The Cost of Credit and the Energy Efficiency Gap: Evidence from the U.S. New Vehicle Market

Kevin Ankney[*†]

February, 2024

Abstract

The "energy efficiency gap" is a puzzle characterized by consumer under-investment in energy-efficient products (e.g., hybrid vehicles), whose higher upfront cost is offset by future energy savings. One common but empirically unsubstantiated explanation for the gap is that credit constraints—high borrowing costs or a lack of access to credit—hinder consumers' ability to make energy efficiency investments. While credit constraints often refer to a consumer's access to credit (i.e., the extensive margin), they can also related to a consumer's financing costs conditional on being approved for a loan (i.e., the intensive margin). This paper studies the intensive margin of credit constraints and provides the first direct evidence of the relationship between consumers' cost of credit and fuel economy demand in the U.S. new vehicle market. On average, increasing a consumer's auto loan interest rate from 2% to 5% APR is associated with a 0.09 MPG decrease in purchased fuel economy. For a typical auto loan, this corresponds to $2,313 in additional interest paid, but only $97 in lifetime fuel cost savings lost. This disparity calls into question the suggestion that credit constraints are a meaningful contributor to the energy efficiency gap for durable goods in the U.S.

Keywords: cost of credit, credit constraints, fuel economy standards, passenger vehicles, energy efficiency

JEL codes: D12, Q58

[*] Georgetown University Department of Economics, kca39@georgetown.edu

[†] I am grateful to the following people for helpful comments and support on this project: Laurent Bouton, Becka Brolinson, Raphael Calel, Peter Caradonna, Rachel Feldman, Maria Hernandez de Benito, Shai Knight-Winnig, Benjamin Leard, Arik Levinson, Joshua Linn, Bridget Matikainen-Ankney, J.J. Naddeo, John Rust, Lutz Sager, Deniz Sanin, Katalin Springel, Arthur van Benthem, Lina Yu, participants at the Georgetown Economics Graduate Student Organization and Georgetown Applied Microeconomics seminars, and participants at the following workshops: OSWEET, the Northeast Workshop on Energy Policy and Environmental Economics, Camp Resources, the WashU Economics Graduate Student Conference, the Southern Economic Association 91st Annual Meeting, and the 2022 ASSA Annual Meeting. I would like to especially thank Benjamin Leard, Joshua Linn, and Resources for the Future for facilitating my use of the Ipsos (formerly InMoment) survey data for this project.

1 Introduction

Embracing energy efficiency is widely believed to be essential to reduce greenhouse gas emissions. Energy efficiency programs and technology are often regarded as a “win-win” for consumers and the environment, the thinking being that consumers will simultaneously save money from reduced energy expenditures and will use less energy. From this perspective, consumer purchases of energy-efficient appliances, cars, and other durable goods should be ubiquitous. Nevertheless, the apparent low uptake of these seemingly profitable energy efficiency investments is a puzzle. People who drive a lot or expect to pay high gasoline prices would likely save money in the long run if they invested in more fuel-efficient vehicles, but they often instead purchase less expensive, less efficient alternatives. This behavior of consumers foregoing energy efficiency investments that would eventually pay for themselves is referred to broadly as the “energy efficiency gap” or “energy paradox” (Jaffe and Stavins, 1994).[1] Part of the justification for regulations such as the Corporate Average Fuel Economy (CAFE) standards is the existence of the energy efficiency gap; the regulations are purported to both help the environment and save consumers money.

A large literature in economics studies the energy efficiency gap to identify its possible causes and inform appropriate policy responses. One common explanation is that credit constraints—a lack of access to credit or high borrowing costs—deter consumer investment in energy efficiency (Gerarden et al., 2017; Gillingham and Palmer, 2014).[2] For example, a fuel-inefficient car costs less to buy than a fuel-efficient car, all else equal, but the inefficient car costs more to operate because it uses more fuel per mile driven.[3] For a budget-constrained buyer, purchasing a less efficient car at a cheaper price is similar to taking out a loan from a bank—the buyer saves money today but pays “interest” in future years in the form of

[1]More generally, the energy efficiency gap refers to the under-provision of profitable energy-saving technologies. This under-provision could be due to either demand or supply-side factors (or both); this paper focuses on the demand side by investigating consumer investment in fuel economy.

[2]Other common explanations for the energy efficiency gap include consumer undervaluation of future fuel cost savings/consumer myopia (e.g., Busse et al., 2013; Allcott and Wozny, 2014; Sallee et al., 2016; Leard et al., 2023b), information provision issues (e.g., Allcott and Knittel, 2018), inattention (e.g., Allcott, 2011; Sallee, 2014), loss aversion (e.g., Greene, 2011), principal-agent problems (e.g., Gillingham and Palmer, 2014; Blonz, 2019), and investment irreversibility (e.g., Metcalf and Hassett, 1999). See Gerarden et al. (2017) or Allcott and Greenstone (2012) for reviews of research on the energy efficiency gap.

[3]Throughout the paper I refer to “cars” and “vehicles” interchangeably. In either case, I am referring to both passenger cars (e.g., sedans, hatchbacks) and light trucks (e.g., sport utility vehicles, pickup trucks).

higher fuel expenditures. Thus, given a finite budget constraint and a high price for a loan, purchasing an inefficient vehicle could be rational for credit-constrained buyers.

Few empirical studies exist which either corroborate or refute the claim that credit constraints contribute to the energy efficiency gap. In their assessment of the energy efficiency gap, Allcott and Greenstone (2012) state "[c]redit constraints are a frequently discussed investment inefficiency. Although we note the issue in theory, there is not much empirical evidence in the context of energy efficiency, so we will not discuss it further." Moreover, the limited evidence that exists supporting credit constraints as a market barrier to energy efficiency investments typically uses income as a proxy for credit constraints (e.g., Hausman, 1979) and predominantly concerns home energy retrofits (e.g., Ameli and Brandt, 2015; Berry, 1984; Palmer et al., 2013) rather than energy-intensive durable goods like cars and appliances. More recently, Berkouwer and Dean (2022) used a randomized controlled trial (RCT) to show that providing access to credit closes the energy efficiency gap for adoption of energy-efficient cookstoves in Kenya. Though Berkouwer and Dean focus on the developing world—a potential locus of future global energy demand—the role that credit constraints play in the energy efficiency investment decisions for U.S. consumers remains an open empirical question.

Credit constraints typically come in two forms: 1) a lack of access to necessary credit to finance present consumption with resources to be received in the future, or 2) having access to funds at an interest rate that increases in the amount borrowed (Attanasio et al., 2008). One can think of these two forms as the extensive and intensive margin of consumer financing costs, respectively.[4] Unlike Berkouwer and Dean (2022), whose RCT focuses on the extensive margin, this paper studies consumers who were approved for an auto loan and who used an auto loan to finance their vehicle purchase (i.e., the *intensive* margin). Thus, studying consumers who were denied or otherwise unable to obtain an auto loan (i.e., the extensive margin) is outside the scope of this paper. However, given the substantial carbon footprint of automobiles, the steadily growing volume of U.S. auto loan debt (CFPB, 2018),

[4]Further, Attanasio et al. (2008) point out that the first form can be thought of as a special case of the second form in which the interest rate becomes infinite after a certain amount borrowed.

and the fact that most new cars are purchased using loans, the U.S. new vehicle market represents an ideal setting in which to explore the relationship between consumer financing costs and energy efficiency investment decisions. Indeed, according to Experian Automotive, as of Q3 2023 over 86% of new passenger vehicles were financed with a loan or lease, the average amount financed was $40,184, and the average loan rate was over 7%.

This paper documents the first direct evidence to my knowledge of a statistical relationship between consumers' cost of credit and demand for fuel economy in the U.S. new vehicle market. I use direct measures for the cost of credit in the form of self-reported auto loan annual percentage rates (APR) and also supplement my analysis with self-reported buyer credit histories. These measures allow me to distinguish between buyers with a low or high cost of credit and is an advantage over existing studies that use income as an imperfect proxy for credit constraints.

I first perform a simple calculation of the "break-even" auto loan APR that makes investing in additional fuel efficiency financially profitable for consumers. I show that this break-even APR is often well above the auto loan rate obtained by consumers, and that even under conservative assumptions, a large percentage of consumers would likely profit from purchasing more fuel-efficient cars. I take these break-even APR calculations as suggestive evidence of an energy efficiency gap in the U.S. new vehicle market. Many buyers are leaving money on the table by not investing in more fuel economy. Buyers whose break-even APR lies above their actual APR would save an average of $809 in discounted lifetime fuel costs by purchasing an additional mile per gallon of fuel economy.[5] The question I then attempt to answer is: to what extent do consumers' cost of credit contribute to this under-investment?

I use several different empirical specifications to estimate the relationship between the cost of credit and fuel efficiency choices made by new car buyers. I motivate the empirical approach with a two-good consumer choice model described in the Appendix. The model underscores the importance of using a direct measure of consumers' cost of credit rather than using income as an imperfect proxy. I also perform two alternative tests for evidence of the

[5] $809 represents net savings after accounting for the estimated cost of one mile per gallon of around $239.

cost of credit hindering fuel efficiency investment. First, I examine whether car buyers facing high gasoline prices are more likely to purchase a fuel-efficient car if they face a relatively low cost of credit. Second, I estimate a linear probability model to examine the association between consumers' cost of credit and their relative likelihood of purchasing a hybrid vehicle as opposed to its gasoline-powered equivalent.

The primary identification challenge in all of the empirical approaches is an omitted variable problem—I cannot rule out the possibility that financially savvy consumers both have good credit (and thus a relatively low cost of credit) *and* purchase fuel-efficient cars. This makes causal identification of the relationship between consumers' cost of credit and fuel efficiency investment difficult. I attempt to correct any omitted variable bias using self-reported credit history as a proxy variable for unobserved financial literacy, which may be correlated with both fuel efficiency choice and a buyer's auto loan interest rate.

