a zip code has a bachelors degree, the imputed control for observations in that zip code would be 0.63).

[41] We control for fuel economy stringency to account for the possibility that automakers comply to the standards by adjusting vehicle prices. We define regulatory stringency as the absolute distance between the make-level average fuel consumption rate for the vehicle mix in 2010 and the target fuel make-level fuel consumption rate (measured in gallons per mile) based on the 2020 Corporate Average Fuel Economy (CAFE) standards for that same 2010 vehicle mix. Regulatory stringency is thus a measure of how close or far away a vehicle manufacturer is from future CAFE compliance as of 2010. We interact this stringency variable with model year fixed effects to allow for changing regulatory pressure over time.

Next, we estimate the quantity effect to obtain $\hat{\beta}$. We model our quantity equation using a Poisson specification because our sales data consist of non-negative integers with many zeros in the data.[42]

We assume monthly vehicle sales follow a Poisson distribution and estimate the following model:[43]

$$\mathbb{E}[Q_{jt}] = exp\left\{\beta \cdot cpm_{jt} + \overline{Z}_{jt}\psi + \tau_t + \nu_j\right\}. \tag{6}$$

The dependent variable is sales volumes of model variant j in month by year t.[44] The controls and fixed effects are the same in equation (6) as equation (5), with one minor difference being that the fuel cost variable and vehicle characteristics in $\overline{Z}_{jt}$ are averaged across transactions, since we are aggregating to the market year, month, and vehicle stub level.[45] We use the same fixed effects in our quantity regression as the price regression since we want to use the same identifying variation for estimating α and β before combining them to compute γ.

We augment our quantity data by adding zero sales rows to fill in month pairs (e.g., January and February are a pair) in which we do not observe any transactions for a particular trim.[46] This is important because our vehicle stubs are defined at a disaggregated level, so there are month pairs in which we do not observe sales of particular trims. Ignoring those month pairs in our estimate of equation (6) would introduce bias away from zero and overstate the quantity response to changes in fuel costs. The Poisson model is well-suited for count data containing many "zero observations" and provides similar-to-interpret estimates to a log-linear model, while correcting bias a log-linear model would introduce by omitting month pairs with zero sales of particular trims.[47]

[42] Poisson models are preferable to log-linear approaches in empirical settings such as this, since a log-linear model cannot easily accommodate zeros in the data (Wooldridge, 2010).

[43] We use the standard Poisson functional form assumption that $\mathbb{E}[q|X] = exp\{X\theta\}$, where X is the vector of covariates in equation (6) and θ is the corresponding vector of coefficient parameters. See chapter 19 of Wooldridge (2010) for an overview of the Poisson regression model.

[44] "Sales" refer to both leases and purchases here.

[45] Most vehicle characteristics do not vary materially within a stub.

[46] Since we do not have transaction data for months with zero sales, we assign average vehicle and demographic characteristics from nonzero sales with the same make, model, market year, and month to these zero observations.

[47] We estimate equation (6) using the STATA command `ppmlhdfe`, which estimates Poisson models via pseudo maximum likelihood and can accommodate high dimensional fixed effects. See Correia et al. (2020) for details on the estimation procedure for `ppmlhdfe`.

Our main identifying variation comes from changes in cost per mile due to exogenous shifts in retail gasoline prices. As a reminder, we include three fixed effects in our main specification—market year fixed effects, bimonthly fixed effects corresponding to the ALG residual value forecast schedule, and vehicle stub fixed effects. Since there is not material variation in fuel economy within a vehicle stub, cost per mile does not vary within a stub due to the fuel economy of the car purchased. Thus, α and β are identified by changes in gasoline prices within a market year separate from typical seasonal variation in gasoline prices, which we account for with the bimonthly fixed effects.

Once we have estimates $\hat{\alpha}$ and $\hat{\beta}$, we convert the cost per mile estimates to a relationship between the change in WTP and the marginal change in lifetime fuel costs as follows :[48]

$$\hat{\gamma} = \frac{\hat{\alpha} - \frac{\hat{\beta}}{\mu} \cdot \frac{P_{ijt}}{Q_{jt}} \cdot e^{\hat{\beta} \cdot cpm_{jt} + \overline{Z}_{jt}\psi + \tau_t + \nu_j}}{\mathbb{E}\left[\sum_{n=1}^{N_j} \frac{VMT_{ijn} \cdot prob_{jn}^{survive}}{(1+\delta_i)^{n-1}}\right]}. \tag{7}$$

Equation (7) contains the familiar terms from equation (4) and divides them by the sum of expected discounted lifetime VMT to convert from cost per mile to lifetime fuel cost estimates.[49] Here N_j represents the useful life of each vehicle based on our scrappage schedules (in years), VMT is based on the NHTS-based VMT estimates by demographic group, and δ_i represents the consumer's discount factor. For all consumers, we assume a discount factor of 4 percent and demand elasticity -3 for our main specification.[50] We use average prices, quantities, VMT, and cost per mile and compute $\hat{\gamma}$ at the vehicle stub and market year level. We then take the average across all vehicle stub/market year combinations to arrive at the final value we report in our results.

[48]See Appendix Section A.3 for a derivation of this conversion.

[49]The expected value in equation (7) is over survival probability based on the vehicle scrappage schedules.

[50]The 4 percent discount factor is similar to discount factors commonly assumed in the literature (e.g., Gillingham et al. (2021)) and also lies between the two discount factors used in the CAFE standards RIAs (3 and 7 percent). We use 2 and 8 percent as alternative discount factors in our robustness checks. We follow Leard et al. (2023b) and assume a benchmark demand elasticity equal to -3, and vary the assumed demand elasticity from -5 to -2.

4.2 Extension to Leasing Market

4.2.1 Lessees

Consider a market with a single manufacturer that supplies one type of vehicle for lease.[51] In equilibrium, the WTP of the marginal consumer to lease the vehicle can be expressed as $WTP = P - RV$, where P is the negotiated price of the car and RV is the residual value, as described in Section 2.[52] Because the lessee only pays for depreciation (plus interest, taxes, and fees), the effective price the lessee faces is the difference between the negotiated price of the vehicle, P, and the RV set by the leasing company. WTP is affected by many attributes of the car, such as horsepower, size, body style, and drive type, which we control for via the vehicle stub fixed effect. Additionally, WTP is affected by fuel costs for the vehicle. Following our pooled sample analysis, we define FC as lifetime fuel costs, which include both the term of the lease and the vehicle's life beyond the lease.. Similar to the purchase market, demand for fuel efficient vehicles relative to demand for fuel inefficient vehicles is expected to rise as gasoline prices increase. This exogenous shift in demand increases the effective price directly as a result of the change in fuel costs but also indirectly through an increase in quantity (Q) supplied to the market.[53] Thus, we can express the effective price as a function of fuel costs and quantity (which is also a function of fuel costs):

$$P - RV = WTP(FC, Q(FC)). \tag{8}$$

Partially differentiating equation (8) with respect to fuel costs and rearranging yields the following:

$$\frac{\partial WTP}{\partial FC} = \frac{\partial P}{\partial FC} - \frac{\partial RV}{\partial FC} - \frac{\partial WTP}{\partial Q} \cdot \frac{\partial Q}{\partial FC}. \tag{9}$$

[51]We consider one car type and manufacturer for simplicity here, but our setting represents a market where all cars are identical except for fuel efficiency and other observable characteristics.

[52]Our data do not contain residual values for leases, so we calculate them using the industry standard formula for a lease monthly payment. We discuss our calculation further in Appendix Section A.2.

[53]In other words, the equilibrium price is affected by both the WTP of consumers for reduced fuel costs and the supply-side response to an increase in demand for the vehicle.

Similarly to what we did in Section 4.1.1, we make functional form assumptions to allow us to estimate equation (9) from data.[54] Incorporating our assumptions into equation (9), we obtain a simplified expression for consumer WTP for fuel cost savings in the leasing market:

$$\gamma_L \equiv \frac{\partial WTP}{\partial FC} = \alpha_L - \lambda - \frac{\beta_L}{\mu} \cdot \frac{P - RV}{Q} \cdot e^{\beta_L \cdot FC}. \tag{10}$$

Equation (10) has three parameters of interest, $\alpha_L, \beta_L, \lambda$, that correspond to the lessee, supply-side, and leasing company responses to changes in fuel costs, respectively. The combined leasing company and lessee change, $\alpha_L - \lambda$, represents the overall change in cost to the lessee, and β represents the same equilibrium quantity effect as described in Section 4.1.1. We use a similar range of assumptions for μ as in the pooled sample analysis.

We illustrate this calculation in Panel (b) of Figure 4. This figure is similar to the purchase market figure in Panel (a). The key difference is that the vertical axis is price minus residual value instead of just price.

4.2.2 Leasing Companies' Perception of the Used Car Market

The company that leases the vehicle to the consumer expects to sell the vehicle in the used car market once the lease expires.[55] We make the common assumption of a competitive used car market and define the residual value as the leasing company's expected sale price for the car in the used car market once the lease expires:[56]

$$RV = P_u. \tag{11}$$

[54]Specifically, we assume linear relationships between price and fuel costs $\left(\frac{\partial P}{\partial F} = \alpha_L\right)$, RV and fuel costs $\left(\frac{\partial RV}{\partial FC} = \lambda\right)$, and a log-linear relationship between leases (i.e., quantity) and fuel costs $\left(\frac{\partial Q}{\partial FC} = \beta_L \cdot e^{\beta_L \cdot FC}\right)$. Additionally, we assume constant price elasticity of demand, where μ represents the average price elasticity of demand for all vehicles $\left(\frac{\partial WTP}{\partial Q} \cdot \frac{Q}{WTP} = \frac{1}{\mu}\right)$.

[55]It is possible that the lessee buys the car from the manufacturer when the lease expires, but this does not happen often. Most leases last 3-4 years per the NVCS, and among this population we expect fewer than 5 percent of lessees to purchase their vehicle at the end of the lease (see Figure A.1 for additional information).

[56]See, for example, Busse et al. (2013).

Here, P_u represents the average expected price of the car that the leasing company will be paid when the car is sold in the used car market following the expiration of the lease.[57] If gasoline prices change, so too should the lifetime expected fuel costs for the car. Unlike the consumer described in Section 4.2.1, the company forms expectations of the sale price of the vehicle at the expiration date of the lease that are a function of remaining fuel costs after the lease ends. In this setting, we define fuel costs as post-lease fuel costs, denoted as FC_u. The company's expectations for the used car price (and thus RV) should respond accordingly to fuel cost changes that affect the resale value of the car (i.e., the post-lease fuel costs):

$$\frac{\partial RV}{\partial FC_u} = \frac{\partial P_u}{\partial FC_u}.$$

Recall our linear relationship assumption for residual value and lifetime fuel costs from Section (4.2.1):

$$\lambda = \frac{\partial RV}{\partial FC_u} = \frac{\partial P_u}{\partial FC_u}. \tag{12}$$

We estimate λ separately from α_L using residual values calculated from the leasing and auto loan data provided in the InMoment survey. The estimate for $\lambda = \frac{\partial RV}{\partial FC_u}$ represents how leasing companies expect changes in fuel costs to be capitalized in used car prices.

This formulation presents a unique test of undervaluation. Prior studies have estimated the relationship between used vehicle prices and fuel costs, which provides a direct test of whether used vehicle buyers undervalue fuel cost savings: with a fixed used vehicle supply, used vehicle prices should move one-for-one with changes in fuel costs for consumers to fully value fuel cost savings (Busse et al., 2013; Allcott and Wozny, 2014; Sallee et al., 2016). Our setting differs from prior approaches along a relevant dimension: expected future used vehicle supply is unlikely to be fixed in response to current changes in gasoline prices. Prior studies have found that new vehicle registrations respond to changes in gasoline prices

[57] Given the competitive nature of the used vehicle market, it is reasonable to assume that leasing companies set residual values equal to the expected resale value of the vehicle when it returns from lease. As discussed earlier in section 2, leasing companies should not default to setting residual values *above* the expected resale value, since they will lose money doing this. Additionally, leasing companies would not want to set residual values *below* expected resale values because this would make leases more expensive and less attractive to new vehicle customers, and would likely reduce lease sales. In fact, Pierce (2012) points out that leasing companies may have strategic incentives to do the opposite (i.e., set residual values higher) to help move inventory, for example.

(Busse et al., 2013; Leard et al., 2017). As a result, the expected future supply of used vehicles—that is, current new vehicle transactions that become used in the future – should also respond to changes in current gasoline prices. In summary, a change in gasoline prices today can be expected to shift both the demand and supply of the future stock of used vehicles. Therefore, in our framework, we account for both supply and demand movements to quantify how leasing companies expect the used vehicle market to value fuel cost changes.

We assume that the expected equilibrium price of used vehicles is equal to the expected willingness to pay of the marginal buyer of used vehicles, WTP_u.

$$P_u = WTP_u(FC_u, Q_u(FC_u)) \tag{13}$$

This formulation allows for expected movements along and shifts in the willingness to pay schedule and shifts in the supply schedule in response to changes in fuel costs. Differentiating equation with respect to fuel costs and rearranging yields

$$\frac{\partial WTP_u}{\partial FC_u} = \frac{\partial P_u}{\partial FC_u} - \frac{\partial WTP_u}{\partial Q_u} \cdot \frac{\partial Q_u}{\partial FC_u} \tag{14}$$

By substituting the relationship between residual value and used vehicle price in equation (12), we get

$$\frac{\partial WTP_u}{\partial FC_u} = \lambda - \frac{\partial WTP_u}{\partial Q_u} \cdot \frac{\partial Q_u}{\partial FC_u}. \tag{15}$$

We assume a constant elasticity of used demand, where $\frac{\partial WTP_u}{\partial Q_u} \cdot \frac{Q_u}{WTP_u} = \frac{1}{\mu_u}$. Rearranging and substituting this assumption along with equations (13) and (11) into equation (15) yields

$$\frac{\partial WTP_u}{\partial FC_u} = \lambda - \frac{1}{\mu_u} \frac{RV}{Q_u} \cdot \frac{\partial Q_u}{\partial FC_u}. \tag{16}$$

The term Q_u represents the expected number of used vehicle sales for a particular model variant. We define this as the fraction of current period new vehicle purchases and leases that are expected to enter the used vehicle market. To clarify this definition, suppose we observe a leased model variant that has a 3 year lease length. Then Q_u would be the expected number of this model variant being available in the used vehicle market in three years from the beginning of the lease. The expected supply would include leases ending and purchased vehicles that are sold as used 3 year old vehicles. Formally, expected used vehicle sales for a given model variant at the end of that model variant's lease is $Q_u = \phi Q + Q_L$, where Q denotes new vehicle purchases of a particular model variant. The term ϕ, denotes the expected fraction of model variant new vehicle purchases that eventually are sold on the used vehicle market in a year defined by the end of an observation's lease expiration date, and Q_L denotes new vehicle leases of a model variant (which will be sold on the used vehicle market when the lease ends).[58] We observe the number of leases ending (this is just the number of model variants leased in our data scaled up to represent the entire US market).[59] We estimate the fraction ϕ with responses to InMoment survey questions.[60]

We measure the term $\frac{\partial Q_u}{\partial FC_u}$ by combining coefficient estimates from the new vehicle purchase and leasing market, β and β_L, respectively, with similar assumptions about Q_u on the fraction of current period new vehicle purchases and leases that are expected to enter the used vehicle market. Given our assumption for Q_u,we have $\frac{\partial Q_u}{\partial FC_u} = \phi \frac{\partial Q}{\partial FC_u} + \frac{\partial Q_L}{\partial FC_u}$. Making substitutions for identities and functional forms into equation (16) yields our equation for estimating leasing company expectations of used vehicle buyer willingness to pay:

$$\gamma_u = \frac{\partial WTP_u}{\partial FC_u} = \lambda - \frac{1}{\mu_u} \frac{RV}{\phi Q + Q_L} \cdot \left(\phi \beta e^{\beta \cdot FC} + \beta_L e^{\beta_L \cdot FC} \right). \tag{17}$$

[58]A small fraction of leases are expected to be purchased by the original lessee. We treat these transactions as used vehicle sales, so that all new vehicle leases end up being sold on the used vehicle market.

[59]To scale up our observations to represent the entire US market, we use annual national sales volumes from the Federal Reserve Bank of St. Louis. We remove 15 percent of sales as assumed fleet sales, 3 percent as assumed diesel sales, and yearly national electric vehicle sales obtained from energy.gov. Finally, we multiply this number by the annual percentage of leases observed in the InMoment data.

[60]We use the combination of two InMoment survey questions to compute ϕ. These questions are 1) "Approximately how long until your household will acquire its next vehicle?" and 2) "Will this next vehicle replace the vehicle you just acquired?" Among new vehicle buyers in the InMoment survey who answer "Yes" to question 2, we use the time they report in question 1 to approximate when their vehicle will enter the used vehicle market (e.g., a respondent says they are going to replace their current vehicle in 3 to 4 years). The expected replacement ranges span multiple years (e.g., 3 to 4 years), so we use observed ages of different used vehicle types (car vs. light truck) that were purchased in the past year according to the 2017 National Household Travel Survey (NHTS) to split the InMoment responses into specific years. For example, if the NHTS had 60 3-year old cars and 40 4-year old cars purchased in the past year, then we would assume that 60 percent of InMoment "3 to 4 year" responses would be sold as used vehicles in 3 years and 40 percent would be sold in 4 years.

Panel (c) of Figure 4 illustrates our calculation. In this figure, both supply and demand shift out in response to a gasoline price change. The change in quantity, $Q_2 - Q_1$ in the figure, represents the estimated change in used vehicle sales, which is defined in our model by quantity equation parameter estimates β and β_L and expected used vehicle sales $\phi Q + Q_L$. We combine the estimated change in quantity with an assumed value for the price elasticity of demand for used vehicles to make a quantity adjustment to the estimated relationship between fuel costs and residual value ($RV_2 - RV_1$ in the figure) to obtain a change in willingness to pay.

This formulation identifies how leasing companies expect the used vehicle market to capitalize fuel costs, which has implications for consumer undervaluation of fuel cost savings. If residual values net of quantity effects move less than one-for-one with changes in post-lease fuel costs, then leasing companies expect that the used vehicle market to undercapitalize fuel cost savings and used vehicle buyers to undervalue fuel cost savings.

Unlike our pooled analysis in Section 4.1.2, the framework described in this section and Section 4.2.1 enables us to decompose the price response in WTP into two components: a consumer response on the negotiated price (α_L), and a leasing company response based on the change in future expected resale value of the vehicle (λ). This approach allows us to separately assess valuation of future fuel cost savings by the new vehicle market consumer and the leasing company's expectation of used vehicle buyer valuation, whose adjustment of RV and expected used vehicle supply changes in response to fuel cost changes essentially acts as a forecast of the used vehicle market's response.

4.2.3 Estimation Equations

We estimate three regression equations that we use to recover our parameters of interest. We estimate regressions for lease price, residual value, and quantity leased . We use similar estimation techniques as for equations (5) and (6) in Section 4.1.2, and our estimation equations are as follows:

$$P_{ijt} = \alpha_L \cdot cpm_{ijt} + X_i\zeta_1 + Z_j\omega_1 + \tau_t + \nu_j + \varepsilon_{ijt}, \tag{18}$$

$$RV_{ijt} = \lambda \cdot cpm_{ijt} + X_i\zeta_2 + Z_j\omega_2 + \tau_t + \nu_j + u_{ijt}, \tag{19}$$

$$\mathbb{E}[Q_{jt}] = exp\left\{\beta_L \cdot cpm_{ijt} + Z_j\omega_3 + \tau_t + \nu_j\right\}. \tag{20}$$

In equations (18), (19), and (20), X_i and Z_j represent consumer and vehicle characteristics, respectively; τ_t and ν_j are time and vehicle stub fixed effects, respectively; ε_{ijt} and u_{ijt} are error terms. We index the equations for price and residual value by respondent i since we use household-level transaction prices and estimated residual values to estimate α_L and λ, respectively. These regressions also control for regulatory stringency as described in Section 4.1.2, which we interact with model year fixed effects. Equation (20) is defined similarly to equation (6) as a Poisson specification and is estimated via Poisson pseudo maximum likelihood.

To estimate equation (19), we must first calculate residual values based on the industry standard lease monthly cost formula and predicted loan annual percentage rates (APRs) for lessees.[61] We solve for the residual value in the monthly cost of lease formula, yielding[62]

$$RV = \frac{1 + f \cdot T}{1 - f \cdot T} \cdot (P - D - Z) - \frac{m \cdot T}{1 - f \cdot T}, \tag{21}$$

where f is the lease money factor, T is the lease length in months, P is the sales price, D is the down payment, Z, is the value of a trade-in vehicle applied to the lease, and m is the monthly payment amount. In the InMoment data, we directly observe T, P,D, Z, and m. The lease money factor f—the rate that is used to calculate interest payments made while borrowing the vehicle from the leasing company—is the only input into equation (21) that we do not directly observe. Money factors are more commonly discussed in terms of APR. In fact, money factors have a direct mapping to loan APR—a money factor is equal to loan APR divided by 2,400. We estimate APR for lessees based on a regression model that includes observed variables from the InMoment data that are well-known predictors of

[61] See Appendix Section A.2 to see the monthly cost formula and for additional details on how we calculate residual value.