Two things are important to note regarding the potential existence of omitted variable bias in the paper's estimates, both of which I discuss further in Section 4. First, the bias associated with omitted financial literacy is likely downward bias with respect to the relationship between consumers' cost of credit and fuel economy choice. Because the estimated association between cost of credit and fuel economy choice is negative, estimates suffering from downward bias would overstate (i.e., be more negative than) any true effect. Further, even without correcting for any bias, the paper's estimates are consistently negative and small in magnitude, so the most likely source of bias does not materially affect the results. Second, the estimates that include self-reported credit histories are consistent with the presence of downward bias in that they remain negative and are smaller in magnitude than the original estimates. Nevertheless, though the empirical analyses of this paper yield internally consistent findings that suggest a negative and economically small association between the cost of credit and consumer fuel economy choices, the results are correlational in nature and should not be interpreted causally.

The paper's results are among the first to document the role that the cost of credit may play in the energy efficiency gap, and in particular are the first to my knowledge to do so in the important empirical setting of the U.S. new vehicle market. The results tell a consistent story—consumers' cost of credit is negatively associated with fuel economy choices in the U.S. new vehicle market, but the magnitude of the relationship is small and cannot explain a meaningful portion of the energy efficiency gap. For example, a 3 percentage point change in loan APR (e.g., going from a 2% to 5% APR loan) is associated with only a 0.09 mile per gallon (MPG) decrease in the fuel economy of vehicles consumers purchase. A change from 2% to 5% APR is economically meaningful—it corresponds to a $2,313 increase in total interest paid for an average loan the sample, which represents a 156% increase. However, the 0.09 MPG decrease is negligible and results in an average increase of around $97 in discounted lifetime fuel costs. These results call into question the suggestion that credit constraints explain the energy efficiency gap in the context of U.S. durable goods markets.

2 Data

The primary data I use for this paper have been generously provided by Resources for the Future. The repeated cross-sectional data contain responses from a survey of new car buyers conducted annually by Ipsos (formerly InMoment), a market research firm. Ipsos contacts millions of new car buyers each year using vehicle registration records, and the survey is completed either online or by mail. The survey has a response rate of roughly 9% and represents approximately 0.5% of the new vehicle market, including purchases from all fifty states and the District of Columbia (Leard et al., 2023b). Ipsos strives to make the survey representative of the new vehicle market and thus tries to obtain survey responses for models spanning the entire vehicle spectrum. The survey responses include information about the vehicle purchased, transaction details (e.g., *actual* price paid, trade-in allowances), customer demographic information (e.g., income, education level, age, household size, marital status), and importantly, financing details (e.g., down payment amount, APR, loan length, self-reported credit history). Throughout the paper I use inflation-adjusted real APR—Figure 1 shows the average monthly real APR for the sample period, along with the fifth and ninety-fifth percentiles of the real APR distribution by month for the main regression sample that I analyze.

I enrich the Ipsos data with detailed trim-level vehicle characteristics from Wards Automotive (e.g., MPG, weight, horsepower) and regional average gasoline prices from the U.S. Energy Information Administration (EIA).[6] The gasoline prices are at the Petroleum Administration for Defense District (PADD) level.[7] Figure 2 shows the monthly average gasoline price variation by PADD. I use Edmunds.com and similar online sources to obtain vehicle characteristics for any trims that are completely or partially missing from Wards. All dollar amounts in the paper have been converted to 2017 U.S. dollars using the historical CPI-U from the U.S. Bureau of Labor Statistics.[8]

The merged Ipsos/Wards data contain 1,813,684 new vehicle transactions from the years 2009-2018. I drop 559,122 transactions that are labeled as leases or are missing the lease/purchase indicator. I drop 697,212 purchases with incomplete loan information and another 20,422 with missing purchase prices. After also removing loan amount and price outliers and purchases that are missing consumer demographic data, the main sample I analyze contains 369,425 new vehicle purchases spanning October 2009 to September 2018. Summary statistics are provided in Table 1.[9]

3 Suggestive Evidence of an Energy Efficiency Gap

This section provides evidence that many consumers under-invest in fuel economy, suggesting the existence of an energy efficiency gap in the U.S. new vehicle market.[10] I consider a new car buyer who is deciding whether to pay a bit more for an identical but slightly

[6]The Wards data are matched to Ipsos in two steps. First, the data are merged based on an exact match of vehicle model year, make, model, fuel type, drive type, body style, and engine liters. This creates a one-to-many match of each Ipsos purchase to several Wards vehicle trims. I then perform a text-based comparison of the vehicle trims in Ipsos and Wards to reduce the dataset to a one-to-one match based on the trim that is most similar across datasets (e.g., this step would match a Ipsos purchase of the 2012 Ford Focus Titanium to the "Titanium" trim rather than to the "SE" or "SEL" trim). Any purchase that has multiple trim-level "best matches" is assigned average values of Wards characteristics across the matched trims.

[7]A map of the PADDs can be found here. I use monthly average gasoline prices from the five main PADD regions.

[8]https://www.bls.gov/cpi/tables/supplemental-files/historical-cpi-u-201905.pdf

[9]I also use several other supplementary data sources to provide suggestive evidence of an energy efficiency gap. I discuss these data sources in Section 3.

[10]The existence of an energy efficiency gap, as well as its magnitude, has been debated by economists (see, for example, Allcott and Greenstone (2012)).

more fuel-efficient car and calculate the buyer's "break-even" loan APR. I define the the "break-even" APR as that below which the buyer's expected discounted lifetime fuel cost savings from the fuel efficiency upgrade exceed the cost of borrowing the *additional* funds necessary to purchase the more efficient car. Buyers who can obtain a loan for below this break-even APR would presumably save money in the long run by investing in additional fuel efficiency.[11]

I calculate the break-even APR for 328,873 new car purchases in my sample.[12] To do this, I consider each buyer's decision of whether to invest in additional fuel efficiency. From a purely financial perspective, the buyer should be willing to pay for a slightly more efficient car if the discounted expected fuel cost savings resulting from the investment exceed the cost of the investment (i.e., the total principal and interest paid for the loan). As such, the buyer should be willing to invest if the following inequality holds:

$$\mathbb{E}\left[\sum_{t=1}^{T} \delta^{t-1} \cdot S_t\right] \geq \sum_{t=1}^{L} \delta^{t-1} \cdot 12 \cdot M \tag{1}$$

In inequality (1), T is the length of ownership of the car in years;[13] S_t is the annual fuel cost savings from the increased fuel efficiency in year t; L is the length of the loan used to purchase the car (in years); M is the monthly payment amount on the loan (in dollars);[14] δ is the buyer's discount factor. Inequality (1) importantly allows for fuel cost savings to be enjoyed beyond the length of the loan. For instance, a buyer might have a five year loan for their car but may own the car for 10 years, so the fuel cost savings enjoyed by purchasing additional fuel efficiency may extend well beyond the loan repayment period.

[11] I am assuming that a buyer's auto loan APR is the relevant cost of borrowing the buyer considers when deciding whether or not to borrow more money. It is possible that a buyer might have credit card debt or another source of debt that carries a higher interest rate than the buyer's auto loan APR, in which case it might not be optimal financially for the buyer to purchase a more expensive car (i.e., it may be better for the buyer to borrow less money for a car and pay off their higher interest loan instead). To address this limitation, I assume a larger discount factor of 10% for all consumers in some of my calculations, which is much higher than the typical auto loan rate in the sample and approximates a higher implicit cost of borrowing.

[12] I restrict the break-even APR calculations to transactions with auto loan lengths of 2, 3, 4, 5, 6, or 7 years for computational simplicity. This subset of transactions represents nearly 90% of my main regression sample.

[13] Not all buyers will own their vehicle for the vehicle's entire useful life. If a buyer owns the vehicle for its entire useful life, the vehicle is scrapped at $t = T$. If the buyer sells or trades in the vehicle prior to the end of its useful life, then the sale/trade-in occurs at $t = T$ and I assume that any expected future operating costs are fully capitalized into the used car sale price/trade-in value.

[14] I use the industry standard levelized formula for monthly payments on auto loans. For an n-month loan, if p is the principal borrowed and r is the APR, the monthly payment amount is $\frac{p \cdot \frac{r}{12}}{1-(1+\frac{r}{12})^{-n}}$. To calculate each buyer's break-even APR, I only need to consider the additional amount borrowed to purchase more fuel economy—not the entire loan amount for the car.

To calculate M, I need the cost of the incremental fuel efficiency since this cost is the principal amount borrowed for the right hand side of inequality (1). To obtain the cost of one additional mile per gallon, I regress purchase prices from the Ipsos survey on detailed vehicle characteristics from Wards Automotive. These regression results are presented in Table 2. I use the estimate from column 5, which includes vehicle model year, month of purchase, PADD region, and vehicle make fixed effects; on average, one additional mile per gallon costs consumers \$239.10. This cost is consistent with other studies in this literature. For instance, Levinson and Sager (2023) estimate a marginal cost of fuel economy ranging from \$110 to \$340, and Leard et al. (2023b) estimate an approximate consumer willingness-to-pay of \$631 for a 1-MPG improvement based on average characteristics in their sample.[15] I take this estimate and plug it into the standard monthly payment formula for an auto loan. The break-even APR equation is updated as follows:

$$\mathbb{E}\left[\sum_{t=1}^{T}\delta^{t-1}\cdot S_t\right]=\sum_{t=1}^{L}\delta^{t-1}\cdot 12\cdot\frac{239.10\cdot\frac{r}{12}}{1-(1+\frac{r}{12})^{-12\cdot L}} \tag{2}$$

In equation (2), M is replaced by the monthly payment formula for an auto loan, and r is the break-even APR. For each consumer's break-even APR calculation, I use the actual length of their loan (L in equation (2)).

I calculate S_t for each consumer by computing the difference between the expected discounted lifetime fuel costs for the car they actually purchased and for a car that is 1-MPG more efficient.[16] First, I assume that the gasoline price from the month in which the buyer purchased the vehicle remains constant for the life of the vehicle.[17] Second, I assume there is no rebound effect associated with the purchase of additional fuel efficiency.[18] Third, I use vehicle miles traveled (VMT) and scrappage probability schedules for each vehicle to

[15] To arrive at \$631, I divide the estimated consumer willingness-to-pay for a 1% increase in fuel economy from Leard et al. (2023b) (\$134) by 1% of the mean fuel economy in their sample (23.9 MPG). I then adjust the result to 2017 USD.