[62] See Appendix Section A.2 for a derivation of this equation.

APR, including time period fixed effects, sociodemographics such as education and income, and credit history.[63] We describe details of the APR estimation model in the appendix. This calculation means that there could be measurement error in one of our dependent variables, but based on our modeling methodology and robustness checks, we do not believe the presence of measurement error materially affects our estimates. Fundamentally, because residual value is our dependent variable, measuring this variable with error influences only the variance of our estimates but not their consistency (Hausman, 2001).[64] To address the effects of measurement error in our calculation of residual value, in the appendix we show estimates from a series of robustness checks that vary assumptions for estimating APRs. In particular, we provide estimates using alternative residual values that are calculated using estimated loan APRs plus or minus 3 percentage points, and residual values that are calculated after adding mean zero noise to the estimated loan APRs. These alternative residual values allow for the possibility that our estimates of loan APR are significantly overstated or understated, or are generally inaccurate. Furthermore, 89 percent of the residuals from the predictive regressions for APR are within 3 percentage points, so we think that the robustness check which varies APR by 3 percentage points covers a reasonable range of possible measurement error.[65] As we show in the appendix, these alternative specifications yield similar results to our benchmark specification for the residual value estimation equation (19).

The key parameters of interest are α_L, β_L, and λ. We convert our estimates of these parameters from cost per mile to lifetime fuel costs, then combine our estimates with assumptions on μ, expected VMT, and discount factors to estimate γ_L. Similar to the baseline model, we calculate γ_L based on prices, quantities, and cost per mile at the market year and vehicle stub level, then compute an overall unweighted average. The final equation that we use to compute γ_L for each market year and vehicle stub is as follows:

[63] We then convert the estimated APR to the money factor by dividing the APR by 2,400.

[64] Measurement error in the dependent variable will tend to increase standard errors and will bias estimates only if the measurement error is correlated with the regression covariates (Wooldridge, 2010). While there is likely some correlation between the measurement error for imputed APR, which we use to compute RV, and cost per mile, this correlation is likely to be small and any bias introduced as a result does not affect our results. Measurement error in APR would not be correlated with gasoline prices, so any problematic correlation would have to be with miles per gallon. Ankney (2021) estimates a statistically significant negative relationship between loan APR and fuel economy for purchases in the new vehicle market, but the magnitude of the relationship is economically small. Thus, we believe that any potential bias related to imputation measurement error is small and does not impact our results.

[65] The APR regression results and residual calculations are available from the authors upon request.

$$\hat{\gamma}_L = \frac{\hat{\alpha}_L - \hat{\lambda} - \frac{\hat{\beta}_L}{\mu} \cdot \frac{P_{ijt}}{Q_{jt}} \cdot e^{\hat{\beta}_L \cdot cpm_{jt} + Z_j \hat{\omega_3} + \tau_t + \nu_j}}{\mathbb{E}\left[\sum_{n=1}^{N_j} \frac{VMT_{ijn} \cdot prob_{jn}^{survive}}{(1+\delta_i)^{n-1}}\right]}. \tag{22}$$

We compute $\hat{\gamma}_L$ using both lifetime fuel costs and lease-specific fuel costs as the fuel cost variable. If the lessee is not planning on buying the vehicle at the end of the lease, they should only care about fuel cost savings that occur during the lease term. Thus, for lessees we expect to observe undervaluation of lifetime fuel cost savings but higher valuation of lease-specific fuel cost savings.

While we include both lifetime and lease-specific fuel cost savings in our estimates, we think lease-specific fuel cost savings are most appropriate to consider when assessing lessee valuation of fuel cost savings. Rational lessees should not care about post-lease fuel cost savings unless they are planning on purchasing the vehicle when the lease expires. Our data suggest that a large majority of lessees return their vehicles at the end of the lease.[66] We compare the timeline for lessees' next vehicle acquisition with their lease length to determine whether we expect them to buy their current vehicle at the end of its lease. Over 95 percent our sample leases a vehicle for one to four years,[67] and almost 100 percent of lessees who indicated whether they plan to return the leased vehicle or keep it post-lease state that they plan to return their vehicle at the end of their lease.[68]

To compute the leasing companies' expectation of used vehicle buyer implied WTP, we estimate formula based on equation (17):

$$\hat{\gamma_u} = \frac{\hat{\lambda} - \frac{1}{\mu_u} \frac{RV_{ijt}}{\phi Q_{jt} + Q_{L_{jt}}} \cdot \left(\phi \hat{\beta} e^{\hat{\beta} \cdot cpm_{ijt} + \overline{Z}_{jt} \hat{\psi} + \tau_t + \nu_j} + \hat{\beta}_L e^{\hat{\beta}_L \cdot cpm_{ijt} + Z_j \hat{\omega_3} + \tau_t + \nu_j}\right)}{\mathbb{E}\left[\sum_{n=x}^{N_j} \frac{VMT_{ijn} \cdot prob_{jn}^{survive}}{(1+\delta_i)^{n-1}}\right]}. \tag{23}$$

[66] Appendix Figure A.1 illustrates this for around 106,000 leases in our sample. These lessees indicated on the InMoment survey that their next vehicle will replace the vehicle they just leased. The remaining lessees did not answer this question on the survey so we cannot determine whether they will return their vehicle or purchase it when the lease expires.

[67] See Appendix Figure A.1 for more details.

[68] For example, someone with a three year lease who says they will acquire their next vehicle in three to four years, then we assume that they return their current vehicle when the lease expires. On the other hand, for a respondent who has a two-year lease who says they will acquire their next vehicle in three to four years, we assume that purchase their vehicle at the end of the current lease. We leave the small number of "expected post-lease purchasers" in our sample as lessees, but we also perform a robustness check in the Appendix where we treat them as purchasers instead of lessees—the results are similar to our main specification.

Equation (23) uses the combined used vehicle quantity $\phi Q_{jt} + Q_{L_{jt}}$, which represents the originally purchased new vehicles that are expected to be sold as used vehicles plus the number of leases that are expiring and will be sold in the used vehicle market. Additionally, the denominator of equation (23) represents *post-lease* discounted expected lifetime VMT, where x is the year in the vehicle's life when it is sold in the used vehicle market.[69]

A final point regarding our set of estimation equations is that since the effective price that a lessee pays for their vehicle is the negotiated sale price minus residual value, one might think that the appropriate analogue to a price regression for lessees is a price minus residual value ($P - RV$) regression. In the theory section 4.2.1, we explain our motivation for estimating price and residual value regressions separately, but we include regressions with $P - RV$ as the dependent variable in Appendix Table A.4 for robustness. Because we use linear estimation equations for price and residual value, taking the difference of point estimates in separate price and residual value equations is mathematically equivalent to estimating a single $P - RV$ regression. This is illustrated by the cost per mile coefficient estimates included in Table A.4 (i.e., the point estimate for the $P - RV$ regression is equal to the point estimate of the price regression minus the point estimate of the residual value regression).

5 Results

We present our main specification regression results in Table 2. Columns 1 and 2 show the baseline model estimates based on equation (4) for the pooled and purchase samples, while column 3 shows estimates for the lease-only sample.[70] Taking column 1 as an example, panel A indicates that a $1 increase in cost per mile is associated with a $24,731 decrease in negotiated price. This may seem quite large at first, but keep in mind that the average cost

[69] For computational simplicity, we make a substitution when estimating the three WTP equations (7), (17), and (23). We use the fact that quantity purchased or leased should approximately equal the exponential of cost per mile plus controls (see, for example, equation (20)) and substitute quantity into our WTP formulas for the exponential expressions. We use observed quantities in the InMoment data for this substitution for our pooled, buyer, and lessee WTP estimation and use nationally scaled up purchase and lease quantities for the leasing company implied used vehicle market WTP estimation. We use the same procedure to scale up national purchases that we describe for leases in section 4.2.2.

[70] For panels A and B, the lease estimates in column 3 follow the same specification as the pooled and purchase samples in columns 1 and 2. Residual value only enters the lease-specific model estimates in panel C.

per mile for our pooled sample is around 13 cents, so a \$1 increase corresponds to more than a 750 percent increase in cost per mile. To make our results comparable to those of prior work, we provide implied elasticities corresponding to our point estimates. For example, in column 1 of panel A, a 1 percent increase in cost per mile is associated with a 0.092 percent decrease in purchase price. This implied elasticity is similar to the ordinary least squares estimates of transaction price on cost per mile provided in Leard et al. (2023b), who use a similar empirical specification and estimate elasticities ranging from −0.113 to −0.156. Our estimated elasticities are slightly lower; this could be because our sample spans 2009-2018 while that of Leard et al. (2023b) spans 2009-2014. The period of 2015-2018 experienced a marked decline in gasoline prices relative to 2009-2014; Leard et al. (2017) provide suggestive evidence that consumers respond more intensely to gasoline price increases than decreases and that consumers are less responsive to gasoline price changes after a period of sustained high prices. Panel B indicates that the implied elasticities with respect to quantity are between −0.660 and −0.514; these are also consistent with Leard et al. (2023b), whose implied elasticities from their quantity regressions are around −0.7. Finally, panel C of column 3 shows that the magnitude of changes in residual value associated with changes in cost per mile is around 27 percent lower than that of price responses by lessees. This difference is the first indication in our results that leasing companies may believe that used vehicle buyers significantly undervalue post-lease fuel cost savings.[71]

We use the price, quantity, and residual value regression estimates from Table 2 to compute the valuation ratios—our estimates of $\hat{\gamma}$ and $\hat{\gamma}_L$—and implied payback periods in Table 3.[72] For our calculations, we assume a benchmark discount rate of 4 percent following

[71] While in our main specification we estimate price and residual value regressions separately for leases, recall that this is mathematically equivalent to estimating a single $P - RV$ regression. Appendix Table A.4 illustrates this equivalence using the sample of leases from our main specification.

[72] We follow the method used in Bento et al. (2018) when calculating implied payback periods based on the estimated valuation ratios. For lifetime fuel cost implied payback periods, we assume a maximum useful vehicle life of 32 years. We also re-scale the implied payback periods for lease-specific fuel cost valuation ratios to put them in terms of the typical lease length. To do this, we multiply the lease-specific valuation ratio by the average lease length in the sample. Thus, a lease-specific valuation ratio that is close to 1 will have a corresponding implied payback period of around 3 years, which is the typical lease length in the sample. We use this simplified rescaling method for lease specific implied payback periods because the relationship between implied payback period and valuation ratio flattens out significantly for vehicle purchases as you approach full valuation (i.e., increasing the valuation ratio from 0.99 to 0.995 has a much smaller effect on the implied payback period than increasing the valuation ratio from 0.49 to 0.495). This "flattening out" is due to the discounting of fuel costs many years in the future and would bias implied payback periods for leases, whose fuel costs are only discounted a few years at most.

Gillingham et al. (2021). We also assume an average own-price elasticity of demand of -3 for all consumers. Focusing first on panel A of Table 3,the baseline specification shows a valuation ratio for the pooled sample of buyers and lessees between 0.64 and 0.73, meaning consumers are, on average, indifferent between $1 of discounted future fuel cost savings and a 64-73 cent increase in purchase price. This benchmark result implies undervaluation of fuel cost savings but suggests higher valuation relative to other recent estimates from studies conducted in the new vehicle market during the same sample period. For example, Gillingham et al. (2021) estimate valuation ratios of 0.16-0.39 estimate a fuel cost savings valuation ratio of 0.54 in their baseline specification. However, our pooled sample estimates are comparable to Leard et al. (2023b) after accounting for differences in the assumed discount rate.[73] Though our valuation ratio is somewhat higher than theirs, both are consistent with undervaluation.

By contrast, our main result differs from those of Busse et al. (2013), who also compute consumer WTP for fuel cost savings in the new vehicle market, albeit during an earlier sample period of 1999-2008. Rather than computing valuation ratios, Busse et al. calculate the implied discount rate which rationalizes the equilibrium price and quantity changes they observe among vehicles in different fuel economy quartiles. For new vehicles, they estimate implied discount rates between -3 percent and 6.7 percent when assuming a demand elasticity of -3, which they claim implies full valuation since the range is in line with prevailing real auto loan interest rates during the period.[74] Our main specification assumes a 4 percent discount factor (near the top of Busse et al.'s range) and suggests undervaluation. One reason why our results may differ from those of Busse et al. is the differing sample periods and gasoline price movements during those periods. From 1999 to 2008, the United States experienced a large increase in gasoline prices, whereas our sample period (2009-2018) includes a sharp decline in prices, particularly at the end of 2014. As suggested in the context of our regression results, these differences in sample period gasoline

[73] Leard et al. (2023b)'s base specification assumes a 1.3 percent real discount rate, and both valuation ratios quoted here assume a demand elasticity of -3.

[74] The implied discount rates of Busse et al. (2013) vary based on assumptions for VMT estimates and based on the chosen fuel economy quartiles for which equilibrium price effects are compared.

price variation could explain why our valuation ratios are lower in magnitude than those implied by Busse et al.

Next, we compare valuation ratios between buyers and lessees. In the baseline model, it appears that lessees value fuel cost savings about the same as lessees as their valuation ratio 95 percent confidence intervals overlap. However, when calculated using only lease-specific fuel costs, lessees appear to significantly overvalue fuel cost savings with an implied valuation ratio of 2.25. Absent closer examination, after accounting for when fuel costs are incurred, it appears that lessees have noticeably higher valuation of fuel costs than buyers.[75]

Panel B of Table 3 accounts for the leasing company's adjustment of residual value in response to fuel cost changes. Since this adjustment moves in the same direction as lessee WTP, ignoring it overstates lessee valuation of fuel cost savings. Indeed, the first column of Table 3 in panel B shows that after correcting for the company adjustment of residual value, lessees value 28 percent of lifetime fuel costs. When considering lease-specific fuel costs, accounting for the residual value adjusts the lessee valuation ratio to 0.96, implying nearly full valuation. The payback periods for lessees in panel B also imply nearly full valuation for lessees—the payback period 3 years when considering lease-specific fuel costs.[76]

Our calculations of valuation ratios and implied payback periods incorporate several assumptions related to factors such as consumer demand elasticities, discount factors, gasoline prices, and VMT. We vary these assumptions in the appendix and generally find results consistent with our main specification. In particular, because we are not aware of any existing empirical estimates of consumer demand elasticities which distinguish between buyers and lessees, we want to account for the possibility that buyers and lessees do not have the same demand elasticity. To do this, we perform robustness checks in which we vary the demand elasticity assumption from -2 to -5 in our calculations of valuation ratios for both

[75] People leasing vehicles may have different driving patterns than buyers. It could be that people with high expected miles sort into leased vehicles since a lease involves paying a fixed monthly payment during the lease period. On the other hand, since leasing contracts tend to have mileage caps, people that lease could drive less. In the appendix, we explore the implications of this possibility by using self-reported expected annual miles traveled data from the InMoment survey, finding that lessees expect to drive about 1,000 fewer annual miles than buyers. We use the InMoment-reported annual miles for years 1-3 of lifetime fuel costs in an alternative specification for which the valuation ratios and payback periods are provided in Table A.5. Applying these expected annual miles traveled data to our valuation calculations, we find that buyers and lessees still undervalue lifetime fuel cost savings and lessees appear to moderately overvalue lease-specific fuel cost savings.

[76] The average lease length in our sample is 37.2 months.

groups.[77] In the table, we also show results where we vary the assumed discount rate from 2 percent to 8 percent. The results appear in Table A.3. With a discount rate of 4 percent, as we vary the demand elasticity, the point estimate of buyers' valuation ratios ranges from 0.50-0.97 and the point estimate of lessees' valuation ratios (with respect to lease-specific fuel costs) ranges from 0.66-1.34. It is possible that lessees are less price elastic than the typical new vehicle buyer, perhaps because they have higher income and tend to purchase more luxury vehicles (Mannering et al., 2002). This might result in the true valuation ratio of lessees being closer to the high end of the valuation ratio range of 0.66-1.34, since the higher end of the range is associated with a lower demand elasticity. Nevertheless, the estimates across this range of elasticity assumptions support the conclusion that buyers undervalue lifetime fuel cost savings and lessees nearly fully value lease-specific fuel cost savings.[78]

The fuel economy valuation literature focuses primarily on determining whether consumers fully value fuel cost savings. Our paper goes a step further and also documents leasing companies' expectation of used vehicle buyer valuation of fuel cost savings by estimating residual value and sales responses to gasoline price changes. Panel B of Table 3 reports our main estimate of the companies expectation of used vehicle buyer-implied valuation ratio, which has a point estimate of 0.53 with a 95 percent confidence interval of (0.41, 0.66) and indicates that leasing companies expect the used vehicle market to value fuel cost changes to some extent. The residual value reflects the company's expected resale value of the vehicle at the end of the lease, so it makes sense that companies would adjust this value as expected fuel costs change.[79]

While our estimates indicate that leasing companies expect used vehicle buyers to value fuel costs, the low valuation ratio is surprising. Around two-thirds of a leased vehicle's lifetime fuel costs occur after the lease expires, so one might expect leasing companies to

[77] These elasticity assumptions are based on empirical estimates (Berry et al., 1995; Goldberg, 1995) and are used in other papers in this literature (e.g., Busse et al. (2013), Leard et al. (2023b)).

[78] The estimates discussed here, along with additional sensitivity analysis of our main results with respect to demand elasticity and discount factor can be found in Appendix Table A.3.

[79] As discussed in Section 2, if leasing companies do not adjust residual value when gasoline prices change, they could face a situation where a vehicle depreciates much more than expected and they take a loss at the end of a lease upon resale. Alternatively, they could miss out on potential profits if they set residual values too low (e.g., for a high-mpg vehicle in a high gasoline price environment), essentially passing those profits to the lessee.

be just as responsive to fuel costs changes as consumers, if not more responsive. While we cannot determine the reason for this undervaluation with certainty, we offer a couple of possible explanations. First, Pierce (2012) points out that these companies sometimes inflate residual values for strategic reasons, such as to signal confidence in a particular model, to offload excess inventory, or to gain market share. These strategic incentives might be prioritized over capitalizing future fuel costs into residual values, which could manifest in our estimates as a low valuation ratio.[80] Second, it could be that leasing companies are not responsive to fuel cost changes because they perceive that used vehicle buyers undervalue fuel cost savings. As noted by Gillingham et al. (2021), automakers generally believe consumers have short payback periods of one to four years for fuel economy investments (NRC, 2015; McAlinden et al., 2016). If companies believe that consumers undervalue fuel cost savings, there is little economic incentive for them to adjust residual values in a way that reflects full valuation.

We perform robustness checks and sensitivity analyses in which we vary the assumptions used in our estimation procedures. We discuss these results in Appendix Section A.1. The robustness checks are generally consistent with our main findings and vary factors such as assumed discount factors and demand elasticities, gasoline price aggregation periods (e.g., quarterly, monthly), RV imputation methods, and price outlier thresholds.

5.1 Relationship to Other Explanations for the Energy Efficiency Gap

Our examination of fuel cost savings valuation for buyers versus lessees offers insights into proposed explanations for the energy efficiency gap.[81] Our results are consistent with the concept of bounded rationality: when consumers make decisions, their rationality is limited by the tractability of the decision problem. For consumers to fully value fuel costs when making a vehicle buying or leasing decision, they must accurately calculate and compare

[80] The interpretation of our estimates is based on the assumption that the identifying gasoline price variation is uncorrelated with unobserved factors, such as the strategic behaviors described above. Our results would require a different interpretation if strategic behaviors often play a large role in defining residual values and if the strategic behaviors are highly correlated with gasoline price movements. Based on correspondences with representatives at ALG, however, we were given the impression that residual values are generally set mechanically as a forecast of expected resale value of the leased vehicle once the lease ends.