[16] The average expected discounted lifetime fuel costs for purchases in the Ipsos sample are shown in Table 1.

[17] Assuming constant gasoline prices for calculation of future fuel costs is common in the literature—see, for example, Busse et al. (2013). Also, evidence suggests that consumers believe future gasoline prices will not change from current prices (Allcott, 2011; Anderson et al., 2013).

[18] The rebound effect refers to energy savings lost due to increased energy use after obtaining an energy efficient good. For example, if a consumer acquires a more fuel-efficient car, the consumer's cost of driving (per mile) decreases, so they may drive more as a result. Estimates of the magnitude of this effect vary in the literature, with the middle of the range at approximately 15% of energy savings lost due to rebound (Gillingham et al., 2016).

compute expected miles driven over the vehicle's life. The VMT and scrappage schedules are taken from Leard et al. (2023a). The VMT schedules are estimated from 2017 National Household Travel Survey (NHTS) data and are dis-aggregated by driver income, age, and urban/rural status, and by car versus light truck.[19] The scrappage schedules are estimated separately for cars and light trucks using R.L. Polk vehicle registration data from 2002-2014. The scrappage likelihood increases with vehicle age, rising to 100% at 35 years for cars and at 40 years for light trucks.[20]

I use two different assumed discount rates. I start with the average real loan APR within the Ipsos data for the month in which the vehicle was purchased. This approximates the cost of credit for the consumer, which would be a rational discount factor when considering the trade-off between future fuel cost savings and additional auto loan debt. The average real loan APR in the Ipsos data is around 2%, so this a relatively small discount factor. As a second alternative, I use a discount factor of 10% for all buyers.[21] I obtain the break-even APR for each consumer by solving equation (2) for r—the APR at which each consumer should be willing to invest in one additional MPG of fuel efficiency.

Figure 3 plots two empirical cumulative distribution functions (CDF) of differences between the estimated break-even APR and the actual APR at which each consumer financed their vehicle purchase.[22] The portion of the CDF that lies above zero on the horizontal axis represents consumers who—on a purely financial basis—are leaving money on the table by not investing in more fuel efficiency. These consumers have a positive difference between their break-even APR and the APR of the loan they actually obtained, meaning they could profitably purchase an additional MPG of fuel efficiency at their current auto loan rate.

The CDFs in Figure 3 have striking implications. Aside from a small portion of buyers whose break-even APR is at or below the actual APR they received on their loan (i.e., the

[19]Ipsos asks buyers how many miles they expect to drive their new vehicle per year, so it is also possible to use these data for the lifetime fuel cost calculations. However, Ipsos only asks for one number (not a number for each year of ownership), and VMT tends to decrease as a car ages. For lifetime fuel cost calculations, I prefer to use the NHTS-based VMT estimates since they allow for more detailed approximation of VMT as vehicles age through the use of used car data in the survey.

[20]35-40 years may seem unrealistically long for the lifespan for a vehicle, but keep in mind that the probability of a vehicle surviving to this age is very small per the scrappage schedules.

[21]10% is considerably higher than the average real APR in the sample, so this alternative discount rate accounts for the possibility that consumers have high discount rates.

[22]The two CDFs represent the real APR-based discount factor and the 10% discount factor calculations, respectively.

portion of the CDFs that lie below zero), the vast majority of car buyers have a substantial difference between their actual APR and break-even APR. In fact, regardless of the discount factor, for more than 90% of consumers in the sample, their break-even APR is higher than their actual APR, and for most consumers the difference is much larger than prevailing auto loan rates from the sample period. The median difference for the APR-based distribution is around 70 percentage points, while the median difference for the more conservative 10% discounting distribution is approximately 46 percentage points. Moreover, a substantial share of buyers would financially benefit from accepting a loan at *any* APR, because their payback period for the investment is less than one year.

The fuel cost savings that consumers would enjoy from purchasing an additional MPG of fuel economy are non-trivial. Assuming constant gasoline prices and no changes to VMT, consumers whose break-even APR lies above their actual loan APR would save an average of $1,048 in discounted lifetime fuel costs by purchasing an additional MPG of fuel economy. Based on the estimate that an additional MPG costs around $239, this yields an average net savings of $809 per consumer, which represents a 3.6% reduction in discounted lifetime fuel costs.[23] Considering that more than 90% of consumers stand to gain from purchasing an additional MPG based on Figure 3, the cumulative savings that consumers would enjoy from investing in more fuel economy are substantial.[24]

It is important to point out that the situation described above—considering the purchase of an otherwise identical car with 1-MPG higher fuel economy—is not something that consumers realistically encounter. However, repeating this exercise using a larger fuel economy upgrade and a higher upfront cost yields less extreme but similar results. Figure 4 plots CDFs for a similar analysis that instead contemplates an 8.2-MPG increase at a cost of $6,475.[25] These numbers roughly represent the price and MPG increase associated with

[23]The $809 net savings calculation uses the average monthly real APR in the sample as a discount factor. If you instead used the larger 10 percent discount factor, average net savings would be $421, which still represents a 3.1% reduction in discounted lifetime fuel costs.

[24]The rebound effect might erode some of these savings if consumers drive their more fuel-efficient cars farther, but even after accounting for the rebound effect consumers would likely still be leaving considerable money on the table by not investing in more fuel economy.

[25]I also repeat this exercise using the more conservative $631 from Leard et al. (2023b) as the cost for a 1-MPG upgrade. The associated Figure A.1 is in the Appendix.

upgrading from a gasoline-powered to hybrid vehicle.[26] The 8.2-MPG upgrade at a cost of $6,475 implies a higher price per MPG of over $750, and the CDFs in Figure 4 show that many consumers have a break-even APR below zero in this scenario. This is in line with what we should expect when a much larger upfront investment is required. However, there is still a significant portion of the distribution of consumers whose break-even APR is higher than their actual APR. Looking at the APR-based discount factor, around 35% of consumers would still profit from purchasing the more efficient car. Even using the larger 10% discount factor suggests that nearly 20% of consumers would profit from making the fuel efficiency investment.[27] Furthermore, using the sample's average monthly real APR as a discount factor, the estimated net savings on lifetime fuel costs for consumers who stand to gain from upgrading to a hybrid are $3,539. This corresponds to a 15.9% reduction in average lifetime fuel costs.[28] Thus, while fewer consumers stand to benefit financially from this sizable investment in fuel economy relative to a 1-MPG investment, the fuel cost savings that would be enjoyed by the average consumer when upgrading to a hybrid are significantly larger.

The substantial potential lifetime fuel cost savings and the large and persistent gap between available loan APRs and break-even APRs for many car buyers represent compelling suggestive evidence of an energy efficiency gap in the new vehicle market. Even under the conservative assumptions of widespread myopia or a large price premium for a fuel economy upgrade commensurate with switching from a gasoline-powered to hybrid vehicle, many buyers are leaving money on the table by not purchasing more fuel-efficient vehicles. The remainder of this paper empirically investigates the extent to which credit constraints contribute to this under-investment in fuel economy.[29]

[26] Specifically, 8.2 MPG and $6,475 are the median MPG and manufacturer suggested retail price increase from the Ipsos sample of cars that contain an otherwise similar gasoline or hybrid "sibling." I discuss these siblings in more detail in Section 4.4.

[27] It is worth noting that the revised calculations using the 8.2-MPG upgrade suggest that around 65% and 80% of buyers would likely not profit from the upgrade, depending on the discount factor used. This is consistent with Levinson and Sager (2023), who find that some demographic groups may over-invest in fuel efficiency. Nevertheless, regardless of the discount factor used, many drivers stand to profit from upgrading their fuel efficiency.

[28] The corresponding net savings calculations using a 10 percent discount factor are $1,331, or a 9.8% reduction in average lifetime fuel costs.

[29] It is important to note that, because the calculations in this section abstract away from consumer utility from vehicle purchases generally, it is possible that there are non-financial considerations that would deter consumers from upgrading their fuel efficiency and which could be utility maximizing for an individual consumer. For instance, perhaps a consumer has strong

4 Empirical Strategy and Results

Car buyers with a higher cost of credit face relatively higher total costs to purchase a fuel-efficient car. As a result, they may not choose to purchase a fuel-efficient vehicle if gasoline prices are sufficiently low or if they do not expect to drive enough to justify the higher cost. I capture this intuition in a two-good model described in the Appendix. The model illustrates the expected negative relationship between the cost of credit and fuel economy choice, and also underscores the idea that income alone may not be a sufficient proxy for credit constraints/cost of credit when analyzing energy efficiency investment preferences. Indeed, it is possible for two consumers with identical incomes to choose different optimal levels of fuel efficiency based on differences in their costs of credit.

In the sections that follow, I test the hypothesis that higher costs of credit inhibit investment in fuel efficiency. The results have a common theme—as expected, the estimates consistently show a negative relationship between consumers' cost of credit and the fuel economy of cars people buy. However, the magnitude of these estimates is generally small—often effectively zero—implying that higher costs of credit may suppress fuel economy investment, but not to a degree that explains a meaningful portion of the energy efficiency gap.

4.1 Loan APR and Fuel Economy Choice

If consumers' cost of credit influences investment in energy efficiency, buyers with higher auto loan interest rates costs will purchase vehicles with lower fuel efficiency. I test this prediction with the following regression:

$$MPG_{jirt} = \beta_0 + \beta_1 \cdot APR_{irt} + \beta_2' X_j + \beta_3' D_i + \delta_t + \gamma_r + \varepsilon_{jirt} \tag{3}$$

for vehicle j, consumer i, PADD region r, time t (month and year). In equation (3), X represents detailed vehicle characteristics (e.g., horsepower, weight, wheelbase), D represents

preferences for certain attributes of their gasoline vehicle (e.g., body design, interior) and there is not a hybrid version of that particular vehicle available. In that instance, it maybe privately optimal from a utility perspective for the consumer to continue driving their current vehicle even if they could save thousands of dollars in lifetime fuel costs by switching to a hybrid vehicle. Though modeling such trade-offs is outside the scope of this paper, the analysis in this section suggests that there are considerable cumulative potential savings available across all consumers that could be captured if a portion of consumers decided to invest in additional fuel economy.

consumer demographic characteristics (e.g., income, education level, age), δ and γ represent time (i.e., purchase month, purchase year, and model year) and region fixed effects, respectively, and ε is an error term.[30] The fixed effects account for time-specific shocks to vehicle demand, market-wide changes in CAFE standards, seasonality of the new car market and of gasoline prices, and regional differences in consumer preferences for fuel economy. The primary coefficient of interest is β_1, which represents the average change in fuel economy of a car purchased for a corresponding 1 percentage point increase in real APR (e.g., going from a 3% to 4% loan).

It is certainly possible that an omitted variable may bias estimates of equation (3). For instance, people who are financially literate may be more likely to think carefully about lifetime operating costs of their car and thus might have higher demand for fuel efficiency. Those same people may also qualify for lower auto loan interest rates than less financially literate buyers. This type of omitted variable—one that is positively correlated with MPG and negatively correlated with APR—would potentially create a downward bias in my estimates. Since I expect the estimate of β_1 to be negative, correcting this bias would likely result in a revised estimate of β_1 that is closer to zero. Thus, initial estimates of equation (3) may actually overstate the relationship between auto loan interest rates and fuel economy decisions.

Table 3 presents ordinary least squares (OLS) estimates of equation (3). Column 1 contains no fixed effects, while columns 2-6 use various combinations of the time and regional fixed effects discussed above. Column 5 uses model year, month, and PADD region fixed effects and is my preferred specification.[31] The point estimate from column 5 implies that a 1 percentage point increase in real loan APR is associated with an average decrease of 0.0520 MPG of the car purchased by the buyer.

Considering that the average fuel economy in the sample is over 24 MPG, a 0.0520 MPG decrease is essentially zero. On the other hand, a 1 percentage point change in real APR is

[30] For robustness, I vary the time fixed effects used across the columns of my regression results tables.

[31] The point estimates for the coefficient on loan APR are consistent across columns 2-6—they are not sensitive to the choice of fixed effects.

sizable—the average real APR in the sample is 1.928%, so a 1 percentage point increase is more than 50% of the mean real APR. Consider a loan for the average amount and length in the sample, about $28,700 over 5 years. An increase of the APR on that loan from 2% to 3% results in $759.28 in additional interest, representing a 51% increase in interest paid on the loan. Yet despite this significant change in financing charges, the average expected lifetime fuel cost savings lost due to the corresponding reduced fuel economy investment is only $56.[32]

4.2 Self-Reported Credit History as a Proxy for Omitted Financial Literacy

People with bad or no credit history are more likely to have a higher cost of credit (conditional on being approved for a loan), which should in turn have a similar effect on fuel efficiency investment as that of a high APR. The Ipsos survey asks buyers to report their credit history using one of four options: "perfect credit" (well-established credit history with no late payments of any kind), "acceptable credit" (established credit with a few late payments), "difficult credit" (established credit but previous problems make qualifying for auto finance difficult), or "have little or no credit history." Though it is a more coarse measure than an actual credit score, self-reported credit history still allows me to distinguish between buyers who are likely to have relatively higher or lower costs of credit. The frequencies of each of the four category responses are included in Table 1.[33]

I first regress real loan APR on self-reported credit history, loan details, and buyer demographics—these results are shown in Table A.2 in the Appendix.[34] The results in columns 1 and 2 of Table A.2 demonstrate that the relationship between credit history and APR is as one would expect. Buyers with bad credit have average APRs over 5 percentage points higher than buyers with excellent credit, while buyers with no credit history get better rates (2.4 percentage points higher than excellent credit buyers) and buyers with good credit see even better rates, on average (1.4 percentage points higher than excellent credit buyers).

[32] The $56 calculation is based on the average change in discounted expected lifetime fuel costs for a consumer whose fuel economy decreases by 0.0520 MPG relative to the vehicle they purchased. Similar calculations in other parts of the paper are done the same way, just considering different MPG reductions.

[33] Throughout the paper, I refer to the four credit history categories as excellent, good, bad, and no credit history.

[34] The "excellent" credit category is omitted so all estimates in Table A.2 are relative to a buyer with excellent credit.

Next, I include both APR and self-reported credit history in the same regression and use self-reported credit history as a proxy variable for omitted financial literacy. We know that a proxy variable must satisfy two assumptions. First, the conditional mean of the dependent variable must be unchanged when conditioning on the covariates, the proxy variable, and the omitted variable or just on the covariates and the omitted variable.[35] Second, the omitted variable must not be correlated with any covariates after you partial out the proxy variable. In the case of self-reported credit history, the first assumption seems reasonable since financial literacy is likely a strong signal of creditworthiness. The second assumption is reasonable for most of the covariates in equation (3). While it may not be true for all covariates (e.g., income may still be correlated with financial literacy after controlling for self-reported credit history), the second assumption is reasonable for loan APR's correlation with financial literacy. As a result, using self-reported credit history as a proxy variable—while not a panacea for all potential omitted variable bias—may improve estimates from equation (3).

Table 4 reports results of the proxy variable regressions. Columns 1, 3, and 5 estimate regressions without self-reported credit history, while columns 2, 4, and 6 repeat the previous column's regression with self-reported credit history included as a proxy variable.[36] The results in these pairs of columns are consistent across choice of fixed effects. Taking columns 5 and 6 as an example, the inclusion of self-reported credit history results in the point estimate for loan APR changing from -0.0517 MPG to -0.0287 MPG. This shift toward zero aligns with the expected correction of downward bias discussed in Section 4.1.

To put this result into context, consider again a typical loan in the sample, around $28,700 over 5 years. Increasing this loan's APR from 2% (close to the average real APR in the sample) to 5% (more than one standard deviation from the average real APR) would result in an additional $2,313 in interest charges.[37] Yet despite this substantial increase in interest, column 6 of Table 4 implies that the corresponding MPG decrease would be just 0.09 MPG.

[35] In other words, if y and x are the dependent/independent variables, q is the omitted variable, and z is the proxy variable, we must have $\mathbb{E}(y|x, q, z) = \mathbb{E}(y|x, q)$. See Wooldridge (2010) for additional information.

[36] The regressions in columns 1, 3, and 5 of Table 4 are similar to the regressions in columns 2, 3, and 5 of Table 3, except they are run on a sub-sample from the Ipsos survey that contains self-reported credit history information.

[37] An APR shift of this size can be thought of as going from having an average cost of credit to a relatively high cost of credit—the $2,313 in additional interest represents a 156% increase in interest charges over the life of a typical loan in the sample.

Extrapolating this MPG decrease over the vehicle's lifetime results in a $97 average increase in discounted lifetime fuel costs.[38]

Thus, even a sizable change in loan APR is associated with an economically insignificant change in fuel economy chosen by consumers, and this change has a negligible impact on lifetime fuel costs.

4.3 Heterogeneous Response to Gasoline Price Changes

The previous three sections examine a direct relationship between consumers' cost of credit and fuel efficiency choices for new car buyers. In the next two sections, I present two alternative approaches for assessing the role that the cost of credit may play in fuel efficiency investment decisions.

First, I test whether buyers with a high cost of credit are less responsive to gasoline price fluctuations than relative to buyers with a lower cost of credit in regards to fuel economy choices. As described in Busse et al. (2013), gasoline price changes should not necessarily affect demand for all cars uniformly. If gasoline prices *increase*, for example, fuel-efficient cars become cheaper to operate relative to less efficient alternatives, so one might expect to see demand for efficient cars rise and demand for inefficient cars fall. Said another way, an increase in gasoline prices may result in increased consumer demand for fuel efficiency, so in general there should be a positive relationship between gasoline prices and the fuel economy of cars purchased.

One way to test for the cost of credit hindering fuel economy investment is to see if this positive relationship between gasoline prices and fuel economy choice is dampened for buyers with a relatively high cost of credit. Since these buyers face higher upfront costs when purchasing fuel-efficient cars, one might expect them to be less able to respond to gasoline price changes relative to buyers with a lower cost of credit. To test this, I regress the fuel efficiency of vehicles consumers purchase on the gasoline price they faced gasoline price in the month of purchase. I estimate this regression over five subsamples: one for each

[38]For a 1 percentage point increase in loan APR, the corresponding decrease in fuel economy purchased of 0.0287 MPG results in an average increase of $31 in discounted lifetime fuel costs.

of the four quartiles of the real APR distribution in my main sample, and one for buyers who indicated that they purchased their vehicle with cash and did not use financing.[39] The cash buyers can be thought of as not subject to a cost of credit, since they are often paying large amounts upfront when purchasing their new vehicle.[40]

Table 5 provides estimates of the gasoline price response regressions across the five subsamples. The first row of Table 5 shows the estimated MPG response of each subsample to gasoline price increases. Taking column 1 as an example, for buyers in the lowest real APR quartile (i.e., buyers with the lowest real APRs), a $1 increase in gasoline prices corresponds to a 1.866 MPG increase in average fuel economy purchased. As you move from columns 1 to 4, the magnitude of the estimated relationship between gasoline prices and purchased fuel economy decreases, with the response getting as low as 0.757 MPG purchased in response to a $1 increase in gasoline prices for buyers in the highest real APR quartile. This is consistent with the idea that buyers who face higher costs of credit are less responsive to gasoline price changes; buyers with higher loan APRs face increased upfront costs and may not be as willing or able to purchase additional fuel economy when facing higher gasoline prices relative to buyers with lower APRs. Additionally, column 5 suggests that cash buyers respond most similarly to buyers in the lowest quartile of the APR distribution; for cash buyers, a $1 increase in gasoline prices is associated with an average of 1.635 additional MPG purchased.[41]

Buyers in the highest APR quartile appear to be less than half as responsive as buyers in the lowest APR quartile, but this difference does not explain much of the energy efficiency gap for the new vehicle market. To see this, consider the second row of Table 5, which computes the implied average increase in lifetime fuel costs that would occur if buyers in each subsample drove the same number of miles but experienced a persistent $1 gasoline price increase and increased their purchased fuel economy by the amount indicated in the

[39] I define the real APR quartiles by year. For example, the "Q1" group includes buyers who had the lowest real APRs among consumers who purchased a vehicle in the same year.