[81] See Allcott and Greenstone (2012) and Gillingham and Palmer (2014) for a detailed overview of the energy efficiency gap and its potential causes.

the present value of vehicle fuel costs in equation (1). This is a nontrivial calculation since it requires forecasting expected VMT, the probability that the vehicle is scrapped, gasoline prices, and fuel economy, where the expectation is taken over the interval of the vehicle holding period. This calculation is much more tractable for people leasing a vehicle because of the following reasons:[82]

1. VMT limits are often explicitly written in leasing contracts.[83]
2. The probability that a vehicle is scrapped during the first three years of operation (which is the modal lease length in our sample) is close to zero.
3. Short-run forecasting is generally more reliable and believable than long-run forecasting.[84]

Our results support the explanation posed by Greene (2011) that loss aversion—an over-weighting of losses over potential gains—and uncertainty contribute to the energy efficiency gap. The fact that lessees appear to fully value lease-specific fuel cost savings and face less uncertainty in their cost calculations relative to buyers is consistent with loss aversion and uncertainty deterring investment in energy efficiency. Buyers may be less willing to invest in fuel efficiency than lessees given the increased potential (be it actual or perceived) that the investment will not pay off.[85]

Our results appear inconsistent with hyperbolic discounting, in which near-term payoffs are more heavily discounted relative to an exponential discounting model.[86] A hyperbolic discounting model would predict that lessees would value fuel cost savings less, since their fuel costs tend to occur during the first three years of driving.

[82]Additionally, as illustrated by Figure 3, fuel costs incurred during a lease are lower than post-lease fuel costs, partly because most of the vehicle's useful life will occur post-lease. Lease-specific fuel costs also vary less than lifetime fuel costs—the average standard deviation of lease-specific fuel costs is $1,355 for cars and $1,679 for light trucks, compared to $3,532 and $4,237 for lifetime fuel costs for cars and light trucks, respectively.

[83]Most leases that we observe in the InMoment survey have mileage caps, and lessees on average drive slightly fewer miles than their mileage cap. The mileage caps essentially create an upper bound for lessee VMT, which reduces uncertainty in fuel cost calculations.

[84]For example, Alquist et al. (2013) highlight this with respect to forecasting the price of oil.

[85]Another potential explanation for the energy efficiency gap is that imperfect or complex information is an investment inefficiency that contributes to undervaluation (Allcott and Greenstone, 2012). Our results corroborate this idea as well; lessees face less uncertainty about gasoline prices and miles they expect to drive over the course of a lease, so they are better equipped to calculate expected fuel costs than a buyer.

[86]The presence of hyperbolic discounting may have implications for optimal policy design that encourages adoption of more fuel-efficient vehicles (Heutel, 2015).

Credit constraints are another possible cause for under-investment in energy efficiency.[87] Lessees fully valuing lease-specific fuel cost savings is consistent with the idea that credit constraints hinder energy efficiency investment. For any given vehicle, the monthly cost of driving less for a lease, since the lease requires that the consumer only pay for depreciation (plus interest and fees), not the entire purchase price of the vehicle.[88] This allows a credit-constrained consumer to choose a more expensive vehicle than they would be able to as a buyer. Thus, leasing gives the credit-constrained buyer more flexibility to invest in fuel economy, conditional on being approved for the lease.

Our results point to another possible reason why buyers may undervalue lifetime fuel cost savings of the vehicles they purchase, which is based on how long buyers expect to own their purchased vehicle. According to a recent analysis of over 5 million new vehicle sales by the original owner conducted by iSeeCars.com, owners sell their new vehicles after an average of about 8.4 years (see Table A.1). Notably, this average ownership period is close to the payback period implied by our estimates for buyers of 9.2 years. Many of these owners are likely to sell their vehicle in the secondary market at the end of their holding period. Given the typical ownership period length, a reason why new vehicle buyers may undervalue fuel cost savings is that they expect the used vehicle market to undervalue fuel cost savings, meaning the owner would not expect to capitalize 100 percent of future fuel costs into the resale price of their vehicle. This idea is consistent with our finding that leasing companies perceive undervaluation by used vehicle buyers in the secondary market.

Finally, consider the possibility that consumers are rationally inattentive to differences in fuel costs across product offerings (Sallee, 2014). A rational inattention model would predict that the smaller the fuel cost difference, the more likely consumers are to be inattentive, and the lower their willingness to pay for fuel cost savings. Lessees have a smaller incentive to be attentive since their fuel costs are much smaller because their driving period is only about three years. But we do not find that lessees have a smaller willingness to pay for fuel cost

[87] Ankney (2021) documents the first direct evidence of a relationship between credit constraints and buyers in the US new vehicle market, finding that credit constraints may explain a small portion of the energy efficiency gap.

[88] Argyle et al. (2020) find that consumers are sensitive to monthly payment amounts in the context of auto debt and that they also tend to bunch at round monthly payment numbers (e.g., $300, $400).

savings relative to buyers. Therefore, our results are not consistent with a model of rational inattention.

6 Conclusion

In this paper, we present evidence on how new vehicle consumers value fuel cost savings and how leasing companies expect used vehicle buyers to value fuel cost savings in the US vehicle market. While prior research in this area has pooled leases and purchases when studying fuel cost valuation, our paper takes advantage of the differences in transaction structures between purchases and leases, specifically with respect to vehicle fuel costs. We estimate consumer willingness to pay for future fuel cost savings for a pooled sample and separately for purchases and leases. Moreover, we estimate a lease-specific model that accounts for the fact that the companies that own the leased vehicles respond to fuel cost changes by adjusting residual values—the expected resale value of the vehicle at the end of the lease. We are the first, to our knowledge, to provide an estimate of how a company expects consumers to value fuel cost changes through our decomposition of the lease cost into the negotiated price and the residual value.

Our main results suggest that both buyers and lessees undervalue lifetime fuel cost savings. However, when we account for residual value adjustments made by companies, we find that lessees nearly fully value lease-specific fuel cost savings since the length of a lease is much shorter than a typical life of a vehicle. Furthermore, we find that companies expect used vehicle buyers to significantly undervalue post-lease fuel cost savings, with companies adjusting residual values by 53 cents for every $1 change in post-lease fuel costs.

We show that ignoring residual value adjustments in the leasing market may result in overstatement of fuel cost savings valuation for new vehicle leases. The extent to which leasing companies expect used vehicle buyers to undervalue fuel cost savings is puzzling considering that most of the fuel costs for a vehicle occur post-lease, suggesting that used vehicle prices would be more sensitive to fuel costs changes than new vehicle leases. However, it is possible that leasing companies have other strategic reasons for not adjusting residual values or that they believe there is no incentive to do so given perceived undervaluation of fuel cost savings in the used vehicle market. Our results are consistent with those of other recent research that finds significant undervaluation in the US new vehicle market (Gillingham et al., 2021; Leard et al., 2023b) and we think differences in sample period and corresponding gasoline price variation may explain the differences between our results and those that find full valuation, such as Busse et al. (2013). Moreover, our estimates are robust to changes in assumptions about demand elasticities, discount factors, and data cleaning.

The findings in our paper contribute to the conversation about the underlying mechanisms that influence undervaluation of fuel cost savings and the energy efficiency gap more broadly. Our results are not consistent with models of hyperbolic discounting—regardless of the transaction structure, consumers tend to not value fuel cost savings beyond about three years. However, our results are consistent with loss aversion and information problems as potential explanations for the energy efficiency gap, since lessees' full valuation may be partially a result of reduced uncertainty and complexity surrounding their calculation of expected fuel costs. Lessees' higher valuation may also be consistent with the notion that credit constraints contribute to the energy efficiency gap, since leasing is often pitched as a way to upgrade to a higher quality—and potentially more fuel-efficient—vehicle that a consumer could not afford to buy but can afford to lease because of the lower monthly payment and loan size.

Our results indicate that the source of undervaluation may be attributed to how the used vehicle market capitalizes fuel cost savings. Many new vehicle buyers eventually end up selling their vehicle in the used vehicle market. They could undervalue lifetime fuel cost savings if they expect that these savings will be undervalued at the point when they sell their vehicle. This idea is consistent with evidence from several prior studies. Allcott and Wozny (2014) and Sallee et al. (2016) find that undervaluation is the most severe for older used vehicles.[89]

[89]Furthermore, Leard et al. (2023b) find that low-income households tend to undervalue fuel cost savings more than high-income households. Since low-income households tend to more frequently purchase used vehicles, this pattern of undervaluation is consistent with our results.

Our results come with caveats. A central question that we are not able to directly answer in our study is, Do lessees consider lease-specific fuel costs when negotiating on price and choosing a vehicle, or do they use similar imperfect heuristics similar to those of buyers? We note that the reduced complexity of the fuel cost calculation could be related to the nearly full valuation we estimate, and also that it simply is not rational for lessees to care about post-lease fuel costs, but we cannot be certain based on the limitations of our data. Additionally, it is possible that lessees and buyers are different in unobservable ways that are that are correlated with fuel economy demand, thus making the choice to lease or buy endogenous. Nevertheless, we think empirically highlighting the differences in valuation ratios for buyers and lessees is an important first step in this area. Future work—perhaps in a panel data setting—could attempt to better account for the possibility of selection into leasing or buying.

While leases represent a significant fraction of the new vehicle market currently, they actually constitute an even larger share of the electric vehicle (EV) market.[90] As major automakers continue to amplify their commitment to EVs and other fuel-efficient vehicles, understanding the clean car adoption behavior of lessees is important to increasing market share of clean vehicles in a meaningful way. Our results suggest that there could be potential for exploring policy mechanisms that are differentiated on the basis of buying or leasing to better target consumers who have high demand for fuel economy. For example, federal EV tax credits currently go to the owner of a new vehicle, so buyers receive the credit directly, while lessees must rely on pass-through of the credit since they do not technically own the vehicle. If lessees fully value fuel cost savings over the course of the lease, policies could be designed to specifically encourage clean car adoption through leasing. This type of policy differentiation based on transaction type could offer new avenues for accelerating decarbonization of the US passenger vehicle fleet.

[90] According to the InMoment survey, over 70 percent of new electric vehicles were leased in 2016. This number declined to 46 and 27 percent in 2017 and 2018, respectively.

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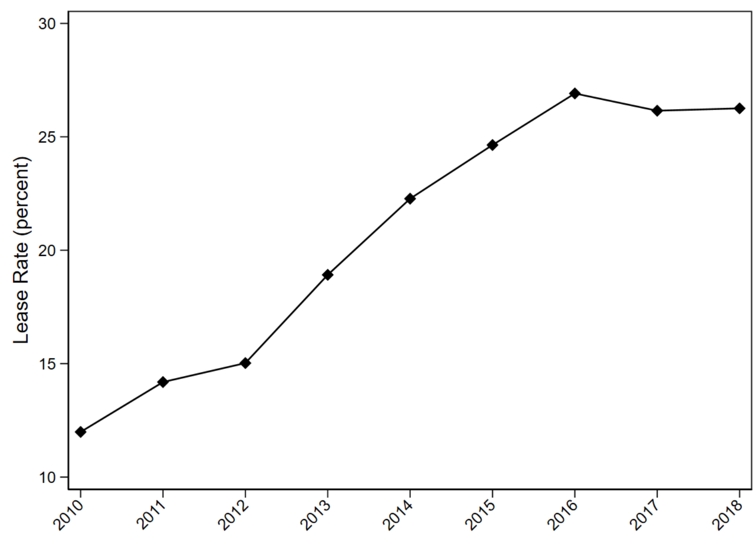
7 Figures and Tables

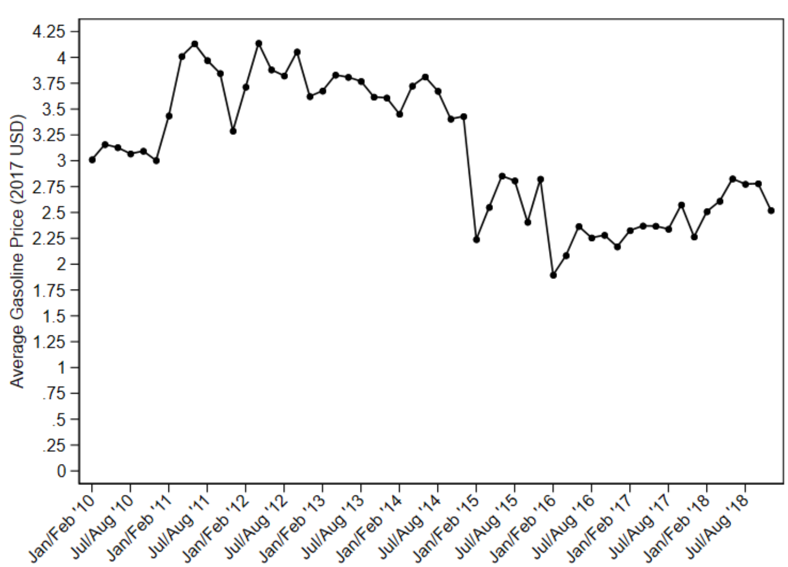
7.1 Figures

Figure 1: US New Car Lease Rates over Time



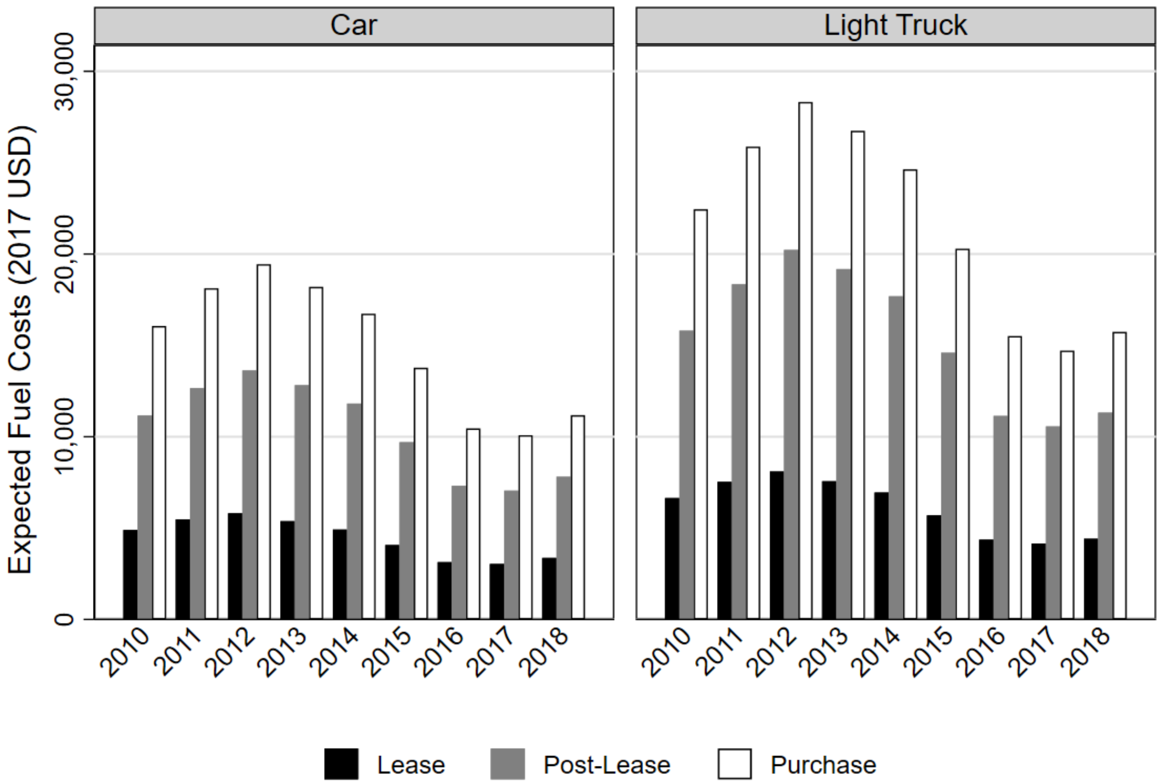
Note: The percentages in this figure are calculated based on the InMoment observations that are not missing a buy/lease designation (approximately 1.5 million transactions).

Figure 2: US Bimonthly Average Regular Gasoline Prices



Source: US Energy Information Administration
(https://www.eia.gov/dnav/pet/pet_pri_gnd_a_epmr_pte_dpgal_m.htm)

Figure 3: Discounted Lease-Specific, Post-Lease, and Lifetime Fuel Costs



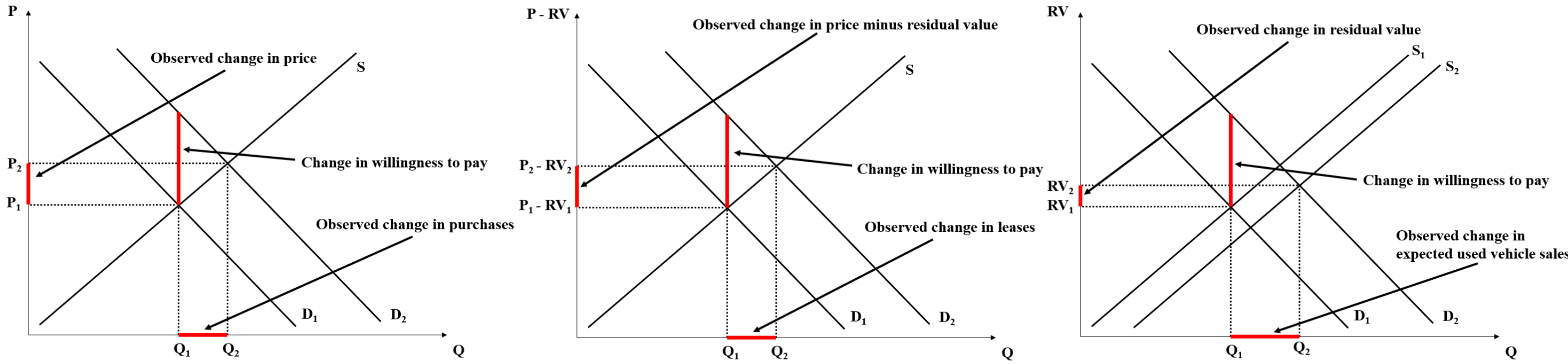
Notes: This graph shows average expected discounted lease-specific and post-lease vehicle fuel costs for each market year in our sample, along with the equivalent lifetime fuel cost if the vehicle was purchased. The fuel cost averages are broken down by car versus light truck and are calculated from the sample of leases used in our main specification (see Table 2); these calculations use bimonthly national gasoline price averages and assume a 4 percent discount factor.

Figure 4: Graphical Representations of Changes in Consumer Willingness To Pay

Panel (a): New Vehicle Purchase Market

Panel (b): New Vehicle Leasing Market

Panel (c): Used Vehicle Market



Notes: This figure shows markets for new vehicle purchases in Panel (a), new vehicle leases in Panel (b), and used vehicles in panel (c). Each panel illustrates how to measure changes in willingness to pay from changes in a vehicle attribute, such as cost per mile caused by gasoline price changes. Panel (a) is a reproduction of Figure 5 from Busse et al. (2013) and serves as a comparison figure for our leasing model figures that appear in Panels (b) and (c). In Panel (a), the horizontal red line along the quantity axis represents the measured change in sales quantities. The vertical red line along the price axis represents the measured change in transaction prices for vehicle purchases. These changes convert to an implied change in willingness to pay, which is the vertical distance separating the two demand curves. Panel (b) shows a similar representation, but with different axis interpretations. The horizontal axis measures lease quantities and the vertical red line along the horizontal axis measures changes in lease quantities. The vertical axis measures price minus residual value and with the vertical red line along the axis measuring the change in price minus residual value. Panel (c) shows a market that is relevant for inferring how leasing companies perceive consumer valuation of fuel cost savings in the used vehicle market. The vertical axis measures residual value as set by the leasing company, which represents an expected price for a used vehicle when the vehicle is sold after the lease ends. The red line along the vertical axis measures changes in the residual value. The horizontal axis measures expected used vehicle sales, and the red line along the horizontal axis measures expected changes in used vehicle sales.

7.2 Tables

Table 1: Selected Summary Statistics

Transaction sample	**Pooled**		**Purchases**		**Leases**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Purchase or lease transaction price (2017 USD)	37,091	15,313	36,605	15,210	39,454	15,549
Cost per mile (dollars per mile)	0.133	0.0477	0.135	0.0487	0.121	0.0409
Vehicle fuel economy (mpg)	24.87	8.352	24.66	8.159	25.90	9.169
Horsepower	240.2	85.02	240.1	86.42	240.5	77.75
Torque	237.8	87.08	238.0	89.08	236.9	76.50
Number of engine cylinders	5.260	1.403	5.300	1.429	5.059	1.249
Vehicle weight (lbs)	3,850	795.0	3,858	818.7	3,809	664.9
Wheelbase (in)	111.3	9.536	111.5	9.939	110.2	7.135
Length (in)	188.5	15.71	188.9	16.27	186.9	12.45
Width (in)	73.48	3.567	73.53	3.670	73.23	2.997
Height (in)	63.49	6.700	63.78	6.812	62.03	5.910
hybrid dummy (1 = Hybrid)	0.0576		0.0596		0.0478	
Plug-in hybrid dummy (1 = PHEV)	0.0145		0.0118		0.0278	
Bimonthly national gasoline price (dollars per gallon)	3.037	0.638	3.064	0.636	2.909	0.634
Expected discounted lifetime fuel costs (2017 USD)	17,856	7,407	18,204	7,582	16,145	6,201
Expected discounted lease fuel costs (2017 USD)					4,693	1,972
Expected discounted post-lease fuel costs (2017 USD)					11,453	4,507
Lease residual value (2017 USD)					18,421	15,973
Lease residual value (percentage of MSRP)					48.22	39.85
Lease length (months)					37.16	6.763
Lease monthly payment (2017 USD)					486.7	344.1
Household income (2017 USD)	120,253	96,715	117,180	94,354	135,254	106,172
Household size (number of people)	2.336	1.189	2.324	1.181	2.396	1.222
Education dummy (1 = has bachelors degree)	0.561		0.551		0.610	
Buyer race dummy (1 = white)	0.835		0.839		0.812	
Urban vs. rural dummy (1 = urban)	0.866		0.852		0.938	
Number of transactions	951,091		789,892		160,911	

Notes: Summary statistics are calculated based on observations from the price regressions in the main specification. All dollar amounts are adjusted to 2017 USD. All fuel cost calculations in this table assume a 4 percent discount factor and bimonthly national average gasoline prices. The following summary statistics from the leases columns are based on slightly fewer observations due to missing data in the sample: lease length, lease monthly payment, residual value, and lease-specific/post-lease fuel costs.