[40] The average sale price for cash buyers in the sample is around $40,000.

[41] The cash buyer regression in column 5 includes slightly fewer controls because the cash buyers do not provide loan attributes (e.g., loan size, loan length) or self-reported credit history in the Ipsos survey. Full regression results for this analysis can be found in Appendix Table A.4.

first row of the table.[42] For example, buyers in the lowest APR quartile would experience an average increase of $4,671 in discounted lifetime fuel costs in response to a persistent gasoline price increase of $1 and an increase in fuel efficiency of their vehicle by 1.866 MPG. While it is clear that the fuel costs of buyers with a higher cost of credit are likely to increase by more ($6,273) than than buyers with a lower cost of credit ($4,671), the main takeaway from these figures is that no one is responding much to gasoline price increases in terms of the fuel efficiency of cars they buy. The average gasoline price in the sample is round $3 per gallon, so $1 represents a substantial increase in gasoline prices. However, despite this increase, lifetime fuel costs are increasing by almost as much for all consumers—specifically, by around 21 percent for buyers in the lowest APR quartile and 28 percent for buyers in the highest APR quartile. The third row of Table 5 relaxes one of the assumptions above and revises the implied lifetime fuel cost increases by assuming that VMT for all consumers drops by 15 percent. In this case, we see the magnitude of the implied fuel cost changes decrease across the board. This is not surprising; in the absence of purchasing a more fuel-efficient vehicle, consumers would need to drive less in order to offset the higher fuel expenditures associated with a gasoline price increase.

Nevertheless, it appears that *everyone*—not just buyers with a high cost of credit—under-invests in fuel economy in response to gasoline price increases. While the under-investment is largest among buyers with a high cost of credit, the fact that even the low-APR buyers do not respond much to gasoline price increases suggests that consumers' cost of credit is not a primary driver of this under-investment.

4.4 Hybrid/Gasoline Vehicle Siblings

Finally, I restrict my sample to analyze hybrid vehicles and their gasoline-powered "siblings"—vehicles that are essentially identical except for engine type (e.g., Toyota Camry and Toyota Camry Hybrid).[43] Many sibling pairs were in the market during the Ipsos sample period, and

[42] I assume for simplicity that drivers will not change their driving behavior in response to gasoline price changes. However, this is a reasonable assumption since demand for gasoline is estimated to be relatively inelastic, especially for consumers who drive the most miles (Goetzke and Vance, 2021). See Lin and Prince (2013) and Goetzke and Vance (2021) for recent estimates of U.S. gasoline price elasticity of demand.

[43] This approach is similar to the gas-hybrid pairs analysis done by Levinson and Sager (2023).

the use of sibling pairs reduces other potential concerns related to unobservables which may be correlated with consumers' cost of credit and MPG choice. I restrict my sample to only include sibling pairs with at least ten hybrid and non-hybrid purchases in the data, and I include flex-fuel vehicles (which can use gasoline or ethanol blends) in the "gasoline-powered" group. The list and counts of sibling pairs are provided in Table A.5 in the Appendix.

If higher costs of credit suppress fuel economy investment, I should see fewer purchases of the fuel-efficient siblings by buyers with a relatively high cost of credit. To test this, I estimate a linear probability model in which the dependent variable, E, is equal to one if the vehicle purchased was an efficient sibling (i.e., hybrid) and is equal to zero if the vehicle purchased was an inefficient sibling (i.e., gasoline-powered). Below is the regression equation that I estimate:

$$
\begin{aligned}
E_{jvirt} = \beta_0 + \beta_1 \cdot APR_{irt} + \beta_2 \cdot \mathbb{I}\{GoodCredit_i\} + \beta_3 \cdot \mathbb{I}\{BadCredit_i\} + \beta_4 \cdot \mathbb{I}\{NoCredit_i\} \\
+ \ \beta_5' X_j + \beta_6' D_i + \delta_t + \gamma_r + \theta_v + \varepsilon_{jvirt} \qquad (4)
\end{aligned}
$$

Equation (4) is defined similarly to the earlier regression equations but now includes a vehicle sibling fixed effect, θ_v. The main coefficient of interest in equation (4) is β_1, which indicates the average change in likelihood of a buyer purchasing a hybrid corresponding to a 1 percentage point increase in real APR.

The sibling fixed effect provides two advantages relative to the other empirical specifications in this paper. First, it controls for unobservable differences between buyers of different car types (e.g., Toyota Camry buyers versus Chevrolet Tahoe buyers). The kinds of people who purchase a Toyota Camry, for instance, may have fundamentally different and unobserved preferences over fuel efficiency than those purchasing a Chevrolet Tahoe. Moreover, these differences may be correlated with buyers' cost of credit in similar fashion to unobserved financial literacy. Comparing hybrids to their otherwise similar gasoline-powered siblings assuages this concern.

Second, the sibling fixed effect controls for unobserved vehicle attributes that could be correlated with both fuel economy and buyer cost of credit. For example, perhaps BMW cars are more likely to be sold to buyers with a relatively low cost of credit, and BMW cars are on average less fuel-efficient than similar cars produced by other manufacturers. This relationship could contribute to a spurious correlation suggesting that buyers with a low cost of credit purchase inefficient cars on average, thus resulting in attenuation bias in my estimates. The sibling fixed effect restricts comparisons to be within a particular make and model, which reduces the possibility of attenuation bias.

Table 6 shows the linear probability model regression results. Column 4 includes model year, month, purchase year, and vehicle sibling fixed effects. In column 4, a 1 percentage point increase in real APR is associated with a 0.2% decrease in the probability of purchasing a hybrid. The sample for the regressions in Table 6 is 27 percent hybrids and 73 percent non-hybrids, and the overall market share for hybrids in the U.S. is around 5 percent. Thus, a 0.2% reduction in likelihood of purchasing a hybrid in response to a non-trivial increase in financing costs is small and does not explain a broad trend of under-investment in fuel economy.

4.5 Interpretation and Caveats

The results of this paper—despite being internally consistent and collectively suggesting that the consumers' cost of credit is not a major driver of fuel efficiency investment decisions—should not be interpreted as the causal effect of the cost of credit on fuel economy choice. Indeed, there are some caveats to consider when interpreting the results.. First, while I discuss potential omitted variable bias and use proxy variables to try to address it, there is still a possibility that other omitted variables may be correlated with buyers' cost of credit and fuel economy preferences. In the absence of an RCT or an ideally situated natural experiment, my analysis of cross-sectional new vehicle purchase and loan survey data may still suffer from omitted variable bias.

Second, the choice set of vehicles that buyers consider may not align with the vehicle sibling regressions estimated from equation (4). Car buyers may not come to a dealership looking to decide between a gasoline-powered Toyota Camry and a Toyota Camry hybrid. Rather, they may know they want to buy a hybrid but could be deciding between multiple models, or they may be interested buying a truck with the roomiest cab and best towing capacity. In short, buyers may not have one model with several variants in mind—they could very well be considering many more options. The vehicle sibling regressions over-simplify the choices buyers are considering, but they nonetheless facilitate an informative descriptive comparison of hybrid and non-hybrid buyers.

Finally, it is possible that there is selection bias or measurement error in the survey responses. People who do not consider fuel costs carefully when buying a car may also be less likely to respond to a lengthy survey about their vehicle purchase. If this behavior is correlated with consumers' cost of credit, my estimates could suffer from an over-representation of buyers with a relatively low cost of credit in the sample. It is also possible that respondents could misreport their self-reported credit history or loan APR. This potential measurement error affecting a right hand side variable could introduce attenuation bias into the results.

It is important to note that approximately 94% of the Ipsos sample who provided self-reported credit history indicated that they had good or excellent credit, leaving only 6% with bad or no credit history. As a point of comparison, an Experian report on the state of the auto finance market for Q3 2017 indicated that only 8%-10% of new vehicle loan/lease financing customers fell in the subprime credit score range, leaving approximately 90% in the non-prime, prime, and super prime ranges.[44] While the "bad credit" or "no credit" consumers in the Ipsos data may be a slight under-representation (6%) of buyers with a relatively high cost of credit, their share of the sample is not dramatically different from the national credit profile of new car buyers from the sample period.[45] Further, the Ipsos data are clearly a selected sample (the typical new car buyer is not representative of the typical American

[44] The Experian report can be found here.

[45] I reference a report from 2017 (near the end of the sample period) since auto lending standards were most strict in the early years of the sample immediately following the 2008 financial crisis.

consumer), but this is not problematic because I am studying the cost of credit among new car buyers—the analysis is conditional on a consumer participating in the new vehicle market. Moreover, the sample contains low income buyers, buyers with no credit history, buyers with bad credit, and buyers with high APRs. Though they may not represent the majority, there are buyers with nontrivial costs of credit in the sample.

Taken together, the results tell a consistent story. While plenty of evidence supports the expected negative relationship between the cost of credit and investment in fuel efficiency, the magnitude of the relationship is small and thus cannot explain the energy efficiency gap for new vehicles.

5 Conclusion

This paper provides direct evidence of the relationship between the cost of credit and consumer investment in fuel efficiency in the U.S. new vehicle market. I enrich unique survey data with detailed vehicle characteristics and regional gasoline prices and then use several empirical specifications to estimate the degree to which higher costs of credit hinder fuel economy investment. I also provide suggestive evidence of the existence of an energy efficiency gap in the U.S. new vehicle market and use a simple theoretical model to motivate the paper's empirical findings. The data I use offer multiple direct measures of credit constraints on the intensive margin (i.e., consumers' cost of credit) in the form of actual loan terms and self-reported credit histories, which improve upon existing work that uses income as an imperfect proxy for credit constraints.

The results in this paper contribute to the ongoing investigation of why consumers underinvest in fuel efficiency. While there are important empirical caveats to consider when interpreting the results, this paper is the first to my knowledge to estimate a direct statistical relationship between consumers' cost of credit and fuel economy demand in the important setting of the U.S. new vehicle market. The results show persistent evidence that indicate a negative association between the cost of credit and fuel economy adoption by consumers. However, the magnitude of the estimates is small and thus cannot explain a meaningful portion of the energy efficiency gap. It is possible that the sample of new vehicle buyers has relatively low costs of credit compared to the typical American consumer, or even that higher costs of credit are more prevalent in the used car market than in the new vehicle market. Future work could investigate the potential relationship between the cost of credit and fuel economy demand in the used car market, where consumers may face higher financing costs than in the new vehicle market. Nevertheless, the CAFE standards apply specifically to the new vehicle market and the Ipsos survey is intended to be representative of the national new vehicle market.

Finally, this paper's findings also suggest that "green auto loans," which are growing in popularity and provide APR discounts and other incentives for purchasers of fuel-efficient vehicles (e.g., longer repayment periods), may not incentivize consumers to purchase more fuel-efficient vehicles.[46] The benefits of green auto loans may simply be going to consumers who were already going to purchase a clean car anyway. If the goal of such programs is to increase clean vehicle adoption, it may be more effective to consider alternative incentives such as point-of-sale rebates, which consumers may be more responsive to than APR discounts.

[46] See this article for additional information on green auto loans.

References

Allcott, Hunt, "Consumers' perceptions and misperceptions of energy costs," *American Economic Review*, 2011, *101* (3), 98–104.

_ **and Christopher Knittel**, "Are Consumers Poorly Informed about Fuel Economy? Evidence from Two Experiments," *American Economic Journal: Economic Policy*, 2018, *11* (1), 1–37.

_ **and Michael Greenstone**, "Is There An Energy Efficiency Gap?," *Journal of Economic Perspectives*, 2012, *26* (1), 3–28.

_ **and Nathan Wozny**, "Gasoline Prices, Fuel Economy, and the Energy Paradox," *Review of Economics and Statistics*, 2014, *96* (5), 779–795.

Ameli, Nadia and Nicola Brandt, "What Impedes Household Investment in Energy Efficiency and Renewable Energy?," *International Review of Environmental and Resource Economics*, 2015, *8*, 101–138.

Anderson, Soren T., Ryan Kellogg, and James M. Sallee, "What do consumers believe about future gasoline prices?," *Journal of Environmental Economics and Management*, 2013, *66* (3), 383–403.

Attanasio, Orazio P., Pinelopi Koujianou Goldberg, and Ekaterini Kyriazidou, "Credit Constraints in the Market for Consumer Durables: Evidence from Micro Data on Car Loans," *International Economic Review*, 2008, *49* (2), 401–436.

Berkouwer, Susanna B. and Joshua T. Dean, "Credit, Attention, and Externalities in the Adoption of Energy Efficient Technologies by Low-Income Households," *American Economic Review*, 2022, *112* (10), 1–40.

Berry, Linda, "The Role of Financial Incentives in Utility-Sponsored Residential Conservation Programs: A Review of Customer Surveys," *Evaluation and Program Plannning*, 1984, *7* (2), 131–141.

Blonz, Joshua A., "The Welfare Costs of Misaligned Incentives: Energy Inefficiency and the Principal-Agent Problem," *Finance and Economics Discussion Series 2019-071. Washington: Board of Governors of the Federal Reserve System, https://doi.org/10.17016/FEDS.2019.071*, 2019.

Busse, Meghan, Christopher Knittel, and Florian Zettelmeyer, "Are Consumers Myopic? Evidence from New and Used Car Purchases," *American Economic Review*, 2013, *103* (1), 220–256.

CFPB, "https://www.consumerfinance.gov/data-research/consumer-credit-trends/auto-loans/origination-activity/," 2018.

Gerarden, Todd D., Richard G. Newell, and Robert N. Stavins, "Assessing the energy-efficiency gap," *Journal of Economic Literature*, 2017, *55* (4), 1486–1525.

Gillingham, Kenneth and Karen Palmer, "Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence," *Review of Environmental Economics and Policy*, 2014, *8* (1), 18–38.

_ **, David Rapson, and Gernot Wagner**, "The rebound effect and energy efficiency policy," *Review of Environmental Economics and Policy*, 2016, *10* (1), 68–88.

Goetzke, Frank and Colin Vance, "An increasing gasoline price elasticity in the United States?," *Energy Economics*, 2021, *95*, 104982.

Greene, David L., "Uncertainty, Loss Aversion, and Markets for Energy Efficiency," *Energy Economics*, 2011, *33* (4), 608–616.

Hausman, Jerry A., "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables," *The Bell Journal of Economics*, 1979, *10* (1), 33–54.

Jaffe, Adam B. and Robert N. Stavins, "The energy-efficiency gap What does it mean?," *Energy Policy*, 1994, *22* (10), 804–810.

Leard, Benjamin, Joshua Linn, and Katalin Springel, "Vehicle Attribute Tradeoffs and the Distributional Effects of US Fuel Economy and Greenhouse Gas Emissions Standards," *Working Paper 23-04, Washington, DC: Resources for the Future*, 2023.

_ , _ , and Yichen Christy Zhou, "How Much Do Consumers Value Fuel Economy and Performance? Evidence from Technology Adoption," *The Review of Economics and Statistics*, 2023, *105* (1), 158–174.

Levinson, Arik, "Energy Efficiency Standards Are More Regressive Than Energy Taxes: Theory and Evidence," *Journal of the Association of Environmental and Resource Economists*, 2019, *6* (S1), S7–S36.

_ and Lutz Sager, "Who Values Future Energy Savings? Evidence from American Drivers," *Journal of the Association of Environmental and Resource Economists*, 2023, *10* (3), 717–751.

Lin, C. Y.Cynthia and Lea Prince, "Gasoline price volatility and the elasticity of demand for gasoline," *Energy Economics*, 2013, *38*, 111–117.

Metcalf, Gilbert E. and Kevin A. Hassett, "Measuring the energy savings from home improvement investments: Evidence from monthly billing data," *Review of Economics and Statistics*, 1999, *81* (3), 516–528.

Palmer, Karen, Margaret Walls, Hal Gordon, and Todd Gerarden, "Assessing the energy-efficiency information gap: results from a survey of home energy auditors," *Energy Efficiency*, 2013, *6* (2), 271–292.

Sallee, James M., "Rational Inattention and Energy Efficiency," *Journal of Law and Economics*, 2014, *57* (3), 781–820.

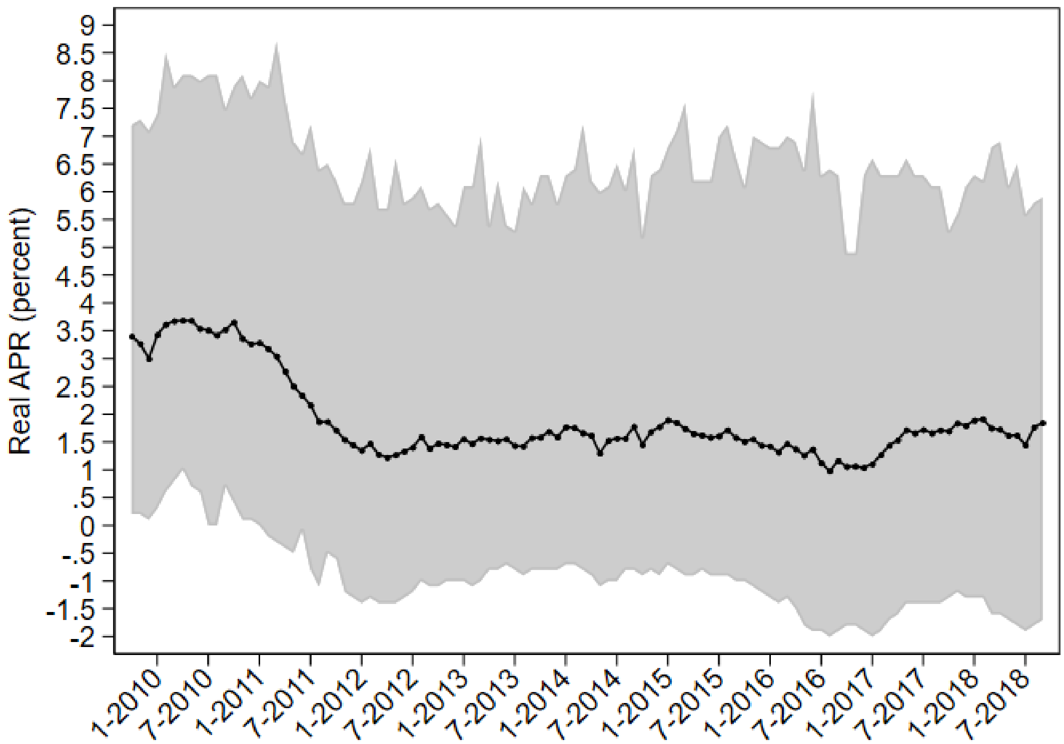
_ , Sarah E. West, and Wei Fan, "Do Consumers Recognize the Value of Fuel Economy? Evidence from Used Car Prices and Gasoline Price Fluctuations," *Journal of Public Economics*, 2016, *135*, 61–73.

Wooldridge, Jeffrey M, *Econometric Analysis of Cross Section and Panel Data*, Cambridge, MA: MIT Press, 2010.