Table 2: Main Specification Regression Results

Transaction sample	Baseline model Pooled	Baseline model Purchases	Lease model Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-24,731*	-23,892*	-27,804*
	(2,051)	(1,880)	(3,741)
Implied elasticity (price with respect to cost per mile)	-0.092	-0.092	-0.087
95 percent confidence interval	[-0.107, -0.077]	[-0.107, -0.078]	[-0.110, -0.064]
Number of observations	951,091	789,892	160,911
R^2	0.944	0.945	0.939
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-4.747*	-4.678*	-3.883*
	(0.583)	(0.591)	(0.713)
Implied elasticity (quantity with respect to cost per mile)	-0.660	-0.652	-0.514
95 percent confidence interval	[-0.818, -0.501]	[-0.813, -0.490]	[-0.699, -0.329]
Number of observations	57,111	55,510	33,819
Pseudo-R^2	0.580	0.565	0.412
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-20,179*
			(3,662)
Implied elasticity (residual value with respect to cost per mile)			-0.120
95 percent confidence interval			[-0.163, -0.077]
Number of observations			115,560
R^2			0.558

Notes: This table reports price, quantity, and residual value regression results across different sample populations. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. $*p < 0.05$.

Table 3: Main Specification Valuation Ratios and Implied Payback Periods

	Vehicle lifetime fuel costs		**Lease-specific fuel costs**	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.73	9.7		
	[0.67, 0.78]	[8.5, 10.8]		
Buyers	0.71	9.2		
	[0.65, 0.76]	[8.1, 10.3]		
Lessees	0.64	7.9	2.25	3.1
	[0.55, 0.74]	[6.5, 9.9]	[1.92, 2.57]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.28	2.9	0.96	3.0
	[0.19, 0.37]	[1.9, 4.0]	[0.65, 1.27]	[2.0, 3.1]
Leasing company perception	0.53	6.1	0.53	6.1
of used car market	[0.41, 0.66]	[4.5, 8.3]	[0.41, 0.66]	[4.5, 8.3]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table 2. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

A Appendix

A.1 Robustness Checks and Sensitivity Analysis

A.1.1 Discount Factors and Demand Elasticity

We vary our assumptions about discount rates and own price demand elasticities. Table A.3 shows these results for our main specification—we use alternative discount factors of 2 and 8 percent and assumed demand elasticities ranging from -5 to -2. Note that the leasing company implied valuation ratios are not sensitive to demand elasticity, so alternative company estimates are based only on changes in the discount factor.

There are two trends worth highlighting in Table A.3 that are consistent throughout our robustness checks. First, as the assumed discount factor increases (i.e., as you look across the rows of Table A.3), so too does the estimated valuation ratio. A higher discount factor implies buyers and lessees are less patient, so an increase in gasoline prices changes future expected fuel costs more for low discount factor consumers than for high discount factor consumers. Thus, for the same observed change in equilibrium price, it appears that the high discount factor consumer responds to fuel cost changes most intensely, since their fuel cost change is small relative to low discount factor consumers. Second, as demand elasticity increases in absolute value (i.e., as you look down the columns of Table A.3), valuation ratios decrease. This results from the final term in equations (4) and (10) becoming smaller as the elasticity increases in absolute value. Consumers are more responsive to changes in price if demand is more elastic, so this amounts to the overall change in demand being dampened. As an example, if an increase in demand for a fuel-efficient car occurs after a gasoline price increase, the higher elasticity consumers would be less likely to purchase or lease this car as the price goes up relative to less-elastic consumers.

The results in Table A.3 are generally consistent with our main findings. With the exception of the highest assumed discount factor (8 percent) combined with the lowest assumed demand elasticity (-2), buyers tend to undervalue lifetime fuel cost savings. For lessees, we find nearly full valuation of lease-specific fuel cost savings across all discount factor assumptions using our default elasticity assumption of -3—willingness to pay values range from 95 to 100 cents per $1 of future fuel savings. As discussed earlier in this section, increasing the demand elasticity results in lower willingness to pay estimates for lessees, with the lowest being around 65 cents per $1 of future fuel savings. Finally, panel C shows valuation ratios that are generally consistent with our main results leasing companies' expectation of used car buyers. Even at a high discount factor of 8 percent, leasing companies expect used car buyers to be willing to pay 56-94 cents in response to a $1 increase of post-lease fuel costs, with the high end of that range corresponding to a demand elasticity assumption of -2.[91] This range still represents undervaluation of post-lease fuel cost savings.[92]

A.1.2 Gasoline Prices

Our main specification uses bimonthly gasoline price variation to align with ALG's publication of residual value forecasts. We also repeat our analysis using monthly and quarterly gasoline price variation. Appendix Tables A.6-A.11 show our estimates using alternative gasoline price variation. The monthly gasoline price estimates are largely unchanged from our bimonthly estimates—Table A.7's valuation ratios and implied payback periods are nearly identical to those of our main specification. The quarterly results, on the other hand, are consistent for buyers but indicate higher valuation ratios for lessees and leasing companies' expectation of used car buyer valuation of fuel cost savings. For example, panel B of Table A.10 shows point estimates of lessees and companies' expectation of used car buyer valuation of lifetime fuel cost savings as 0.46 and 0.77, respectively, which is up 45-64 percent from our main specification estimates. Table A.10 also indicates that lessees actually overvalue lease-specific fuel cost savings with a valuation ratio in panel B ranging from 1.26-1.97. These higher estimates could be from an increase in the variation within fixed effects groups due to using quarterly gasoline price variation, resulting in larger estimated

[91] Used car buyers are likely to have lower household incomes than new car buyers, all else equal. As a result, they are also likely to be more price elastic, so the low end of our elasticity assumption range is less realistic for used car buyers than for new car buyers.

[92] We also perform a robustness check in which we reclassify lessees who are likely to purchase their vehicle at the end of the lease as buyers, since these lessees should care about the lifetime fuel costs for their vehicles. See Section 4.2.3 and Figure A.1 for more information on how we make this determination. The reclassification results in treating a few thousand lessees as buyers. Results are provided in Appendix Tables A.39-A.41 and are similar to our main specification's results.

effects.[93] Nevertheless, the quarterly results are consistent with our finding that lessees fully value fuel cost savings and leasing companies expect used car buyers to undervalue fuel cost savings.

A.1.3 Alternative Residual Value Calculations

Our main specification uses residual values calculated from equation (A.3) in the appendix, which assumes that state sales taxes have been included in the InMoment survey reported prices. We also provide estimates that incorporate state sales tax in the RV formula, as in equation (A.2). These estimates are provided in Appendix Tables A.12-A.14 and are not materially different from our main results. To address the possibility of measurement error in our residual value imputation, we also provide estimates using alternative residual values that are calculated using the imputed loan APR for lessees plus or minus 3 percent, as well as residual values that are calculated after adding mean zero noise to the imputed loan APR. These alternative residual values allow for the possibility that our imputation of loan APR is significantly overstated or understated, or is just generally inaccurate.[94] Appendix Tables A.15-A.23 display estimates using these modified residual values. The estimates for these specifications are similar to our main results—valuation ratio point estimates for lessees range from 0.80 to 1.10 and for leasing companies' perception of used vehicle buyers range from 0.47 to 0.60—giving us confidence that our results are not sensitive to classical measurement error or to systematic over or understatement of loan APR in our imputation process.[95]

A.1.4 Captive Leases

Most leased passenger vehicles are owned by either an in-house "captive" leasing company (e.g., Ford Credit) or a bank (e.g., Wells Fargo). While the financial incentives for setting

[93] This is particularly true for the population of leases, since there are fewer of them in our sample and there are likely some vehicle stub/bimonthly/market year combinations containing a small number of leases. Increasing the time period fixed effect from two to three months allows for more price, quantity, and residual value variation in the lease sample, which drives the lessee and company valuation ratio estimates.

[94] We discuss these alternative residual values further in Appendix Section A.2.

[95] While the possibility remains that there exists measurement error which is correlated with cost per mile, we think any bias introduced will not materially affect our results. See Section 4.2.3 for additional discussion of this.

residual values should be the same for both banks and captive leasing companies, in practice they may be different. Captives might have strategic reasons for keeping residual values high, such as to move excess inventory or gain market share in a particular vehicle segment (Pierce, 2012). These incentives should generally not exist for banks that lease vehicles because the banks are not concerned with market share and other competitive elements of the auto industry; they should just be concerned with profitably leasing the vehicles they purchase. As a result, we might expect to see lower overall responsiveness to fuel cost changes if we examine leases financed by captive companies only.[96] The results in Appendix Tables A.24-A.26 are somewhat consistent with this expectation, as implied valuation ratio point estimate for used car buyers expected by captive leasing companies is around 13 percent lower (0.46 versus 0.53) than the estimate from our larger main sample. This is consistent with some of the strategic reasons suggested by Pierce (2012) as to why captives may purposely inflate residual values even when they are not directly expected to be profitable.[97]

A.1.5 Price Outliers and Limited Data Imputation

Our main specification excludes any transactions whose negotiated price differs by MSRP by more than 25 percent in either direction. We change this threshold to 20 percent and 30 percent and provide the results in Appendix Tables A.27-A.32. In both cases, the results are consistent with those of our main specification. Furthermore, to assuage any concern that we are overexcluding observations, we also provide estimates for which we include any observations whose price is at least 50 percent of MSRP and at most twice as large as MSRP. Using such a wide range will likely include some extreme outliers, and it is not surprising that the corresponding results, shown in Appendix Tables A.33-A.35, have larger standard errors than our main specification. Nevertheless, the point estimates and valuation ratios when including these extreme outliers are similar to those of our main specification, giving us confidence that our findings are not driven by the exclusion of price-based outliers.

[96] The InMoment survey provides the financing source for auto loans and leases. We use this to identify the leases that are underwritten by captive financing companies and re-estimate our results using this reduced sample.

[97] Unfortunately, we do not have enough non-captive lease transactions to produce precise estimates to compare with the captive leases.

Finally, to ensure that our results are not sensitive to the demographic variables we impute, we provide estimates that omit observations with missing demographic variables. We provide the results of this limited imputation specification in Appendix Tables A.36-A.38. The results are similar to those of our main specification: buyers undervalue lifetime fuel cost savings, lessees nearly fully value lease-specific fuel cost savings, and leasing companies expect used car buyers to undervalue post-lease fuel cost savings.

A.2 Imputing Residual Value

Starting with the standard lease monthly payment formula, we have[98]

$$m = (1+\tau)\left(\frac{P-D-Z-RV}{T} + f\cdot(P-D-Z+RV)\right), \tag{A.1}$$

where

- RV = residual value
- m = monthly payment amount
- P = negotiated purchase price
- D = down payment amount
- Z = trade-in value
- T = lease length (months)
- f = lease money factor
- τ = state sales tax rate

We rearrange equation (A.1) to solve for the lease residual value:

$$RV = \frac{1+f\cdot T}{1-f\cdot T}\cdot(P-D-Z) - \frac{m\cdot T}{(1+\tau)(1-f\cdot T)}. \tag{A.2}$$

[98]The final term in parentheses of equation (A.1) is typically written as $(P + fees - D - rebates + RV)$. We assume that any fees and rebates associated with the lease are already incorporated into the negotiated purchase price reported in the InMoment data.

If we assume that state sales taxes are already incorporated into the lease monthly payment data provided by InMoment, equation (A.2) simplifies to:

$$RV = \frac{1 + f \cdot T}{1 - f \cdot T} \cdot (P - D - Z) - \frac{m \cdot T}{1 - f \cdot T}. \tag{A.3}$$

We use equation (A.3) to calculate our main residual variable for our analysis. In our data we observe everything on the right hand side of equation (A.3) except for f, the lease money factor. The lease money factor is the leasing market's analogue of loan APR—it is the rate that is used to calculate interest payments made while borrowing the vehicle from the leasing company. In fact, money factors have a one-to-one mapping to loan APR—to obtain a money factor from a loan APR, one simply divides the loan APR by 2,400 (e.g., 3 percent APR corresponds to a money factor of $3/2,400 = 0.00125$).

We leverage the one-to-one mapping between loan APR and the money factor to impute residual value. We do this in two steps. First, we regress loan APR on self-reported credit history, demographic variables (education, urban/rural, race, income, household size), and month and year fixed effects for the *buyers* in our sample.[99] We then use this linear relationship to predict loan APR for the lessees in our sample. Second, for any lessees who are missing self-reported credit history, we perform a second linear prediction by regressing the predicted loan APR on the same demographic variables and year and month fixed effects for the lessees who now have a predicted loan APR. We use this second linear relationship to predict the APRs for lessees who were not able to use the buyer-based prediction. We divide these predicted APRs by 2,400 to obtain the money factors that we use to calculate residual value.[100]

[99] We assume leases that are missing down payment information have a down payment of zero. Down payments typically range between \$0 and \$3,000 and have the effect of prepaying the lease. Down payments are not common on leases and are generally disadvantageous since they are essentially prepaying the depreciation owed on the lease without giving the lessee any equity in the vehicle. We do not observe any zeros in our data, so it is reasonable to think that lessees who did not make a down payment left this field blank on the InMoment survey.

[100] Many leases in the InMoment data are missing trade-in values. We leverage vehicle disposal data in the InMoment survey to infer trade-in values of zero for a portion of these leases. If lessees indicated that they did not dispose of a vehicle or did not own a vehicle when they acquired their new lease, we assume a trade-in value of zero. We also assume a trade-in value of zero if a lessee's disposed vehicle was also a lease (i.e., the lessee is returning one leased vehicle and acquiring a new leased vehicle).

Figure A.3 plots the distributions of calculated residual value (expressed as a percentage of MSRP) using equations (A.2) and (A.3). While there are some potential outliers, much of the distribution lies within the 40 to 80 percent range, which lines up with typical residual values that get quoted through online sources such as Edmunds.com and TrueCar.com.[101] Additionally, we explore the possibility of significant measurement error in Figure A.4, which plots distributions of our main RV variable and alternative calculations that add or subtract 3 percent to our imputed APR values, as well as a distribution that adds mean zero noise from a normal distribution to imputed APR.[102] The purpose of this figure is to illustrate the potential ramifications of our APR imputation being significantly inaccurate, which we think is unlikely. A 3 percent shift represents more than one standard deviation change in APR. However, these changes cause only modest shifts in the residual value distributions, causing the means to change by around 11 to 14 percent relative to our main RV variable. We also substitute these modified residual values into our main analysis as robustness checks. Tables A.15-A.23 display results from our main specification with the shifted residual values used instead of our main RV variable. The results are similar to our main specification, which further alleviates any concern that measurement error in our imputation of loan APR is significantly biasing our estimates.

[101] Leases at the higher and lower end of the residual value distribution are likely associated with shorter or longer leases, respectively, as length of lease is a primary determinant of residual value.

[102] We add random noise using a normal distribution with mean zero and standard deviation equal to the sample standard deviation of loan APR from our purchase sample.

A.3 Converting Regression Estimates from Cost per Mile to Lifetime Fuel Costs

This section shows the conversion of our model estimates in terms of cost per mile to lifetime fuel costs. Consider a modified version of the model described in Section 4.1.1, where we have

$$P = WTP(cpm, Q(cpm)). \tag{A.4}$$

Here, cpm is the cost per mile of of a vehicle. Partially differentiating (A.4) with respect to cost per mile and rearranging yields

$$\frac{\partial WTP}{\partial cpm} = \frac{\partial P}{\partial cpm} - \frac{\partial WTP}{\partial Q} \cdot \frac{\partial Q}{\partial cpm}. \tag{A.5}$$

We make the same functional form assumptions as earlier to simplify equation (A.5). Specifically, we assume a linear relationship between equilibrium prices and cost per mile ($\frac{\partial P}{\partial cpm} = \alpha$), a log-linear relationship between sales and cost per mile ($\frac{\partial Q}{\partial cpm} = \beta \cdot e^{\beta \cdot cpm}$), and constant elasticity of demand, where $\frac{\partial WTP}{\partial Q} \cdot \frac{Q}{WTP} = \frac{1}{\mu}$ represents the average own price elasticity across all vehicle model variants. Incorporating these assumptions gives us the following:

$$\frac{\partial WTP}{\partial cpm} = \alpha - \frac{\beta}{\mu} \cdot \frac{P}{Q} \cdot e^{\beta \cdot cpm}. \tag{A.6}$$

We want to convert equation (A.6) to be in terms of expected lifetime fuel costs. To do this, we index terms with household i, vehicle j, and time period t subscripts to match the level of detail of our data and define expected lifetime fuel costs as

$$FC_{ijt} = \mathbb{E}\left[\sum_{n=1}^{N_j} \frac{cpm_{jt} \cdot VMT_{ijn} \cdot prob_{jn}^{survive}}{(1+\delta_i)^{n-1}}\right]. \tag{A.7}$$

Rearranging, we solve for cost per mile:[103]

$$cpm_{jt} = \frac{FC_{ijt}}{\mathbb{E}\left[\sum_{n=1}^{N_j} \frac{VMT_{ijn} \cdot prob_{jn}^{survive}}{(1+\delta_i)^{n-1}}\right]},$$

which implies that

$$\frac{\partial WTP}{\partial cpm_{jt}} = \frac{\partial WTP}{\partial FC_{ijt}} \cdot \mathbb{E}\left[\sum_{n=1}^{N_j} \frac{VMT_{ijn} \cdot prob_{jn}^{survive}}{(1+\delta_i)^{n-1}}\right].$$

Finally, substituting equation (A.6) in for $\frac{\partial WTP}{\partial cpm_{jt}}$ and solving for $\frac{\partial WTP}{\partial FC_{ijt}}$, we arrive at the final conversion equation:

$$\gamma = \frac{\partial WTP}{\partial FC_{ijt}} = \frac{\alpha - \frac{\beta}{\mu} \cdot \frac{P}{Q} \cdot e^{\beta \cdot cpm_{jt}}}{\mathbb{E}\left[\sum_{n=1}^{N_j} \frac{VMT_{ijn} \cdot prob_{jn}^{survive}}{(1+\delta_i)^{n-1}}\right]}. \tag{A.8}$$

Equation (A.8) characterizes the conversion from our baseline model cost per mile regression estimates to our desired valuation ratio γ, which is relative to vehicle fuel costs. We show the derivation of the conversion only for our baseline model here, but the same approach applies to converting estimates for our leasing model and for leasing companies' implied used vehicle buyer WTP.

The final conversion equation for the leasing model is as follows:

$$\gamma_L = \frac{\partial WTP}{\partial FC_{ijt}} = \frac{\alpha_L - \lambda - \frac{\beta_L}{\mu} \cdot \frac{P_{ijt}}{q_{jt}} \cdot e^{\beta_L \cdot cpm_{jt}}}{\mathbb{E}\left[\sum_{n=1}^{N_j} \frac{VMT_{ijn} \cdot prob_{jn}^{survive}}{(1+\delta_i)^{n-1}}\right]}.$$

Similarly, the conversion equation for leasing companies' implied used vehicle buyer WTP is as follows:

$$\gamma_u = \frac{\partial WTP}{\partial FC_{ijt}} = \frac{\lambda - \frac{1}{\mu_u} \frac{RV}{\phi Q + Q_L} \cdot \left(\phi \beta e^{\beta \cdot FC} + \beta_L e^{\beta_L \cdot FC}\right)}{\mathbb{E}\left[\sum_{n=x}^{N_j} \frac{VMT_{ijn} \cdot prob_{jn}^{survive}}{(1+\delta_i)^{n-1}}\right]},$$

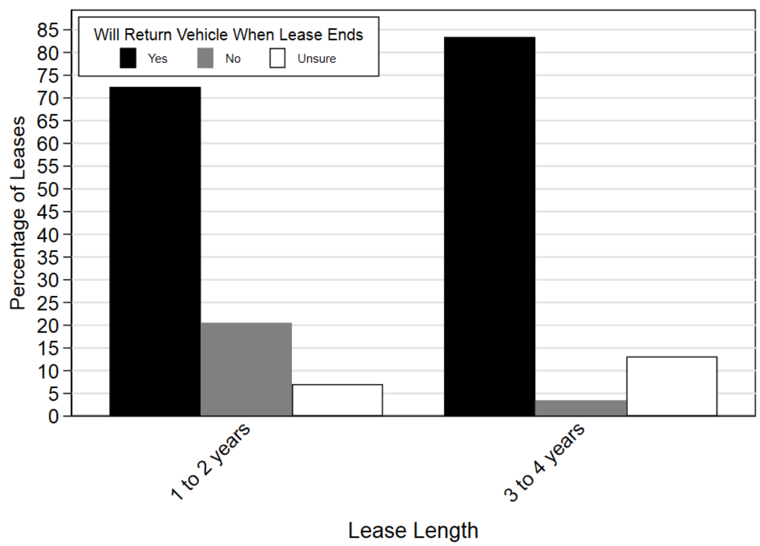
[103]Note that cost per mile does not vary with time even thought it has a t subscript. Thus, it can be factored out of the summation in equation (A.7).

where x represents the first year after the leased vehicle is returned by the original lessee or the purchased vehicle is sold by the original buyer in the used market (i.e., the lifetime expected VMT in the denominator represents *post-lease* discounted expected VMT).

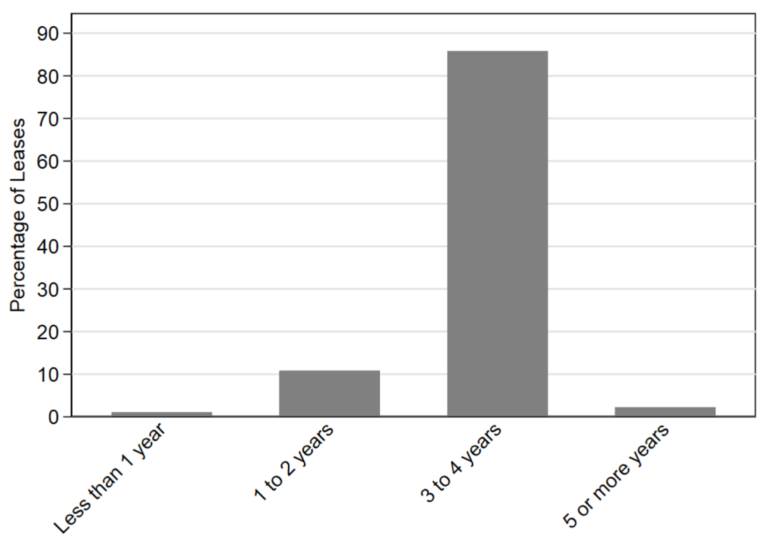
A.4 Appendix Figures

Figure A.1: Lease Return Frequency and Lease Length

Panel A: Lease return rates

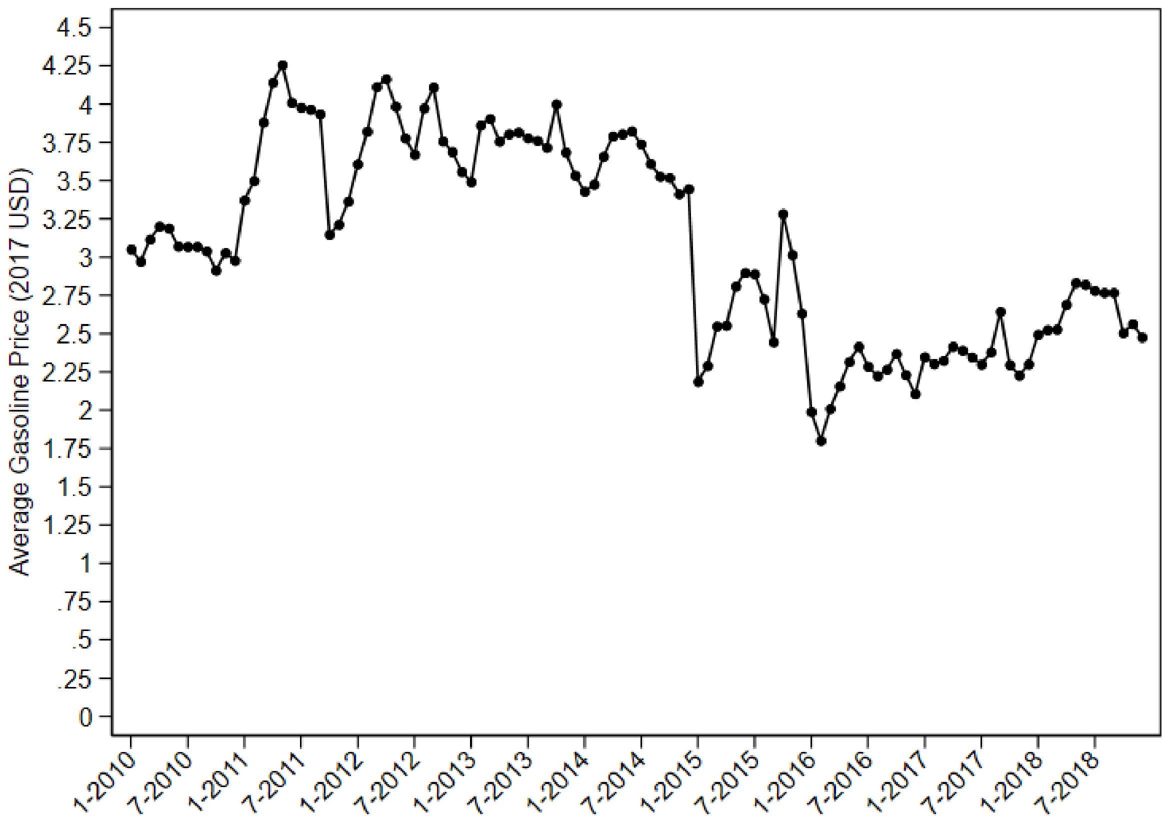


Panel B: Distribution of lease length



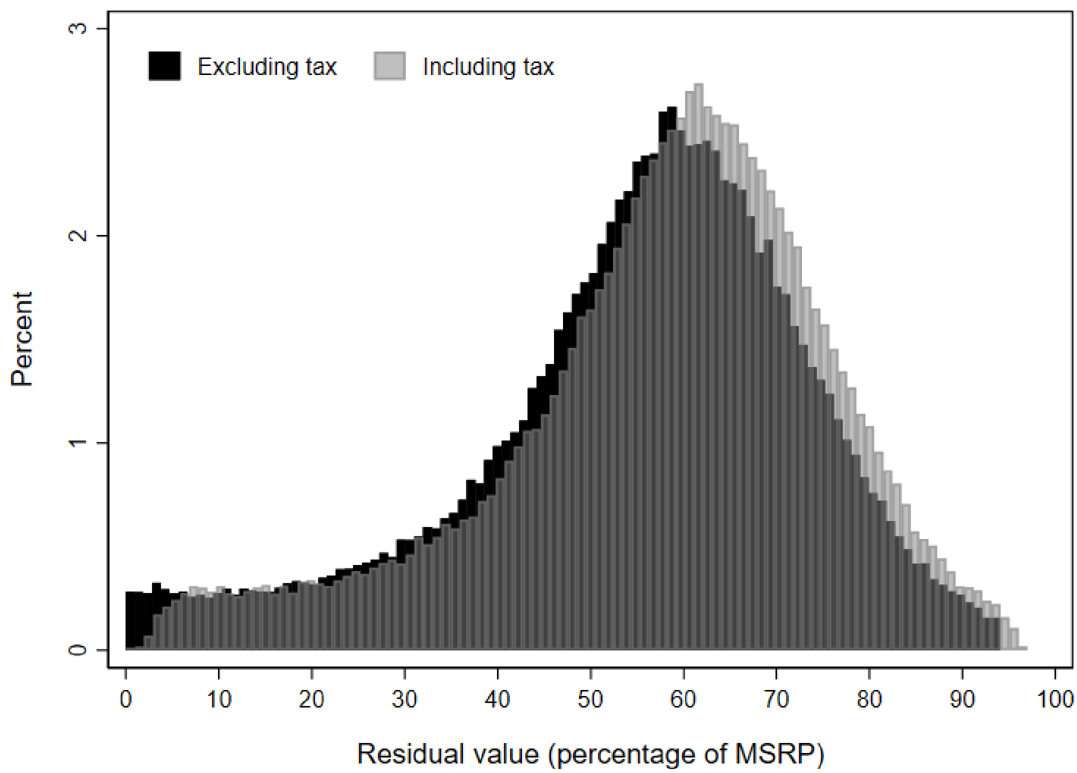
Notes: Panel A of this figure shows the percentage of lessees who are likely to return their vehicle at the end of the lease, broken down by lease length. We calculate this rate for lessees who expect their next vehicle to replace their current lease (around 106,000 leases) by comparing the time until their next vehicle acquisition with their lease length. Lessees who expect to acquire their next vehicle within the same time frame as their lease expiration are deemed likely to return their leased vehicle, while lessees who expect to acquire their next vehicle beyond their lease expiration are deemed likely to purchase their current vehicle at the end of the lease. Panel B shows the distribution of lease lengths in our sample. Over 90 percent of leases fall in the 1-to-4 year range, so we only include this range in Panel A.

Figure A.2: US Monthly Average Regular Gasoline Prices



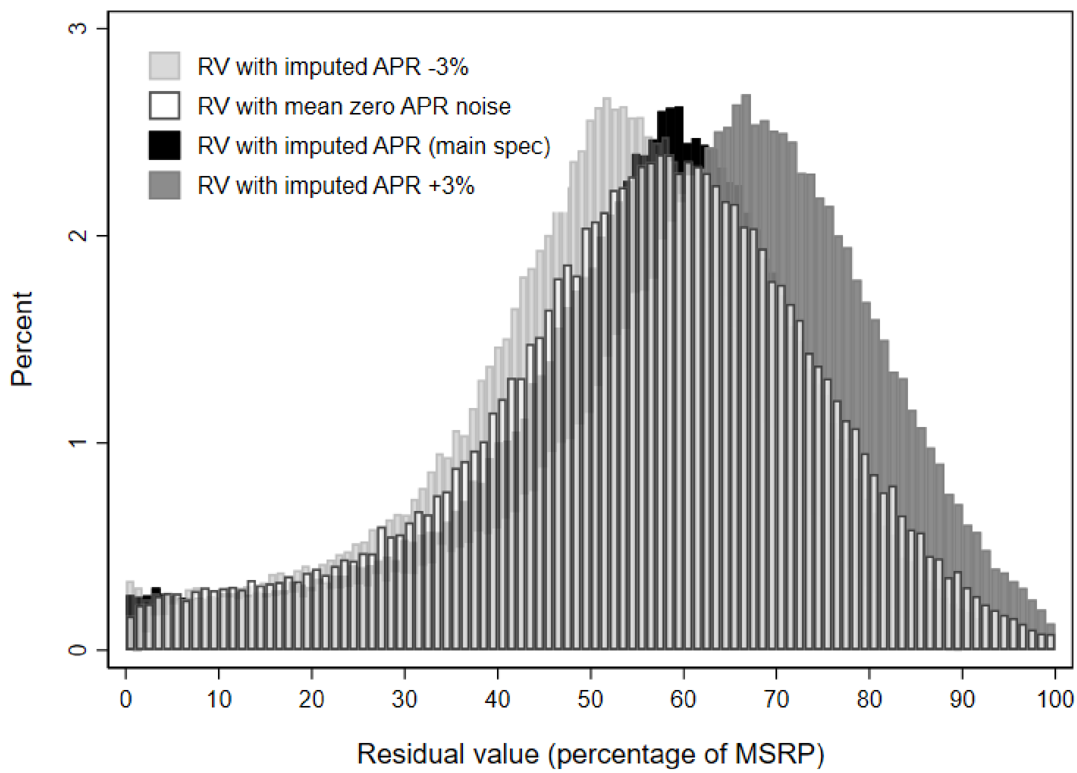
Source: US Energy Information Administration
(https://www.eia.gov/dnav/pet/pet_pri_gnd_a_epmr_pte_dpgal_m.htm)

Figure A.3: Distributions of Calculated Lease Residual Values



Notes: This graph shows histograms of calculated residual values as a percentage of MSRP (after removal of outliers). The graph plots histograms based on residual value calculations that exclude or include state sales tax in the formula, respectively. The vertical lines indicate the means of each distribution. Vehicle residual values vary widely. For example, according to Edmunds.com, 36-month leases tend to have RVs around 50 percent, but they can range from the low 40s to the mid-60s.

Figure A.4: Calculated Residual Values with APR Margin of Error (3 percent)



Notes: This graph shows histograms of calculated residual values as a percentage of MSRP (after removal of outliers). The distribution in the center is the *RV* variable used in our main specification. The three alternative distributions add or subtract 3 percent to the imputed APR values that we use to calculate residual value, or add mean zero noise to the residual value imputation. A 3 percent swing in APR represents more than one standard deviation, so this figure illustrates how the distribution of residual values could shift if our imputation process contained substantial measurement error. The distributions largely overlap and the means of the alternative distributions differ from our main *RV* variable by around 11 to 14 percent.

A.5 Appendix Tables

Table A.1: Characteristics of Buying versus Leasing a Passenger Vehicle

	Buying a passenger vehicle	**Leasing a passenger vehicle**
New vehicle market share (2018)	74%	26%
Who owns the vehicle	Household buyer	Leasing company
Consumer role	Owns the vehicle	Rents the vehicle for a fixed period of time
Holding/driving period	Until the vehicle is sold, scrapped, or given away (average ownership 8.4 years)[104]	Specified in a leasing contract; the model lease length is 3 years.
Consumer costs	Purchase price, taxes, and interest (if purchased with a loan)	Monthly payment during lease; primarily a function of price minus residual value
How residual value plays a role	Does not play a role	The higher the residual value, the lower the monthly lease payment.
Price negotiation	Yes	Yes
Miles driven limit	No	Yes

[104] Average ownership of 8.4 years according to a study conducted by automotive research firm iSeeCars.com, which analyzed over 5 million vehicles sold by the original owners.

Table A.2: Data Cleaning and Missing Data Sample Reduction: Lease/Residual Value Model

	Price Regression	**Quantity Regression**	**RV Regression**
Initial number of new vehicle transactions	1,813,684	1,813,684	1,813,684
Drop observations missing lease flag	223,733	223,733	223,733
Drop purchases from sample	1,254,562	1,254,562	1,254,562
Drop diesel, electric, fuel cell, and natural gas vehicles	8,614	8,614	8,614
Drop leases with missing prices	87,482	87,482	87,482
Drop price/MSRP outliers (+/- 25% difference)	75,601	75,601	75,601
Drop extremely low selling vehicles (<100 per Wards)	172	172	172
Drop observations from singleton regression clusters	274	315	287
Drop RV outliers and negative RV values	N/A	N/A	10,291
Drop observations with missing residual value	N/A	N/A	35,876
Drop observations missing demographic variables	199	199	0
Drop observations missing regulatory stringency	2,136	2,137	1,506
Final sample	**160,911**	**33,819**	**115,560**

Notes: This table breaks down how we arrived at the final sample for the lease model specification (column 4 of Table 2) due to missing data, price outliers, bespoke low-selling vehicles, etc. The quantity regression data are aggregated to the market year/make/model/bimonthly/stub-level, causing the total observations in the regression to be lower than the price and residual value regressions. The data cleaning/reduction is similar for the pooled and purchase-only samples.

Table A.3: Sensitivity Analysis

Discount factor	2 percent		4 percent		8 percent	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.85	13.7	0.97	19.6	1.22	32.0
	[0.79, 0.92]	[11.9, 16.8]	[0.90, 1.05]	[14.7, 32.0]	[1.12, 1.31]	[32.0, 32.0]
-3	0.62	8.3	0.71	9.2	0.89	12.4
	[0.57, 0.67]	[7.5, 9.3]	[0.65, 0.76]	[8.1, 10.3]	[0.82, 0.96]	[10.2, 16.5]
-4	0.51	6.5	0.58	6.9	0.72	8.0
	[0.47, 0.55]	[5.9, 7.1]	[0.53, 0.62]	[6.1, 7.6]	[0.67, 0.78]	[7.1, 9.2]
-5	0.44	5.5	0.50	5.7	0.63	6.5
	[0.40, 0.47]	[4.9, 5.9]	[0.46, 0.54]	[5.2, 6.3]	[0.57, 0.68]	[5.6, 7.3]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.32	3.1	1.34	3.1	1.39	3.1
	[0.98, 1.65]	[3.0, 3.1]	[1.00, 1.69]	[3.1, 3.1]	[1.04, 1.75]	[3.1, 3.1]
-3	0.95	2.9	0.96	3.0	1.00	3.1
	[0.64, 1.25]	[2.0, 3.1]	[0.65, 1.27]	[2.0, 3.1]	[0.68, 1.32]	[2.1, 3.1]
-4	0.76	2.3	0.77	2.4	0.80	2.5
	[0.47, 1.05]	[1.5, 3.1]	[0.48, 1.07]	[1.5, 3.1]	[0.50, 1.11]	[1.5, 3.1]
-5	0.65	2.0	0.66	2.0	0.69	2.1
	[0.36, 0.93]	[1.1, 2.9]	[0.37, 0.95]	[1.1, 2.9]	[0.38, 0.99]	[1.2, 3.1]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.58	7.6	0.69	8.8	0.94	14.9
	[0.44, 0.71]	[5.5, 10.1]	[0.52, 0.85]	[6.0, 12.8]	[0.72, 1.16]	[8.0, 32.0]
-3	0.45	5.6	0.53	6.1	0.73	8.2
	[0.34, 0.55]	[4.1, 7.1]	[0.41, 0.66]	[4.5, 8.3]	[0.56, 0.90]	[5.5, 12.8]
-4	0.38	4.6	0.45	5.0	0.62	6.3
	[0.29, 0.47]	[3.4, 5.9]	[0.35, 0.56]	[3.7, 6.6]	[0.47, 0.77]	[4.4, 9.0]
-5	0.34	4.1	0.41	4.5	0.56	5.5
	[0.26, 0.42]	[3.0, 5.2]	[0.31, 0.51]	[3.3, 5.9]	[0.42, 0.69]	[3.8, 7.5]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table 2 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table 2) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.4: Price Minus Residual Value Regressions

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Sale price	Residual value	$P - RV$	Sale price	Residual value	$P - RV$
Cost per mile (2017 USD)	-26,594*	-20,179*	-6,415	-26,372*	-20,237*	-6,135*
	(3,649)	(3,662)	(3,328)	(3,653)	(3,438)	(3,062)
Observations	115,560	115,560	115,560	113,237	113,237	113,237
R^2	0.940	0.558	0.617	0.932	0.593	0.564

Robust standard errors in parentheses

* p<0.05

Notes: This table reports regressions of price, residual value, and price minus residual value on cost per mile. Columns 1-3 use the population of leases from our main specification's residual value regression. Columns 4-6 trim the top and bottom 1 percent of $P - RV$ values from this sample used in columns 1-3. The regressions use average gasoline prices in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. *$p < 0.05$.

Table A.5: Valuation Ratios and Implied Payback Periods Using InMoment-based VMT for Years 1-3

	Vehicle lifetime fuel costs		**Lease-specific fuel costs**	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.81	11.6		
	[0.75, 0.88]	[10.1, 13.8]		
Buyers	0.80	11.3		
	[0.73, 0.86]	[9.7, 13.1]		
Lessees	0.72	9.4	3.39	32.0
	[0.62, 0.82]	[7.6, 11.8]	[2.90, 3.88]	[32.0, 32.0]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.28	2.9	0.96	18.5
	[0.19, 0.37]	[1.9, 4.0]	[0.65, 1.27]	[8.1, 32.0]
Leasing company perception	0.53	6.1	0.53	6.1
of used car market	[0.41, 0.66]	[4.5, 8.3]	[0.41, 0.66]	[4.5, 8.3]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) using assumptions from our main specification but incorporating VMT estimates for years 1-3 from InMoment survey responses rather than NHTS. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.6: Regression Results: Monthly Gasoline Prices

Transaction sample	Baseline model Pooled	Baseline model Purchases	Lease model Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-23,636*	-22,674*	-27,165*
	(2,023)	(1,859)	(3,647)
Implied elasticity (price with respect to cost per mile)	-0.087	-0.086	-0.085
95 percent confidence interval	[-0.102, -0.072]	[-0.100, -0.072]	[-0.108, -0.063]
Number of observations	951,091	789,892	160,911
R^2	0.944	0.945	0.939
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-5.180*	-5.070*	-3.791*
	(0.578)	(0.586)	(0.695)
Implied elasticity (quantity with respect to cost per mile)	-0.718	-0.703	-0.504
95 percent confidence interval	[-0.875, -0.561]	[-0.863, -0.544]	[-0.685, -0.323]
Number of observations	141379	139125	100133
Pseudo-R^2	0.497	0.485	0.381
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-18,989*
			(3,552)
Implied elasticity (residual value with respect to cost per mile)			-0.113
95 percent confidence interval			[-0.156, -0.071]
Number of observations			115,560
R^2			0.558

Notes: This table reports price, quantity, and residual value regression results across different sample populations. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, month, and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by month and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. $*p < 0.05$.