6 Figures and Tables

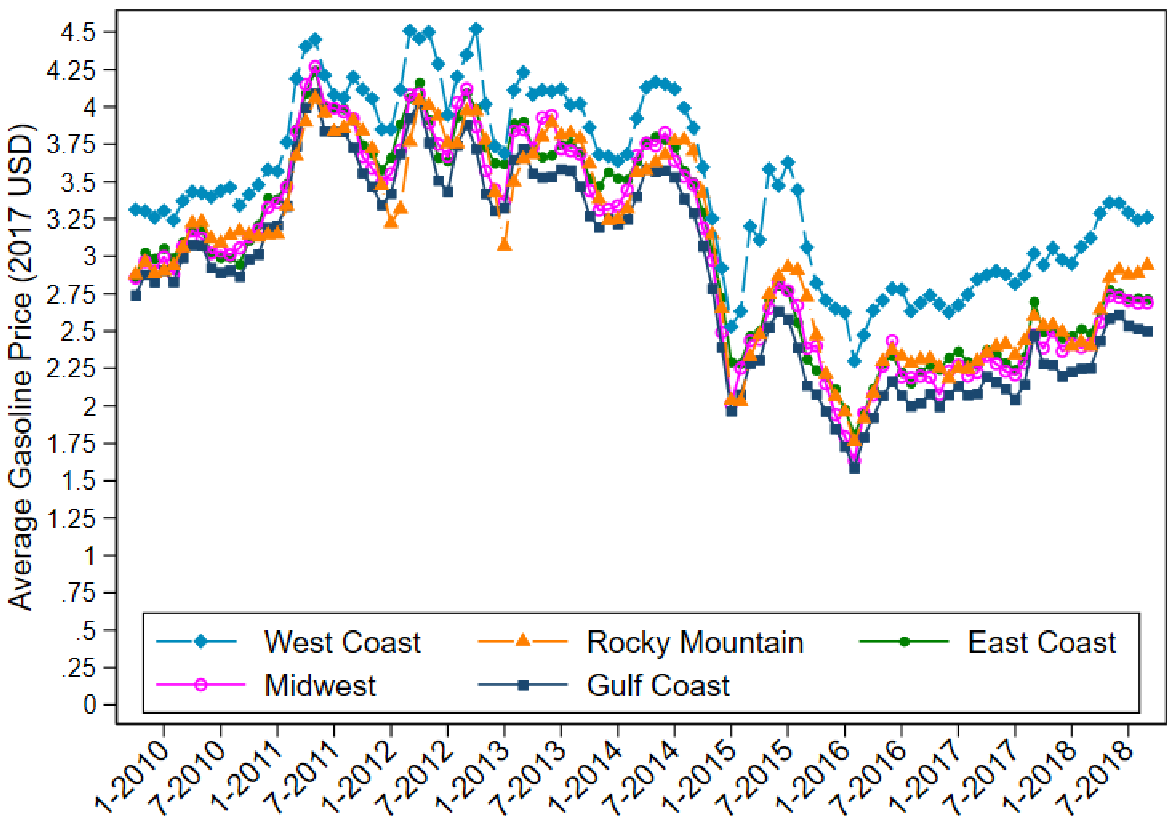
6.1 Figures

Figure 1: Monthly average real APR



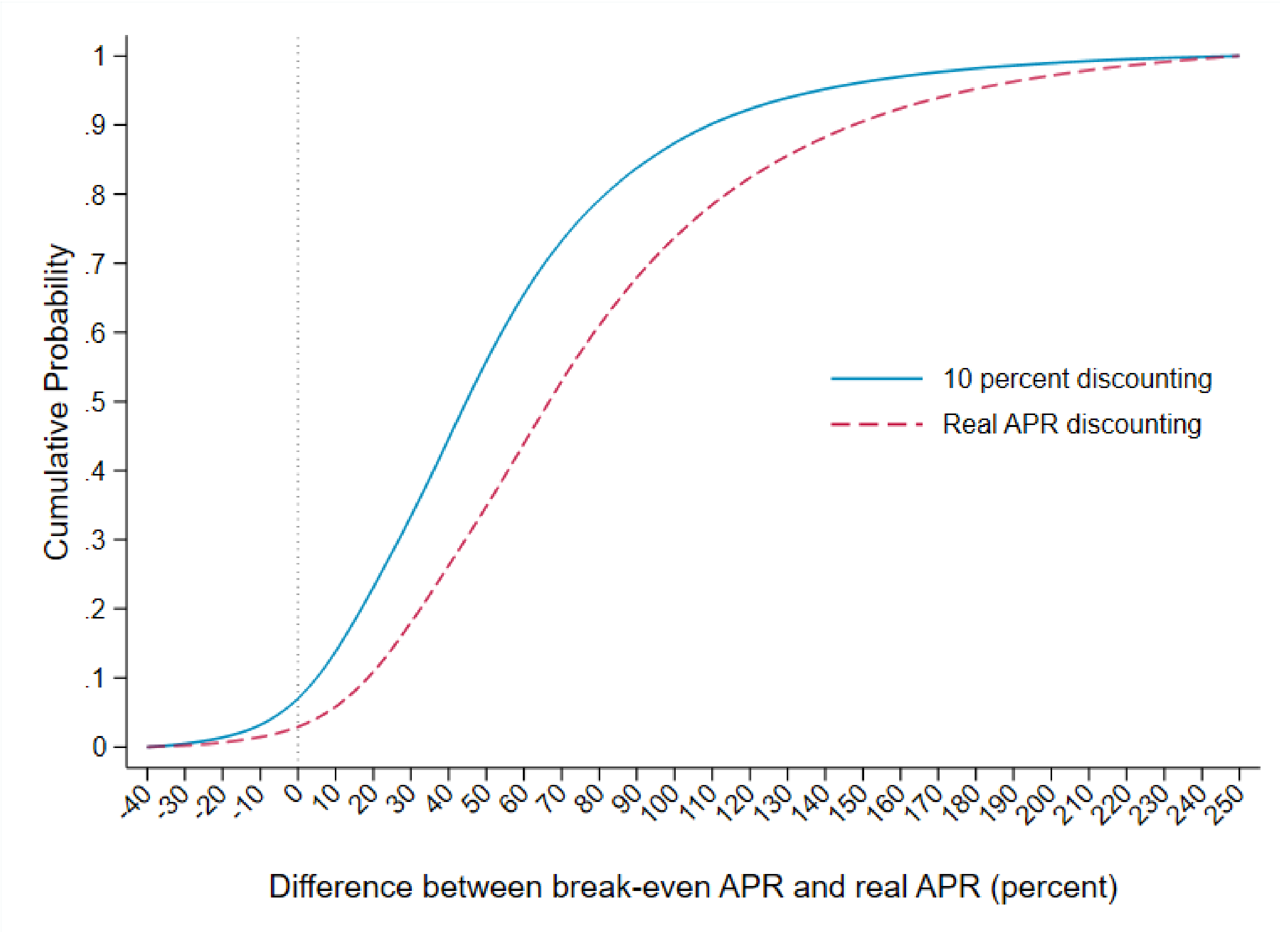
Notes: The source of these data is the Ipsos survey. Loan APRs are adjusted for inflation using the monthly CPI-U from the U.S. Bureau of Labor Statistics. The black line plots the average monthly real APR based on my main regression sample, and the gray shaded area indicates the fifth and ninety-fifth percentiles of the real APR distribution in each month of the sample.

Figure 2: Monthly average gasoline price by PADD region



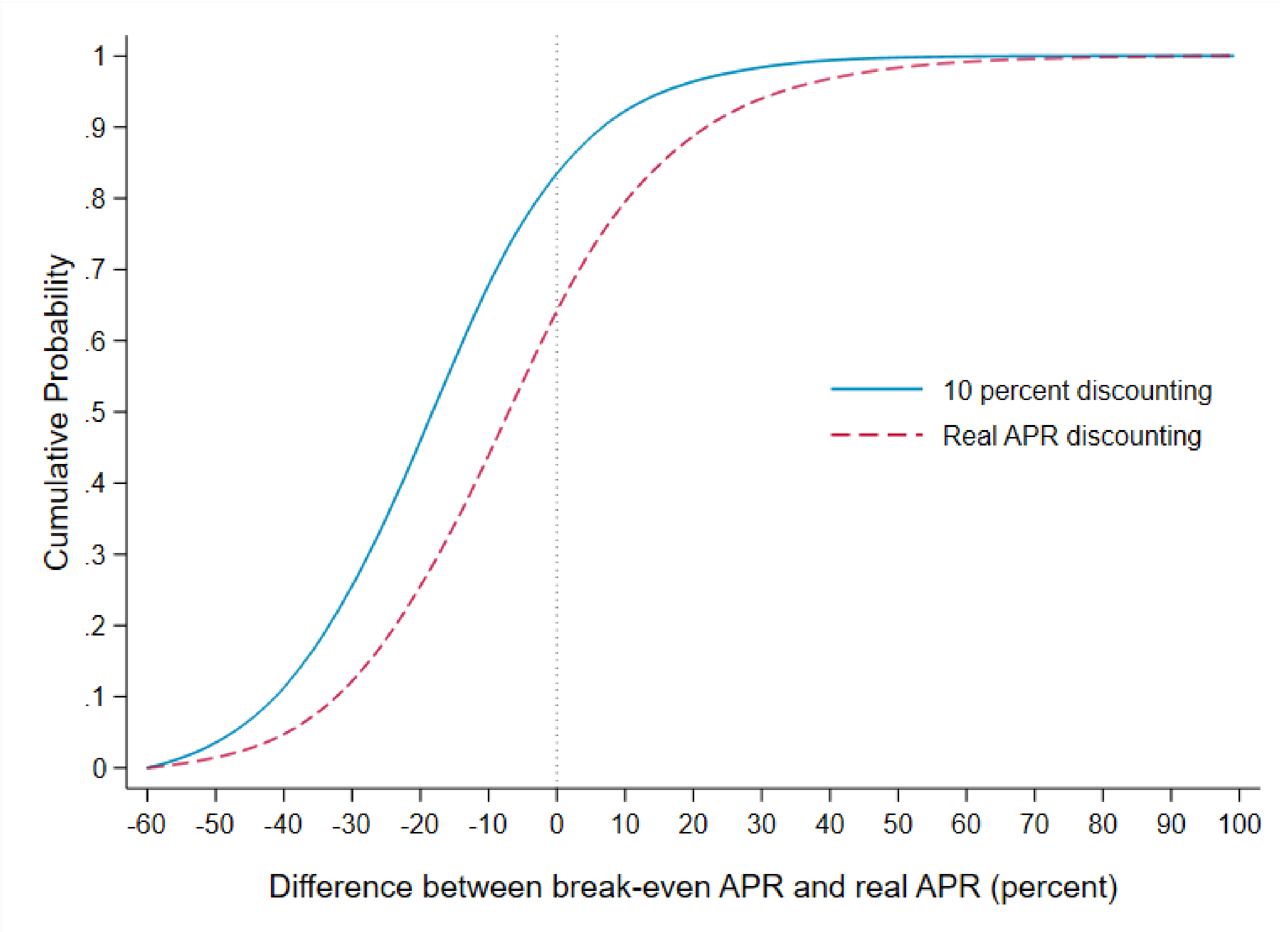
Source: Energy Information Administration