Table A.7: Valuation Ratios and Payback Periods (Monthly Gasoline Prices, 25% Price Outlier Trim)

	Vehicle lifetime fuel costs		Lease-specific fuel costs	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.77	10.6		
	[0.71, 0.82]	[9.2, 11.8]		
Buyers	0.74	9.9		
	[0.69, 0.80]	[8.8, 11.3]		
Lessees	0.63	7.7	2.20	3.1
	[0.54, 0.72]	[6.3, 9.4]	[1.87, 2.52]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.28	2.9	0.96	3.0
	[0.19, 0.36]	[1.9, 3.9]	[0.66, 1.26]	[2.0, 3.1]
Leasing company perception of used car market	0.52	6.0	0.52	6.0
	[0.40, 0.64]	[4.4, 7.9]	[0.40, 0.64]	[4.4, 7.9]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.6. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.8: Sensitivity Analysis (Monthly Gasoline Prices, 25% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.90	15.7	1.03	32.0	1.29	32.0
	[0.84, 0.96]	[13.4, 19.7]	[0.96, 1.10]	[18.5, 32.0]	[1.20, 1.37]	[32.0, 32.0]
-3	0.65	8.9	0.74	9.9	0.93	14.3
	[0.61, 0.70]	[8.2, 9.9]	[0.69, 0.80]	[8.8, 11.3]	[0.87, 0.99]	[11.7, 21.2]
-4	0.53	6.8	0.60	7.2	0.75	8.6
	[0.49, 0.57]	[6.2, 7.5]	[0.56, 0.65]	[6.6, 8.1]	[0.70, 0.81]	[7.7, 10.0]
-5	0.45	5.6	0.52	6.0	0.65	6.8
	[0.42, 0.49]	[5.2, 6.2]	[0.48, 0.56]	[5.4, 6.6]	[0.60, 0.69]	[6.0, 7.5]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.31	3.1	1.33	3.1	1.38	3.1
	[0.98, 1.64]	[3.0, 3.1]	[0.99, 1.67]	[3.1, 3.1]	[1.03, 1.73]	[3.1, 3.1]
-3	0.94	2.9	0.96	3.0	1.00	3.1
	[0.65, 1.24]	[2.0, 3.1]	[0.66, 1.26]	[2.0, 3.1]	[0.68, 1.31]	[2.1, 3.1]
-4	0.76	2.3	0.78	2.4	0.81	2.5
	[0.48, 1.05]	[1.5, 3.1]	[0.49, 1.07]	[1.5, 3.1]	[0.50, 1.11]	[1.5, 3.1]
-5	0.65	2.0	0.67	2.1	0.69	2.1
	[0.37, 0.93]	[1.1, 2.9]	[0.38, 0.95]	[1.2, 2.9]	[0.40, 0.98]	[1.2, 3.0]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.57	7.5	0.67	8.5	0.92	13.8
	[0.43, 0.70]	[5.3, 9.9]	[0.51, 0.83]	[5.9, 12.1]	[0.70, 1.14]	[7.7, 32.0]
-3	0.44	5.5	0.52	6.0	0.71	7.8
	[0.33, 0.54]	[3.9, 7.0]	[0.40, 0.64]	[4.4, 7.9]	[0.54, 0.87]	[5.2, 11.7]
-4	0.37	4.5	0.44	4.9	0.60	6.0
	[0.28, 0.46]	[3.3, 5.7]	[0.34, 0.55]	[3.6, 6.5]	[0.46, 0.75]	[4.2, 8.6]
-5	0.33	3.9	0.39	4.2	0.54	5.2
	[0.25, 0.41]	[2.9, 5.0]	[0.30, 0.49]	[3.2, 5.6]	[0.41, 0.67]	[3.7, 7.1]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.6 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.6) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.9: Regression Results: Quarterly Gasoline Prices

Transaction sample	Baseline model Pooled	 Purchases	Lease model Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-30,551*	-29,106*	-37,000*
	(2,578)	(2,373)	(4,610)
Implied elasticity (price with respect to cost per mile)	-0.112	-0.110	-0.117
95 percent confidence interval	[-0.132, -0.093]	[-0.128, -0.092]	[-0.145, -0.088]
Number of observations	951,091	789,892	160,911
R^2	0.944	0.945	0.940
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-6.827*	-6.641*	-6.523*
	(0.648)	(0.661)	(0.851)
Implied elasticity (quantity with respect to cost per mile)	-0.949	-0.924	-0.869
95 percent confidence interval	[-1.125, -0.772]	[-1.105, -0.744]	[-1.092, -0.647]
Number of observations	39,160	38,279	25,276
Pseudo-R^2	0.632	0.622	0.490
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-24,256*
			(4,362)
Implied elasticity (residual value with respect to cost per mile)			-0.145
95 percent confidence interval			[-0.197, -0.093]
Number of observations			115,560
R^2			0.558

Notes: This table reports price, quantity, and residual value regression results across different sample populations. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, quarter, and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by quarter and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. $*p < 0.05$.

Table A.10: Valuation Ratios and Payback Periods (Quarterly Gasoline Prices, 25% Price Outlier Trim)

	Vehicle lifetime fuel costs		Lease-specific fuel costs	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	1.01	32.0		
	[0.95, 1.06]	[17.6, 32.0]		
Buyers	0.97	19.6		
	[0.91, 1.03]	[15.1, 32.0]		
Lessees	1.01	32.0	3.52	3.1
	[0.92, 1.10]	[15.7, 32.0]	[3.21, 3.83]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.46	5.2	1.62	3.1
	[0.36, 0.57]	[3.9, 6.8]	[1.26, 1.97]	[3.1, 3.1]
Leasing company perception	0.77	10.6	0.77	10.6
of used car market	[0.62, 0.92]	[7.6, 15.7]	[0.62, 0.92]	[7.6, 15.7]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.9. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.11: Sensitivity Analysis (Quarterly Gasoline Prices, 25% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.18	32.0	1.34	32.0	1.68	32.0
	[1.12, 1.24]	[32.0, 32.0]	[1.27, 1.41]	[32.0, 32.0]	[1.59, 1.77]	[32.0, 32.0]
-3	0.85	13.7	0.97	19.6	1.21	32.0
	[0.80, 0.90]	[12.2, 15.7]	[0.91, 1.03]	[15.1, 32.0]	[1.14, 1.28]	[32.0, 32.0]
-4	0.69	9.7	0.78	10.8	0.98	18.9
	[0.65, 0.73]	[8.9, 10.5]	[0.74, 0.83]	[9.9, 12.1]	[0.92, 1.04]	[13.8, 32.0]
-5	0.59	7.8	0.67	8.5	0.84	10.8
	[0.55, 0.63]	[7.1, 8.5]	[0.63, 0.72]	[7.7, 9.4]	[0.78, 0.90]	[9.2, 12.8]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	2.21	3.1	2.25	3.1	2.34	3.1
	[1.85, 2.58]	[3.1, 3.1]	[1.88, 2.63]	[3.1, 3.1]	[1.95, 2.72]	[3.1, 3.1]
-3	1.59	3.1	1.62	3.1	1.68	3.1
	[1.24, 1.94]	[3.1, 3.1]	[1.26, 1.97]	[3.1, 3.1]	[1.31, 2.05]	[3.1, 3.1]
-4	1.28	3.1	1.30	3.1	1.35	3.1
	[0.93, 1.62]	[2.9, 3.1]	[0.95, 1.65]	[2.9, 3.1]	[0.99, 1.71]	[3.1, 3.1]
-5	1.09	3.1	1.11	3.1	1.15	3.1
	[0.75, 1.43]	[2.3, 3.1]	[0.77, 1.45]	[2.4, 3.1]	[0.79, 1.51]	[2.4, 3.1]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.86	14.1	1.02	32.0	1.40	32.0
	[0.70, 1.02]	[9.9, 32.0]	[0.83, 1.22]	[32.0, 32.0]	[1.13, 1.67]	[32.0, 32.0]
-3	0.65	8.9	0.77	10.6	1.05	32.0
	[0.52, 0.77]	[6.7, 11.5]	[0.62, 0.92]	[7.6, 15.7]	[0.85, 1.26]	[32.0, 32.0]
-4	0.54	7.0	0.64	7.9	0.88	12.0
	[0.43, 0.65]	[5.3, 8.9]	[0.52, 0.77]	[6.0, 10.6]	[0.71, 1.06]	[7.8, 32.0]
-5	0.48	6.0	0.57	6.8	0.78	9.2
	[0.38, 0.58]	[4.6, 7.6]	[0.45, 0.69]	[5.0, 8.8]	[0.62, 0.94]	[6.3, 14.9]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.9 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.9) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.12: Alternative RV Regression Results: Bimonthly Gasoline Prices

Transaction sample	Baseline model Pooled	Baseline model Purchases	Lease model Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-24,731*	-23,892*	-27,804*
	(2,051)	(1,880)	(3,741)
Implied elasticity (price with respect to cost per mile)	-0.091	-0.090	-0.087
95 percent confidence interval	[-0.106, -0.076]	[-0.105, -0.076]	[-0.110, -0.064]
Number of observations	951,091	789,892	160,911
R^2	0.944	0.945	0.939
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-4.747*	-4.678*	-3.883*
	(0.583)	(0.591)	(0.713)
Implied elasticity (quantity with respect to cost per mile)	-0.660	-0.652	-0.514
95 percent confidence interval	[-0.818, -0.501]	[-0.813, -0.490]	[-0.699, -0.329]
Number of observations	57,111	55,510	33,819
Pseudo-R^2	0.580	0.565	0.412
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-21,223*
			(3,657)
Implied elasticity (residual value with respect to cost per mile)			-0.122
95 percent confidence interval			[-0.164, -0.080]
Number of observations			116,531
R^2			0.571

Notes: This table reports price, quantity, and residual value regression results across different sample populations. This table is similar to Table 2 except it uses the residual value variable which includes state sales tax in its formula. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. $*p < 0.05$.

Table A.13: Alternative RV Valuation Ratios and Payback Periods: Bimonthly Gasoline Prices

	Vehicle lifetime fuel costs		**Lease-specific fuel costs**	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.73	9.7		
	[0.67, 0.78]	[8.5, 10.8]		
Buyers	0.71	9.2		
	[0.65, 0.76]	[8.1, 10.3]		
Lessees	0.64	7.9	2.25	3.1
	[0.55, 0.74]	[6.5, 9.9]	[1.92, 2.57]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.26	2.7	0.90	2.8
	[0.17, 0.35]	[1.7, 3.7]	[0.59, 1.21]	[1.8, 3.1]
Leasing company perception	0.56	6.6	0.56	6.6
of used car market	[0.43, 0.69]	[4.8, 8.8]	[0.43, 0.69]	[4.8, 8.8]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.12. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.14: Sensitivity Analysis (Alternative RV, Bimonthly Gasoline Prices, 25% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.85	13.7	0.97	19.6	1.22	32.0
	[0.79, 0.92]	[11.9, 16.8]	[0.90, 1.05]	[14.7, 32.0]	[1.12, 1.31]	[32.0, 32.0]
-3	0.62	8.3	0.71	9.2	0.89	12.4
	[0.57, 0.67]	[7.5, 9.3]	[0.65, 0.76]	[8.1, 10.3]	[0.82, 0.96]	[10.2, 16.5]
-4	0.51	6.5	0.58	6.9	0.72	8.0
	[0.47, 0.55]	[5.9, 7.1]	[0.53, 0.62]	[6.1, 7.6]	[0.67, 0.78]	[7.1, 9.2]
-5	0.44	5.5	0.50	5.7	0.63	6.5
	[0.40, 0.47]	[4.9, 5.9]	[0.46, 0.54]	[5.2, 6.3]	[0.57, 0.68]	[5.6, 7.3]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.24	3.1	1.26	3.1	1.31	3.1
	[0.91, 1.57]	[2.8, 3.1]	[0.92, 1.60]	[2.8, 3.1]	[0.96, 1.66]	[3.0, 3.1]
-3	0.88	2.7	0.90	2.8	0.93	2.9
	[0.58, 1.18]	[1.8, 3.1]	[0.59, 1.21]	[1.8, 3.1]	[0.62, 1.25]	[1.9, 3.1]
-4	0.71	2.2	0.72	2.2	0.75	2.3
	[0.42, 1.00]	[1.3, 3.1]	[0.42, 1.02]	[1.3, 3.1]	[0.44, 1.05]	[1.4, 3.1]
-5	0.60	1.9	0.61	1.9	0.63	1.9
	[0.32, 0.88]	[1.0, 2.7]	[0.32, 0.90]	[1.0, 2.8]	[0.33, 0.93]	[1.0, 2.9]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.61	8.2	0.72	9.4	0.98	18.9
	[0.46, 0.75]	[5.7, 11.0]	[0.55, 0.89]	[6.5, 14.2]	[0.75, 1.21]	[8.6, 32.0]
-3	0.47	5.9	0.56	6.6	0.76	8.8
	[0.36, 0.58]	[4.3, 7.6]	[0.43, 0.69]	[4.8, 8.8]	[0.59, 0.94]	[5.9, 14.9]
-4	0.40	4.9	0.48	5.4	0.65	6.8
	[0.31, 0.49]	[3.7, 6.2]	[0.37, 0.59]	[4.0, 7.1]	[0.50, 0.80]	[4.7, 9.7]
-5	0.36	4.3	0.43	4.8	0.58	5.8
	[0.27, 0.44]	[3.2, 5.5]	[0.33, 0.53]	[3.5, 6.1]	[0.45, 0.72]	[4.1, 8.0]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.12 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.12) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.15: High RV Imputation Regression Results: Bimonthly Gas Prices

Transaction sample	Baseline model Pooled	Baseline model Purchases	Lease model Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-24,731*	-23,892*	-27,804*
	(2,051)	(1,880)	(3,741)
Implied elasticity (price with respect to cost per mile)	-0.092	-0.092	-0.087
95 percent confidence interval	[-0.107, -0.077]	[-0.107, -0.078]	[-0.110, -0.064]
Number of observations	951,091	789,892	160,911
R^2	0.944	0.945	0.939
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-4.747*	-4.678*	-3.883*
	(0.583)	(0.591)	(0.713)
Implied elasticity (quantity with respect to cost per mile)	-0.660	-0.652	-0.514
95 percent confidence interval	[-0.818, -0.501]	[-0.813, -0.490]	[-0.699, -0.329]
Number of observations	57,111	55,510	33,819
Pseudo-R^2	0.580	0.565	0.412
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-22,557*
			(3,893)
Implied elasticity (residual value with respect to cost per mile)			-0.119
95 percent confidence interval			[-0.160, -0.078]
Number of observations			116,419
R^2			0.575

Notes: This table reports price, quantity, and residual value regression results across different sample populations. This table is similar to Table 2 except it uses residual values calculated with 3 percent measurement error added to imputed loan APR. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. $*p < 0.05$.

Table A.16: High RV Imputation Valuation Ratios and Payback Periods: Bimonthly Gas Prices

	Vehicle lifetime fuel costs		Lease-specific fuel costs	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.73	9.7		
	[0.67, 0.78]	[8.5, 10.8]		
Buyers	0.71	9.2		
	[0.65, 0.76]	[8.1, 10.3]		
Lessees	0.64	7.9	2.25	3.1
	[0.55, 0.74]	[6.5, 9.9]	[1.92, 2.57]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.23	2.4	0.80	2.5
	[0.14, 0.32]	[1.4, 3.4]	[0.49, 1.11]	[1.5, 3.1]
Leasing company perception	0.60	7.2	0.60	7.2
of used car market	[0.46, 0.74]	[5.2, 9.9]	[0.46, 0.74]	[5.2, 9.9]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.15. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.17: Sensitivity Analysis (High RV Imputation, Bimonthly Gas Prices, 25% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.85	13.7	0.97	19.6	1.22	32.0
	[0.79, 0.92]	[11.9, 16.8]	[0.90, 1.05]	[14.7, 32.0]	[1.12, 1.31]	[32.0, 32.0]
-3	0.62	8.3	0.71	9.2	0.89	12.4
	[0.57, 0.67]	[7.5, 9.3]	[0.65, 0.76]	[8.1, 10.3]	[0.82, 0.96]	[10.2, 16.5]
-4	0.51	6.5	0.58	6.9	0.72	8.0
	[0.47, 0.55]	[5.9, 7.1]	[0.53, 0.62]	[6.1, 7.6]	[0.67, 0.78]	[7.1, 9.2]
-5	0.44	5.5	0.50	5.7	0.63	6.5
	[0.40, 0.47]	[4.9, 5.9]	[0.46, 0.54]	[5.2, 6.3]	[0.57, 0.68]	[5.6, 7.3]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.10	3.1	1.13	3.1	1.17	3.1
	[0.77, 1.44]	[2.4, 3.1]	[0.79, 1.46]	[2.4, 3.1]	[0.82, 1.52]	[2.5, 3.1]
-3	0.78	2.4	0.80	2.5	0.83	2.6
	[0.48, 1.09]	[1.5, 3.1]	[0.49, 1.11]	[1.5, 3.1]	[0.51, 1.15]	[1.6, 3.1]
-4	0.62	1.9	0.63	1.9	0.66	2.0
	[0.33, 0.92]	[1.0, 2.8]	[0.33, 0.94]	[1.0, 2.9]	[0.35, 0.97]	[1.1, 3.0]
-5	0.53	1.6	0.54	1.7	0.56	1.7
	[0.24, 0.82]	[0.7, 2.5]	[0.24, 0.83]	[0.7, 2.6]	[0.25, 0.86]	[0.8, 2.7]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.65	8.9	0.78	10.8	1.06	32.0
	[0.50, 0.81]	[6.3, 12.5]	[0.59, 0.96]	[7.1, 18.5]	[0.81, 1.31]	[32.0, 32.0]
-3	0.50	6.3	0.60	7.2	0.82	10.2
	[0.39, 0.62]	[4.8, 8.3]	[0.46, 0.74]	[5.2, 9.9]	[0.63, 1.01]	[6.5, 32.0]
-4	0.43	5.3	0.51	5.9	0.70	7.7
	[0.33, 0.53]	[3.9, 6.8]	[0.39, 0.63]	[4.2, 7.7]	[0.54, 0.86]	[5.2, 11.4]
-5	0.39	4.8	0.46	5.2	0.63	6.5
	[0.29, 0.48]	[3.4, 6.0]	[0.35, 0.57]	[3.7, 6.8]	[0.48, 0.77]	[4.5, 9.0]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.15 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.15) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.18: Low RV Imputation Regression Results: Bimonthly Gas Prices

Transaction sample	Baseline model Pooled	 Purchases	Lease model Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-24,731*	-23,892*	-27,804*
	(2,051)	(1,880)	(3,741)
Implied elasticity (price with respect to cost per mile)	-0.092	-0.092	-0.087
95 percent confidence interval	[-0.107, -0.077]	[-0.107, -0.078]	[-0.110, -0.064]
Number of observations	951,091	789,892	160,911
R^2	0.944	0.945	0.939
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-4.747*	-4.678*	-3.883*
	(0.583)	(0.591)	(0.713)
Implied elasticity (quantity with respect to cost per mile)	-0.660	-0.652	-0.514
95 percent confidence interval	[-0.818, -0.501]	[-0.813, -0.490]	[-0.699, -0.329]
Number of observations	57,111	55,510	33,819
Pseudo-R^2	0.580	0.565	0.412
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-17,881*
			(3,432)
Implied elasticity (residual value with respect to cost per mile)			-0.118
95 percent confidence interval			[-0.163, -0.073]
Number of observations			114,578
R^2			0.551

Notes: This table reports price, quantity, and residual value regression results across different sample populations. This table is similar to Table 2 except it uses residual values calculated with 3 percent measurement error subtracted from imputed loan APR. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. $^*p < 0.05$.

Table A.19: Low RV Imputation (APR minus 3%) Valuation Ratios and Payback Periods: Bimonthly Gasoline Prices

	Vehicle lifetime fuel costs		**Lease-specific fuel costs**	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.73	9.7		
	[0.67, 0.78]	[8.5, 10.8]		
Buyers	0.71	9.2		
	[0.65, 0.76]	[8.1, 10.3]		
Lessees	0.64	7.9	2.25	3.1
	[0.55, 0.74]	[6.5, 9.9]	[1.92, 2.57]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.32	3.4	1.10	3.1
	[0.23, 0.40]	[2.4, 4.4]	[0.79, 1.41]	[2.4, 3.1]
Leasing company perception	0.47	5.3	0.47	5.3
of used car market	[0.36, 0.59]	[3.9, 7.1]	[0.36, 0.59]	[3.9, 7.1]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.18. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.20: Sensitivity Analysis (Low RV Imputation, Bimonthly Gas Prices, 25% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.85	13.7	0.97	19.6	1.22	32.0
	[0.79, 0.92]	[11.9, 16.8]	[0.90, 1.05]	[14.7, 32.0]	[1.12, 1.31]	[32.0, 32.0]
-3	0.62	8.3	0.71	9.2	0.89	12.4
	[0.57, 0.67]	[7.5, 9.3]	[0.65, 0.76]	[8.1, 10.3]	[0.82, 0.96]	[10.2, 16.5]
-4	0.51	6.5	0.58	6.9	0.72	8.0
	[0.47, 0.55]	[5.9, 7.1]	[0.53, 0.62]	[6.1, 7.6]	[0.67, 0.78]	[7.1, 9.2]
-5	0.44	5.5	0.50	5.7	0.63	6.5
	[0.40, 0.47]	[4.9, 5.9]	[0.46, 0.54]	[5.2, 6.3]	[0.57, 0.68]	[5.6, 7.3]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.49	3.1	1.52	3.1	1.58	3.1
	[1.15, 1.83]	[3.1, 3.1]	[1.17, 1.87]	[3.1, 3.1]	[1.22, 1.94]	[3.1, 3.1]
-3	1.08	3.1	1.10	3.1	1.14	3.1
	[0.78, 1.39]	[2.4, 3.1]	[0.79, 1.41]	[2.4, 3.1]	[0.82, 1.46]	[2.5, 3.1]
-4	0.88	2.7	0.89	2.7	0.93	2.9
	[0.59, 1.17]	[1.8, 3.1]	[0.60, 1.19]	[1.8, 3.1]	[0.62, 1.23]	[1.9, 3.1]
-5	0.76	2.3	0.77	2.4	0.80	2.5
	[0.47, 1.04]	[1.4, 3.1]	[0.48, 1.06]	[1.5, 3.1]	[0.50, 1.09]	[1.5, 3.1]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.52	6.7	0.62	7.6	0.84	10.8
	[0.39, 0.64]	[4.8, 8.7]	[0.47, 0.76]	[5.3, 10.3]	[0.64, 1.04]	[6.6, 32.0]
-3	0.40	4.9	0.47	5.3	0.65	6.8
	[0.30, 0.50]	[3.6, 6.3]	[0.36, 0.59]	[3.9, 7.1]	[0.49, 0.81]	[4.6, 10.0]
-4	0.34	4.1	0.40	4.4	0.55	5.4
	[0.26, 0.42]	[3.0, 5.2]	[0.31, 0.50]	[3.3, 5.7]	[0.42, 0.69]	[3.8, 7.5]
-5	0.31	3.7	0.36	3.9	0.50	4.7
	[0.23, 0.38]	[2.7, 4.6]	[0.27, 0.45]	[2.8, 5.0]	[0.37, 0.62]	[3.2, 6.3]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.18 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.18) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.21: RV (Mean Zero Noise) Regression Results: Bimonthly Gas Prices

Transaction sample	Baseline model Pooled	Baseline model Purchases	Lease model Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-24,731*	-23,892*	-27,804*
	(2,051)	(1,880)	(3,741)
Implied elasticity (price with respect to cost per mile)	-0.092	-0.092	-0.087
95 percent confidence interval	[-0.107, -0.077]	[-0.107, -0.078]	[-0.110, -0.064]
Number of observations	951,091	789,892	160,911
R^2	0.944	0.945	0.939
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-4.747*	-4.678*	-3.883*
	(0.583)	(0.591)	(0.713)
Implied elasticity (quantity with respect to cost per mile)	-0.660	-0.652	-0.514
95 percent confidence interval	[-0.818, -0.501]	[-0.813, -0.490]	[-0.699, -0.329]
Number of observations	57,111	55,510	33,819
Pseudo-R^2	0.580	0.565	0.412
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-19,058*
			(3,714)
Implied elasticity (residual value with respect to cost per mile)			-0.113
95 percent confidence interval			[-0.156, -0.069]
Number of observations			115,400
R^2			0.525

Notes: This table reports price, quantity, and residual value regression results across different sample populations. This table is similar to Table 2 except it uses residual values calculated with mean zero noise added to the imputed loan APR. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. $*p < 0.05$.

Table A.22: RV with Mean Zero Noise Valuation Ratios and Payback Periods: Bimonthly Gasoline Prices

	Vehicle lifetime fuel costs		Lease-specific fuel costs	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.73	9.7		
	[0.67, 0.78]	[8.5, 10.8]		
Buyers	0.71	9.2		
	[0.65, 0.76]	[8.1, 10.3]		
Lessees	0.64	7.9	2.25	3.1
	[0.55, 0.74]	[6.5, 9.9]	[1.92, 2.57]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.28	2.9	0.99	3.0
	[0.20, 0.37]	[2.0, 4.0]	[0.68, 1.30]	[2.1, 3.1]
Leasing company perception	0.52	6.0	0.52	6.0
of used car market	[0.40, 0.65]	[4.4, 8.1]	[0.40, 0.65]	[4.4, 8.1]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.21. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.23: Sensitivity Analysis (RV with Mean Zero Noise, Bimonthly Gas Prices, 25% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.85	13.7	0.97	19.6	1.22	32.0
	[0.79, 0.92]	[11.9, 16.8]	[0.90, 1.05]	[14.7, 32.0]	[1.12, 1.31]	[32.0, 32.0]
-3	0.62	8.3	0.71	9.2	0.89	12.4
	[0.57, 0.67]	[7.5, 9.3]	[0.65, 0.76]	[8.1, 10.3]	[0.82, 0.96]	[10.2, 16.5]
-4	0.51	6.5	0.58	6.9	0.72	8.0
	[0.47, 0.55]	[5.9, 7.1]	[0.53, 0.62]	[6.1, 7.6]	[0.67, 0.78]	[7.1, 9.2]
-5	0.44	5.5	0.50	5.7	0.63	6.5
	[0.40, 0.47]	[4.9, 5.9]	[0.46, 0.54]	[5.2, 6.3]	[0.57, 0.68]	[5.6, 7.3]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.34	3.1	1.37	3.1	1.42	3.1
	[1.00, 1.68]	[3.1, 3.1]	[1.02, 1.71]	[3.1, 3.1]	[1.06, 1.77]	[3.1, 3.1]
-3	0.97	3.0	0.99	3.0	1.03	3.1
	[0.66, 1.28]	[2.0, 3.1]	[0.68, 1.30]	[2.1, 3.1]	[0.70, 1.35]	[2.2, 3.1]
-4	0.79	2.4	0.80	2.5	0.83	2.6
	[0.49, 1.08]	[1.5, 3.1]	[0.50, 1.10]	[1.5, 3.1]	[0.52, 1.14]	[1.6, 3.1]
-5	0.68	2.1	0.69	2.1	0.71	2.2
	[0.39, 0.96]	[1.2, 3.0]	[0.40, 0.98]	[1.2, 3.0]	[0.41, 1.02]	[1.3, 3.1]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.57	7.5	0.68	8.7	0.93	14.3
	[0.43, 0.71]	[5.3, 10.1]	[0.51, 0.84]	[5.9, 12.4]	[0.70, 1.15]	[7.7, 32.0]
-3	0.44	5.5	0.52	6.0	0.71	7.8
	[0.33, 0.54]	[3.9, 7.0]	[0.40, 0.65]	[4.4, 8.1]	[0.54, 0.89]	[5.2, 12.4]
-4	0.37	4.5	0.44	4.9	0.61	6.2
	[0.28, 0.46]	[3.3, 5.7]	[0.33, 0.55]	[3.5, 6.5]	[0.46, 0.76]	[4.2, 8.8]
-5	0.33	3.9	0.40	4.4	0.54	5.2
	[0.25, 0.42]	[2.9, 5.2]	[0.30, 0.50]	[3.2, 5.7]	[0.41, 0.68]	[3.7, 7.3]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.21 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.21) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.24: Captives Only Regression Results: Bimonthly Gas Prices

Transaction sample	Baseline model Pooled	 Purchases	Lease model Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-24,327*	-23,892*	-19,846*
	(1,966)	(1,880)	(2,968)
Implied elasticity (price with respect to cost per mile)	-0.091	-0.092	-0.060
95 percent confidence interval	[-0.106, -0.077]	[-0.107, -0.078]	[-0.077, -0.042]
Number of observations	888,961	789,892	98,793
R^2	0.944	0.945	0.942
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-4.752*	-4.678*	-3.620*
	(0.583)	(0.591)	(0.821)
Implied elasticity (quantity with respect to cost per mile)	-0.661	-0.652	-0.466
95 percent confidence interval	[-0.820, -0.502]	[-0.813, -0.490]	[-0.674, -0.259]
Number of observations	56,573	55,510	24,182
Pseudo-R^2	0.575	0.565	0.376
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-14,483*
			(4,114)
Implied elasticity (residual value with respect to cost per mile)			-0.082
95 percent confidence interval			[-0.129, -0.036]
Number of observations			73,683
R^2			0.566

Notes: This table reports price, quantity, and residual value regression results across different sample populations. This table is similar to Table 2 except it includes only leases from captive leasing companies (i.e., leasing companies that are within the auto manufacturer). Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. *$p < 0.05$.

Table A.25: Captive Leasing Companies Only Valuation Ratios and Payback Periods: Bimonthly Gasoline Prices

	Vehicle lifetime fuel costs		Lease-specific fuel costs	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.72	9.4		
	[0.67, 0.78]	[8.5, 10.8]		
Buyers	0.71	9.2		
	[0.65, 0.76]	[8.1, 10.3]		
Lessees	0.57	6.8	2.00	3.1
	[0.46, 0.68]	[5.2, 8.7]	[1.63, 2.37]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.25	2.6	0.87	2.7
	[0.16, 0.34]	[1.6, 3.6]	[0.55, 1.19]	[1.7, 3.1]
Leasing company perception of used car market	0.46	5.2	0.46	5.2
	[0.32, 0.61]	[3.4, 7.4]	[0.32, 0.61]	[3.4, 7.4]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.24. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.26: Sensitivity Analysis (Captive Leasing Companies, Bimonthly Gas Prices, 25% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.85	13.7	0.97	19.6	1.22	32.0
	[0.79, 0.92]	[11.9, 16.8]	[0.90, 1.05]	[14.7, 32.0]	[1.12, 1.31]	[32.0, 32.0]
-3	0.62	8.3	0.71	9.2	0.89	12.4
	[0.57, 0.67]	[7.5, 9.3]	[0.65, 0.76]	[8.1, 10.3]	[0.82, 0.96]	[10.2, 16.5]
-4	0.51	6.5	0.58	6.9	0.72	8.0
	[0.47, 0.55]	[5.9, 7.1]	[0.53, 0.62]	[6.1, 7.6]	[0.67, 0.78]	[7.1, 9.2]
-5	0.44	5.5	0.50	5.7	0.63	6.5
	[0.40, 0.47]	[4.9, 5.9]	[0.46, 0.54]	[5.2, 6.3]	[0.57, 0.68]	[5.6, 7.3]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.21	3.1	1.23	3.1	1.28	3.1
	[0.84, 1.58]	[2.6, 3.1]	[0.86, 1.61]	[2.6, 3.1]	[0.89, 1.67]	[2.7, 3.1]
-3	0.85	2.6	0.87	2.7	0.90	2.8
	[0.54, 1.17]	[1.7, 3.1]	[0.55, 1.19]	[1.7, 3.1]	[0.57, 1.24]	[1.7, 3.1]
-4	0.68	2.1	0.69	2.1	0.72	2.2
	[0.38, 0.97]	[1.2, 3.0]	[0.39, 0.99]	[1.2, 3.0]	[0.40, 1.03]	[1.2, 3.1]
-5	0.57	1.7	0.58	1.8	0.60	1.8
	[0.28, 0.86]	[0.9, 2.6]	[0.29, 0.87]	[0.9, 2.7]	[0.30, 0.91]	[0.9, 2.8]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.52	6.7	0.61	7.4	0.84	10.8
	[0.35, 0.68]	[4.2, 9.5]	[0.42, 0.81]	[4.6, 11.6]	[0.57, 1.10]	[5.6, 32.0]
-3	0.39	4.8	0.46	5.2	0.63	6.5
	[0.27, 0.51]	[3.2, 6.5]	[0.32, 0.61]	[3.4, 7.4]	[0.43, 0.83]	[3.9, 10.5]
-4	0.32	3.8	0.39	4.2	0.53	5.1
	[0.22, 0.43]	[2.5, 5.3]	[0.26, 0.51]	[2.7, 5.9]	[0.36, 0.70]	[3.1, 7.7]
-5	0.29	3.4	0.34	3.6	0.47	4.4
	[0.19, 0.38]	[2.2, 4.6]	[0.23, 0.45]	[2.4, 5.0]	[0.31, 0.62]	[2.6, 6.3]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.24 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.24) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.27: Regression Results (Bimonthly Gasoline Prices, 20% Price Outlier Trim)

Transaction sample	Baseline model Pooled	 Purchases	Lease model Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-23,245*	-22,384*	-26,929*
	(2,035)	(1,851)	(3,694)
Implied elasticity (price with respect to cost per mile)	-0.086	-0.085	-0.085
95 percent confidence interval	[-0.101, -0.071]	[-0.099, -0.071]	[-0.108, -0.062]
Number of observations	854,086	708,183	145,610
R^2	0.953	0.954	0.950
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-4.556*	-4.457*	-4.039*
	(0.593)	(0.601)	(0.718)
Implied elasticity (quantity with respect to cost per mile)	-0.633	-0.621	-0.534
95 percent confidence interval	[-0.794, -0.471]	[-0.785, -0.457]	[-0.720, -0.348]
Number of observations	56,218	54,518	32,554
Pseudo-R^2	0.567	0.550	0.394
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-18,268*
			(3,744)
Implied elasticity (residual value with respect to cost per mile)			-0.110
95 percent confidence interval			[-0.155, -0.065]
Number of observations			104,678
R^2			0.565

Notes: This table reports price, quantity, and residual value regression results across different sample populations. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 20 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. *$p < 0.05$.

Table A.28: Valuation Ratios and Implied Payback Periods (Bimonthly Gasoline Prices, 5% discount rate, 20% Price Outlier Trim)

	Vehicle lifetime fuel costs		Lease-specific fuel costs	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.69	8.8		
	[0.63, 0.75]	[7.7, 10.1]		
Buyers	0.67	8.5		
	[0.61, 0.72]	[7.4, 9.4]		
Lessees	0.65	8.1	2.28	3.1
	[0.56, 0.74]	[6.6, 9.9]	[1.96, 2.59]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.29	3.0	1.02	3.1
	[0.20, 0.38]	[2.0, 4.1]	[0.71, 1.33]	[2.2, 3.1]
Leasing company perception	0.52	6.0	0.52	6.0
of used car market	[0.39, 0.64]	[4.2, 7.9]	[0.39, 0.64]	[4.2, 7.9]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.27. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.29: Sensitivity Analysis (Bimonthly Gasoline Prices, 20% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.80	12.2	0.91	15.1	1.14	32.0
	[0.73, 0.87]	[10.5, 14.5]	[0.83, 0.99]	[12.1, 23.5]	[1.04, 1.24]	[32.0, 32.0]
-3	0.59	7.8	0.67	8.5	0.83	10.5
	[0.53, 0.64]	[6.8, 8.7]	[0.61, 0.72]	[7.4, 9.4]	[0.76, 0.91]	[8.8, 13.3]
-4	0.48	6.0	0.54	6.3	0.68	7.3
	[0.44, 0.52]	[5.5, 6.7]	[0.50, 0.59]	[5.7, 7.1]	[0.62, 0.74]	[6.3, 8.4]
-5	0.41	5.0	0.47	5.3	0.59	5.9
	[0.38, 0.45]	[4.6, 5.6]	[0.43, 0.51]	[4.8, 5.9]	[0.54, 0.64]	[5.2, 6.6]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.38	3.1	1.41	3.1	1.46	3.1
	[1.05, 1.71]	[3.1, 3.1]	[1.07, 1.75]	[3.1, 3.1]	[1.11, 1.81]	[3.1, 3.1]
-3	1.00	3.1	1.02	3.1	1.05	3.1
	[0.69, 1.30]	[2.1, 3.1]	[0.71, 1.33]	[2.2, 3.1]	[0.73, 1.38]	[2.2, 3.1]
-4	0.81	2.5	0.82	2.5	0.85	2.6
	[0.51, 1.10]	[1.6, 3.1]	[0.52, 1.12]	[1.6, 3.1]	[0.54, 1.16]	[1.7, 3.1]
-5	0.69	2.1	0.70	2.2	0.73	2.2
	[0.41, 0.98]	[1.3, 3.0]	[0.41, 1.00]	[1.3, 3.1]	[0.43, 1.03]	[1.3, 3.1]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.57	7.5	0.67	8.5	0.92	13.8
	[0.43, 0.71]	[5.3, 10.1]	[0.51, 0.84]	[5.9, 12.4]	[0.70, 1.15]	[7.7, 32.0]
-3	0.43	5.3	0.52	6.0	0.71	7.8
	[0.33, 0.54]	[3.9, 7.0]	[0.39, 0.64]	[4.2, 7.9]	[0.53, 0.88]	[5.1, 12.0]
-4	0.37	4.5	0.44	4.9	0.60	6.0
	[0.28, 0.46]	[3.3, 5.7]	[0.33, 0.55]	[3.5, 6.5]	[0.45, 0.75]	[4.1, 8.6]
-5	0.33	3.9	0.39	4.2	0.53	5.1
	[0.24, 0.41]	[2.8, 5.0]	[0.29, 0.49]	[3.0, 5.6]	[0.40, 0.67]	[3.6, 7.1]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.27 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.27) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.30: Regression Results (Bimonthly Gasoline Prices, 30% Price Outlier Trim)

	Baseline model		Lease model
Transaction sample	**Pooled**	**Purchases**	**Leases**
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-25,137*	-24,288*	-28,065*
	(2,069)	(1,913)	(3,743)
Implied elasticity (price with respect to cost per mile)	-0.092	-0.092	-0.088
95 percent confidence interval	[-0.107, -0.077]	[-0.106, -0.077]	[-0.111, -0.065]
Number of observations	1,016,980	845,704	170,994
R^2	0.936	0.938	0.929
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-4.874*	-4.797*	-4.148*
	(0.576)	(0.584)	(0.709)
Implied elasticity (quantity with respect to cost per mile)	-0.678	-0.668	-0.550
95 percent confidence interval	[-0.835, -0.521]	[-0.828, -0.509]	[-0.735, -0.366]
Number of observations	57,654	56,105	34,555
Pseudo-R^2	0.591	0.577	0.423
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-20,630*
			(3,597)
Implied elasticity (residual value with respect to cost per mile)			-0.124
95 percent confidence interval			[-0.167, -0.081]
Number of observations			122,638
R^2			0.548

Notes: This table reports price, quantity, and residual value regression results across different sample populations. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 30 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. *$p < 0.05$.

Table A.31: Valuation Ratios and Implied Payback Periods (Bimonthly Gasoline Prices, 5% discount rate, 30% Price Outlier Trim)

	Vehicle lifetime fuel costs		Lease-specific fuel costs	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.75	10.1		
	[0.69, 0.80]	[8.8, 11.3]		
Buyers	0.73	9.7		
	[0.68, 0.78]	[8.7, 10.8]		
Lessees	0.68	8.7	2.37	3.1
	[0.59, 0.77]	[7.1, 10.6]	[2.06, 2.68]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.29	3.0	1.02	3.1
	[0.21, 0.38]	[2.1, 4.1]	[0.71, 1.32]	[2.2, 3.1]
Leasing company perception	0.56	6.6	0.56	6.6
of used car market	[0.43, 0.68]	[4.8, 8.7]	[0.43, 0.68]	[4.8, 8.7]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.30. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.32: Sensitivity Analysis (Bimonthly Gasoline Prices, 30% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.88	14.8	1.00	32.0	1.25	32.0
	[0.81, 0.94]	[12.5, 18.0]	[0.93, 1.07]	[16.2, 32.0]	[1.16, 1.34]	[32.0, 32.0]
-3	0.64	8.7	0.73	9.7	0.91	13.3
	[0.59, 0.69]	[7.8, 9.7]	[0.68, 0.78]	[8.7, 10.8]	[0.85, 0.98]	[11.0, 18.9]
-4	0.52	6.7	0.59	7.1	0.74	8.4
	[0.48, 0.56]	[6.0, 7.3]	[0.55, 0.64]	[6.5, 7.9]	[0.69, 0.80]	[7.5, 9.7]
-5	0.45	5.6	0.51	5.9	0.64	6.6
	[0.41, 0.49]	[5.0, 6.2]	[0.47, 0.55]	[5.3, 6.5]	[0.59, 0.69]	[5.9, 7.5]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.40	3.1	1.43	3.1	1.48	3.1
	[1.07, 1.73]	[3.1, 3.1]	[1.09, 1.76]	[3.1, 3.1]	[1.13, 1.83]	[3.1, 3.1]
-3	1.00	3.1	1.02	3.1	1.06	3.1
	[0.70, 1.30]	[2.2, 3.1]	[0.71, 1.32]	[2.2, 3.1]	[0.74, 1.37]	[2.3, 3.1]
-4	0.80	2.5	0.81	2.5	0.84	2.6
	[0.51, 1.09]	[1.6, 3.1]	[0.52, 1.11]	[1.6, 3.1]	[0.54, 1.15]	[1.7, 3.1]
-5	0.68	2.1	0.69	2.1	0.72	2.2
	[0.40, 0.96]	[1.2, 3.0]	[0.40, 0.98]	[1.2, 3.0]	[0.42, 1.01]	[1.3, 3.1]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.61	8.2	0.72	9.4	0.99	21.2
	[0.47, 0.74]	[5.9, 10.7]	[0.56, 0.88]	[6.6, 13.8]	[0.77, 1.21]	[9.0, 32.0]
-3	0.47	5.9	0.56	6.6	0.76	8.8
	[0.36, 0.57]	[4.3, 7.5]	[0.43, 0.68]	[4.8, 8.7]	[0.59, 0.93]	[5.9, 14.3]
-4	0.40	4.9	0.47	5.3	0.65	6.8
	[0.31, 0.49]	[3.7, 6.2]	[0.37, 0.58]	[4.0, 6.9]	[0.50, 0.79]	[4.7, 9.5]
-5	0.36	4.3	0.42	4.6	0.58	5.8
	[0.27, 0.44]	[3.2, 5.5]	[0.33, 0.52]	[3.5, 6.0]	[0.45, 0.71]	[4.1, 7.8]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.30 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.30) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.33: Regression Results: Bimonthly Gasoline Prices (100% above/50% below MSRP Outlier Trim)

Transaction sample	Baseline model Pooled	Baseline model Purchases	Lease model Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-26,652*	-25,794*	-29,514*
	(2,292)	(2,176)	(3,902)
Implied elasticity (price with respect to cost per mile)	-0.099	-0.100	-0.091
95 percent confidence interval	[-0.117, -0.081]	[-0.119, -0.082]	[-0.115, -0.067]
Number of observations	1,148,177	955,540	192,358
R^2	0.899	0.909	0.860
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-5.134*	-5.084*	-4.425*
	(0.567)	(0.576)	(0.701)
Implied elasticity (quantity with respect to cost per mile)	-0.714	-0.708	-0.588
95 percent confidence interval	[-0.868, -0.559]	[-0.865, -0.551]	[-0.771, -0.406]
Number of observations	58,629	57,120	36,136
Pseudo-R^2	0.615	0.604	0.445
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-21,029*
			(3,532)
Implied elasticity (residual value with respect to cost per mile)			-0.124
95 percent confidence interval			[-0.166, -0.083]
Number of observations			135,697
R^2			0.503

Notes: This table reports price, quantity, and residual value regression results across different sample populations. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price is 50% less than MSRP or 100% greater than MSRP. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. *$p < 0.05$.

Table A.34: Valuation Ratios and Payback Periods: Bimonthly Gasoline Prices (100% above/50% below MSRP Outlier Trim)

	Vehicle lifetime fuel costs		Lease-specific fuel costs	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.80	11.3		
	[0.75, 0.86]	[10.1, 13.1]		
Buyers	0.79	11.0		
	[0.73, 0.84]	[9.7, 12.4]		
Lessees	0.72	9.4	2.52	3.1
	[0.64, 0.81]	[7.9, 11.6]	[2.22, 2.82]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.32	3.4	1.12	3.1
	[0.23, 0.41]	[2.4, 4.5]	[0.81, 1.42]	[2.5, 3.1]
Leasing company perception	0.58	6.9	0.58	6.9
of used car market	[0.46, 0.71]	[5.2, 9.2]	[0.46, 0.71]	[5.2, 9.2]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.33. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.35: Sensitivity Analysis (Bimonthly Gasoline Prices, 100% above/50% below MSRP Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.95	18.8	1.08	32.0	1.35	32.0
	[0.89, 1.01]	[15.3, 32.0]	[1.01, 1.15]	[32.0, 32.0]	[1.26, 1.44]	[32.0, 32.0]
-3	0.69	9.7	0.79	11.0	0.99	21.2
	[0.64, 0.74]	[8.7, 10.7]	[0.73, 0.84]	[9.7, 12.4]	[0.92, 1.05]	[13.8, 32.0]
-4	0.56	7.3	0.64	7.9	0.80	9.7
	[0.52, 0.60]	[6.7, 8.0]	[0.59, 0.69]	[7.1, 8.8]	[0.74, 0.86]	[8.4, 11.4]
-5	0.48	6.0	0.55	6.5	0.69	7.5
	[0.45, 0.52]	[5.6, 6.7]	[0.51, 0.60]	[5.9, 7.2]	[0.64, 0.74]	[6.6, 8.4]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.53	3.1	1.56	3.1	1.62	3.1
	[1.21, 1.86]	[3.1, 3.1]	[1.23, 1.89]	[3.1, 3.1]	[1.28, 1.96]	[3.1, 3.1]
-3	1.10	3.1	1.12	3.1	1.16	3.1
	[0.80, 1.39]	[2.5, 3.1]	[0.81, 1.42]	[2.5, 3.1]	[0.84, 1.47]	[2.6, 3.1]
-4	0.88	2.7	0.90	2.8	0.93	2.9
	[0.59, 1.17]	[1.8, 3.1]	[0.60, 1.19]	[1.9, 3.1]	[0.62, 1.23]	[1.9, 3.1]
-5	0.75	2.3	0.76	2.4	0.79	2.4
	[0.46, 1.03]	[1.4, 3.1]	[0.47, 1.05]	[1.5, 3.1]	[0.49, 1.09]	[1.5, 3.1]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.64	8.7	0.76	10.3	1.04	32.0
	[0.50, 0.77]	[6.3, 11.5]	[0.60, 0.92]	[7.2, 15.7]	[0.82, 1.26]	[32.0, 32.0]
-3	0.49	6.2	0.58	6.9	0.80	9.7
	[0.39, 0.59]	[4.8, 7.8]	[0.46, 0.71]	[5.2, 9.2]	[0.63, 0.97]	[6.5, 17.5]
-4	0.42	5.2	0.50	5.7	0.68	7.3
	[0.33, 0.50]	[3.9, 6.3]	[0.39, 0.60]	[4.2, 7.2]	[0.53, 0.82]	[5.1, 10.2]
-5	0.37	4.5	0.44	4.9	0.61	6.2
	[0.29, 0.45]	[3.4, 5.6]	[0.35, 0.54]	[3.7, 6.3]	[0.47, 0.74]	[4.4, 8.4]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.33 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.33) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.36: Limited Imputation Regression Results: Bimonthly Gas Prices

Transaction sample	**Baseline model** Pooled	**Baseline model** Purchases	**Lease model** Leases
	(1)	(2)	(3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-24,857*	-23,900*	-28,242*
	(2,072)	(1,896)	(3,797)
Implied elasticity (price with respect to cost per mile)	-0.093	-0.093	-0.089
95 percent confidence interval	[-0.108, -0.078]	[-0.108, -0.078]	[-0.112, -0.065]
Number of observations	714,776	587,922	126,570
R^2	0.944	0.945	0.940
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-4.801*	-4.703*	-4.154*
	(0.577)	(0.584)	(0.722)
Implied elasticity (quantity with respect to cost per mile)	-0.667	-0.655	-0.548
95 percent confidence interval	[-0.824, -0.510]	[-0.814, -0.495]	[-0.734, -0.361]
Number of observations	55,198	53,330	31,265
Pseudo-R^2	0.575	0.559	0.409
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-20,313*
			(3,899)
Implied elasticity (residual value with respect to cost per mile)			-0.121
95 percent confidence interval			[-0.168, -0.075]
Number of observations			92,552
R^2			0.559

Notes: This table reports price, quantity, and residual value regression results across different sample populations. This table is similar to Table 2 except it does not impute missing demographic data using the American Community Survey. As a result, this specification contains fewer observations than our main specification. Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. $*p < 0.05$.

Table A.37: Limited Imputation Valuation Ratios and Payback Periods: Bimonthly Gasoline Prices

	Vehicle lifetime fuel costs		Lease-specific fuel costs	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.72	9.4		
	[0.66, 0.77]	[8.3, 10.6]		
Buyers	0.69	8.8		
	[0.64, 0.75]	[7.9, 10.1]		
Lessees	0.66	8.3	2.32	3.1
	[0.58, 0.75]	[6.9, 10.1]	[2.01, 2.63]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.29	3.0	1.02	3.1
	[0.20, 0.38]	[2.0, 4.1]	[0.70, 1.33]	[2.2, 3.1]
Leasing company perception	0.55	6.5	0.55	6.5
of used car market	[0.42, 0.68]	[4.6, 8.7]	[0.42, 0.68]	[4.6, 8.7]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.36. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.38: Sensitivity Analysis (Limited Imputation, Bimonthly Gas Prices, 25% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.84	13.4	0.95	17.6	1.19	32.0
	[0.77, 0.90]	[11.5, 15.7]	[0.88, 1.02]	[13.8, 32.0]	[1.10, 1.28]	[32.0, 32.0]
-3	0.61	8.2	0.69	8.8	0.87	11.7
	[0.56, 0.66]	[7.3, 9.1]	[0.64, 0.75]	[7.9, 10.1]	[0.80, 0.94]	[9.7, 14.9]
-4	0.50	6.3	0.57	6.8	0.71	7.8
	[0.46, 0.54]	[5.7, 7.0]	[0.52, 0.61]	[6.0, 7.4]	[0.65, 0.76]	[6.8, 8.8]
-5	0.43	5.3	0.49	5.6	0.61	6.2
	[0.39, 0.46]	[4.8, 5.7]	[0.45, 0.53]	[5.0, 6.1]	[0.56, 0.66]	[5.5, 7.0]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.39	3.1	1.42	3.1	1.47	3.1
	[1.05, 1.73]	[3.1, 3.1]	[1.07, 1.77]	[3.1, 3.1]	[1.11, 1.83]	[3.1, 3.1]
-3	1.00	3.1	1.02	3.1	1.06	3.1
	[0.69, 1.31]	[2.1, 3.1]	[0.70, 1.33]	[2.2, 3.1]	[0.73, 1.38]	[2.3, 3.1]
-4	0.80	2.5	0.82	2.5	0.85	2.6
	[0.50, 1.10]	[1.5, 3.1]	[0.51, 1.12]	[1.6, 3.1]	[0.53, 1.16]	[1.6, 3.1]
-5	0.68	2.1	0.70	2.2	0.72	2.2
	[0.39, 0.98]	[1.2, 3.0]	[0.40, 1.00]	[1.2, 3.1]	[0.41, 1.03]	[1.3, 3.1]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.60	8.0	0.71	9.2	0.98	18.9
	[0.46, 0.74]	[5.7, 10.7]	[0.55, 0.88]	[6.5, 13.8]	[0.75, 1.20]	[8.6, 32.0]
-3	0.46	5.7	0.55	6.5	0.75	8.6
	[0.35, 0.57]	[4.2, 7.5]	[0.42, 0.68]	[4.6, 8.7]	[0.58, 0.93]	[5.8, 14.3]
-4	0.39	4.8	0.47	5.3	0.64	6.6
	[0.30, 0.49]	[3.6, 6.2]	[0.36, 0.58]	[3.9, 6.9]	[0.49, 0.79]	[4.6, 9.5]
-5	0.35	4.2	0.42	4.6	0.57	5.6
	[0.27, 0.44]	[3.2, 5.5]	[0.32, 0.52]	[3.4, 6.0]	[0.43, 0.71]	[3.9, 7.8]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.36 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.36) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.39: Likely Lessee Buyers Regression Results: Bimonthly Gas Prices

Transaction sample	Baseline model Pooled (1)	 Purchases (2)	Lease model Leases (3)
Panel A: Price regressions			
Dependent variable: Transaction price (2017 USD)			
Cost per mile (2017 USD)	-24,731*	-23,882*	-28,105*
	(2,051)	(1,882)	(3,767)
Implied elasticity (price with respect to cost per mile)	-0.092	-0.092	-0.088
95 percent confidence interval	[-0.107, -0.077]	[-0.107, -0.078]	[-0.111, -0.064]
Number of observations	951,091	792,924	157,874
R^2	0.944	0.945	0.939
Panel B: Quantity regressions			
Dependent variable: Quantity			
Estimation method: Poisson pseudo maximum likelihood			
Cost per mile (2017 USD)	-4.747*	-4.670*	-3.957*
	(0.583)	(0.590)	(0.707)
Implied elasticity (quantity with respect to cost per mile)	-0.660	-0.650	-0.524
95 percent confidence interval	[-0.818, -0.501]	[-0.812, -0.489]	[-0.707, -0.340]
Number of observations	57,111	55,547	33,577
Pseudo-R^2	0.580	0.566	0.409
Panel C: Residual Value regressions			
Dependent variable: Residual value (2017 USD)			
Cost per mile (2017 USD)			-20,370*
			(3,653)
Implied elasticity (residual value with respect to cost per mile)			-0.121
95 percent confidence interval			[-0.164, -0.078]
Number of observations			113,549
R^2			0.558

Notes: This table reports price, quantity, and residual value regression results across different sample populations. This table is similar to Table 2 except it reclassifies certain lessees as buyers if they are likely to purchase their vehicle at the end of their lease (see Section 4.2.1 and Figure A.1 for more detail on this). Columns 1 and 2 estimate our baseline model, while column 3 uses our lease-only model that incorporates residual value. The regressions use average gasoline prices and sales aggregation in line with the *Automotive Leasing Guide* (ALG) residual value estimates bimonthly publication schedule. ALG publishes estimates that are effective for two month periods (Jan/Feb, Mar/Apr, etc.). Standard errors in parentheses are clustered by market year, make, and model. All dollar amounts are adjusted to 2017 USD. All regressions include market year, bimonthly (i.e., ALG edition), and vehicle stub fixed effects. We define a "vehicle stub" as a unique combination of make, model, fuel type, drive type, body style, engine liters, and trim. We exclude transactions whose sale price differs from MSRP by more than +/- 25 percent. All regressions are unweighted. The dependent variable for the quantity regressions is obtained by aggregating observed quantities of vehicle stubs in the InMoment survey data by bimonthly group (in line with ALG publication schedule) and market year. All regressions include the following additional controls (not shown above): engine cylinders, education level (bachelor's degree dummy, or percentage with bachelor's degree if imputed), urban/rural dummy, household income, household size, and race (white/nonwhite dummy, or percentage white if imputed). We also control for regulatory stringency (interacted with vehicle model year fixed effects) in all regressions. $*p < 0.05$.

Table A.40: Likely Lessee Buyers Reclassified Valuation Ratios and Payback Periods: Bimonthly Gasoline Prices

	Vehicle lifetime fuel costs		Lease-specific fuel costs	
Panel A: Baseline model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Pooled sample	0.73	9.7		
	[0.67, 0.78]	[8.5, 10.8]		
Buyers	0.71	9.2		
	[0.65, 0.76]	[8.1, 10.3]		
Lessees	0.65	8.1	2.28	3.1
	[0.56, 0.75]	[6.6, 10.1]	[1.96, 2.60]	[3.1, 3.1]
Panel B: Lease model	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Lessees	0.28	2.9	0.98	3.0
	[0.19, 0.37]	[1.9, 4.0]	[0.67, 1.29]	[2.1, 3.1]
Leasing company perception	0.54	6.3	0.54	6.3
of used car market	[0.41, 0.66]	[4.5, 8.3]	[0.41, 0.66]	[4.5, 8.3]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.39. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios using a 4 percent discount rate and an assumed own price elasticity of -3, and calculate the ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. We compute lessee implied payback periods using both expected discounted lifetime and lease-specific fuel costs. We scale the lease-specific fuel cost implied payback periods by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.

Table A.41: Sensitivity Analysis (Likely Lessee Buyers, Bimonthly Gas Prices, 25% Price Outlier Trim)

Discount factor	**2 percent**		**4 percent**		**8 percent**	
Panel A: Buyers	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.85	13.7	0.97	19.6	1.21	32.0
	[0.79, 0.92]	[11.9, 16.8]	[0.90, 1.05]	[14.7, 32.0]	[1.12, 1.31]	[32.0, 32.0]
-3	0.62	8.3	0.71	9.2	0.89	12.4
	[0.57, 0.67]	[7.5, 9.3]	[0.65, 0.76]	[8.1, 10.3]	[0.82, 0.96]	[10.2, 16.5]
-4	0.51	6.5	0.58	6.9	0.72	8.0
	[0.47, 0.55]	[5.9, 7.1]	[0.53, 0.62]	[6.1, 7.6]	[0.66, 0.78]	[7.0, 9.2]
-5	0.44	5.5	0.50	5.7	0.62	6.3
	[0.40, 0.47]	[4.9, 5.9]	[0.46, 0.54]	[5.2, 6.3]	[0.57, 0.68]	[5.6, 7.3]
Panel B: Lessees	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	1.34	3.1	1.37	3.1	1.42	3.1
	[1.01, 1.67]	[3.1, 3.1]	[1.03, 1.71]	[3.1, 3.1]	[1.06, 1.77]	[3.1, 3.1]
-3	0.96	3.0	0.98	3.0	1.02	3.1
	[0.66, 1.27]	[2.0, 3.1]	[0.67, 1.29]	[2.1, 3.1]	[0.70, 1.34]	[2.2, 3.1]
-4	0.77	2.4	0.79	2.4	0.82	2.5
	[0.48, 1.06]	[1.5, 3.1]	[0.49, 1.08]	[1.5, 3.1]	[0.51, 1.12]	[1.6, 3.1]
-5	0.66	2.0	0.67	2.1	0.70	2.2
	[0.37, 0.94]	[1.1, 2.9]	[0.38, 0.96]	[1.2, 3.0]	[0.40, 1.00]	[1.2, 3.1]
Panel C: Leasing company perception of used car market	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**	**Valuation ratio**	**Payback period**
Demand elasticity						
-2	0.59	7.8	0.70	9.0	0.95	15.6
	[0.45, 0.72]	[5.6, 10.3]	[0.53, 0.86]	[6.1, 13.1]	[0.73, 1.17]	[8.2, 32.0]
-3	0.45	5.6	0.54	6.3	0.74	8.4
	[0.35, 0.56]	[4.2, 7.3]	[0.41, 0.66]	[4.5, 8.3]	[0.57, 0.91]	[5.6, 13.3]
-4	0.39	4.8	0.46	5.2	0.63	6.5
	[0.30, 0.48]	[3.6, 6.0]	[0.35, 0.57]	[3.7, 6.8]	[0.48, 0.78]	[4.5, 9.2]
-5	0.35	4.2	0.41	4.5	0.56	5.5
	[0.26, 0.43]	[3.0, 5.3]	[0.31, 0.51]	[3.3, 5.9]	[0.43, 0.70]	[3.9, 7.7]

Notes: This table reports valuation ratios and implied payback periods (expressed in years) associated with the results from Table A.39 using different discount factor and own price elasticity assumptions. A valuation ratio of 1 implies full valuation of discounted expected fuel costs. We compute the valuation ratios at the vehicle stub/market year level using average transaction prices, quantities, and cost per mile within each stub/market year. The valuation ratios reported the table are unweighted averages of the stub/market year level averages. We compute 95 percent confidence intervals (in brackets) using the delta method. Implied payback periods are expressed in years and are derived from the valuation ratios using the method from Bento et al. (2018). We use an upper bound of 32 years for implied payback periods corresponding to valuation ratios greater than 1. All lessee valuation ratios and implied payback periods in panel B are computed from the lease-only model (i.e., column 3 of Table A.39) using expected discounted lease-specific fuel costs. We scale the implied payback periods in panel B by multiplying the corresponding valuation ratio by the average lease length (3.1 years) in the sample. We use an upper bound of 3.1 years for lease-specific implied payback periods corresponding to valuation ratios greater than 1.