Figure 3: Gap between consumer break-even APR and real APR – 1-MPG increase



Notes: This figure shows empirical cumulative distribution functions (using 10% discounting and real APR discounting, respectively) of the difference between each consumer's break-even APR for profitable fuel efficiency investment and the actual real APR they obtained for their auto loan. The data, assumptions, and method used to calculate the break-even APR for each consumer are described in Section 3. The portions of the CDFs that lie above zero on the horizontal axis represent consumers who—on a purely financial basis—are leaving money on the table by not investing in more fuel efficiency. These consumers have a positive difference between their break-even APR and the APR of the loan they actually obtained, meaning they could profitably purchase an additional MPG of fuel efficiency at their current auto loan rate.

Figure 4: Gap between consumer break-even APR and real APR – 8.2-MPG increase



Notes: This figure shows empirical cumulative distribution functions (using 10% discounting and real APR discounting, respectively) of the difference between each consumer's break-even APR for profitable fuel efficiency investment and the actual real APR they obtained for their auto loan. The data, assumptions, and method used to calculate the break-even APR for each consumer are described in Section 3. The portions of the CDFs that lie above zero on the horizontal axis represent consumers who—on a purely financial basis—are leaving money on the table by not investing in more fuel efficiency. These consumers have a positive difference between their break-even APR and the APR of the loan they actually obtained, meaning they could profitably purchase a vehicle with an additional 8.2 MPG of fuel efficiency at their current auto loan rate. The analysis in this figure approximates a more realistic scenario that consumers may encounter than that of Figure 3, since it is typically not feasible to upgrade fuel economy by just 1 MPG.

6.2 Tables

Table 1: Summary statistics

	Mean	SD
Vehicle Characteristics:		
Purchase price ($1000s)	35.95	12.85
Miles per gallon (MPG)	24.70	9.393
Hybrid dummy (1 = Hybrid)	0.0469	
EV/PHEV dummy (1 = EV or Plug-in EV)	0.0125	
Horsepower	240.1	85.03
Torque	241.3	89.99
Wheelbase (in)	112.1	11.07
Length (in)	189.2	17.94
Width (in)	73.59	3.865
Height (in)	64.13	7.069
Engine liters	3.091	1.271
Number of engine cylinders	5.298	1.502
Vehicle weight (1000 lbs)	3.844	0.831
Body style - Sedan (1 = Yes)	0.245	
Body style - Sport utility vehicle (1 = Yes)	0.362	
Body style - Pickup truck (1 = Yes)	0.149	
Body style - Hatchback (1 = Yes)	0.0994	
Body style - Station wagon (1 = Yes)	0.0260	
Body style - Coupe (1 = Yes)	0.0606	
Body style - Convertible (1 = Yes)	0.0255	
Body style - Van (1 = Yes)	0.0328	
Buyer Characteristics:		
Loan APR, inflation-adjusted (percent)	1.920	2.882
Loan amount ($1000s)	28.83	12.33
Loan length (months)	62.01	12.90
Buyer credit history - excellent (1 = Yes)	0.722	
Buyer credit history - good (1 = Yes)	0.217	
Buyer credit history - bad (1 = Yes)	0.0478	
Buyer credit history - none (1 = Yes)	0.0133	
Household income ($1000s)	124.9	88.76
Household size (number of people)	2.564	1.226
Buyer age (years)	49.70	14.33
Lives in urban area (1 = Yes)	0.860	
Education dummy (1 = Has bachelors degree)	0.554	
Buyer race dummy (1 = White)	0.822	
Gasoline price (PADD monthly average, $/gal)	3.072	0.669
Buyer expected annual miles (1000s)	12.70	6.506
Buyer expected lifetime fuel costs ($, real APR discount)	22,239	9,383
Buyer expected lifetime fuel costs ($, 10% discount)	13,533	5,667
Total Vehicle Purchases: 369,425		

Notes: Summary statistics are based on sample used for regressions from Table 3, which excludes leases, heavy duty vehicles, and observations with missing data. Loan amount is imputed using standard auto loan monthly payment formula. Household income is approximated using the midpoint of the income bin indicated by survey respondent. All dollar amounts are in 2017 USD. The four buyer credit history variable summary statistics are based on a smaller number of observations (220,195) due to missing data.

Table 2: Estimated cost of one additional MPG

Dependent Variable: Purchase Price	(1)	(2)	(3)	(4)	(5)
MPG	173.9*	190.0*	190.1*	189.3*	239.1*
	(21.00)	(23.05)	(23.07)	(22.81)	(23.54)
Vehicle weight (1000 lbs)	13,686*	13,521*	13,536*	13,454*	6,531*
	(592.5)	(583.9)	(583.8)	(579.6)	(476.0)
Horsepower	37.66*	41.35*	41.34*	42.04*	44.49*
	(5.423)	(5.502)	(5.504)	(5.476)	(4.502)
Torque	40.10*	40.23*	40.22*	39.65*	23.37*
	(4.492)	(4.384)	(4.384)	(4.369)	(4.095)
Length (in)	-171.3*	-164.8*	-165.4*	-162.7*	33.39
	(28.71)	(28.39)	(28.39)	(28.42)	(24.52)
Width (in)	-98.93	-81.12	-82.24	-81.20	51.12
	(71.77)	(71.78)	(71.78)	(71.35)	(53.34)
Height (in)	-901.8*	-914.0*	-913.5*	-914.2*	-307.0*
	(66.47)	(65.75)	(65.79)	(65.71)	(59.89)
Wheelbase (in)	16.25	20.33	20.37	20.41	-79.84*
	(43.94)	(43.18)	(43.16)	(43.28)	(35.01)
Number of engine cylinders	1,961*	1,978*	1,974*	1,971*	454.1*
	(273.6)	(275.0)	(274.8)	(273.8)	(195.0)
Engine liters	-3,285*	-3,564*	-3,560*	-3,561*	-43.91
	(392.1)	(394.5)	(394.4)	(393.7)	(325.6)
Constant	53,465*	50,258*	49,827*	49,567*	8,606
	(6,303)	(5,923)	(5,923)	(5,903)	(4,771)
Fixed effects:					
Model year		✓	✓	✓	✓
Month			✓	✓	✓
PADD region				✓	✓
Vehicle make					✓
Observations	328,873	328,873	328,873	328,873	328,873
R^2	0.680	0.683	0.683	0.685	0.777

Notes: Standard errors in parentheses are clustered by model year, make, and model (* $p<0.05$). All dollar amounts are adjusted to 2017 USD. Controls not shown include body style dummies (e.g., sedan, SUV, convertible) and drive type dummies (e.g., front wheel drive, all wheel drive).

Table 3: Loan APR and fuel economy choice

Dependent variable: MPG	(1)	(2)	(3)	(4)	(5)	(6)
Loan APR, inflation-adjusted (percent)	-0.132*	-0.0512*	-0.0537*	-0.0549*	-0.0520*	-0.0544*
	(0.0166)	(0.0111)	(0.0111)	(0.0110)	(0.0111)	(0.0109)
Fixed effects:						
Model year		✓	✓	✓	✓	✓
Month		✓	✓		✓	
Year			✓			
Month-by-year				✓		
PADD region					✓	
PADD region-by-month-by-year						✓
Observations	369,425	369,425	369,425	369,425	369,425	369,425
R^2	0.525	0.543	0.545	0.546	0.544	0.548

Notes: Standard errors in parentheses are clustered by model year, make, and model (* $p<0.05$). All dollar amounts are adjusted to 2017 USD. Gasoline prices and regional fixed effects are at the Petroleum Administration for Defense District (PADD) level, dividing the fifty states into five districts. These regressions control for many vehicle and demographic characteristics that are not shown here—see Table A.1 in the Appendix for results showing additional controls.

Table 4: Self-reported credit history as a proxy for unobserved financial literacy

Dependent variables: miles per gallon (MPG)	(1)	(2)	(3)	(4)	(5)	(6)
Loan APR, inflation-adjusted (percent)	-0.0509*	-0.0269*	-0.0531*	-0.0287*	-0.0517*	-0.0287*
	(0.0117)	(0.0119)	(0.0117)	(0.0117)	(0.0117)	(0.0118)
Self-reported credit history (“excellent” is omitted category)						
Buyer credit history - good (1 = Yes)		-0.323*		-0.327*		-0.311*
		(0.0508)		(0.0508)		(0.0497)
Buyer credit history - bad (1 = Yes)		-0.560*		-0.565*		-0.536*
		(0.102)		(0.0990)		(0.101)
Buyer credit history - none (1 = Yes)		-0.804*		-0.800*		-0.771*
		(0.125)		(0.124)		(0.122)
Fixed effects:						
Model year	✓	✓	✓	✓	✓	✓
Month	✓	✓	✓	✓	✓	✓
Year			✓	✓		
PADD region					✓	✓
Observations	220,195	220,195	220,195	220,195	220,195	220,195
R^2	0.542	0.542	0.544	0.544	0.543	0.543

Notes: Standard errors in parentheses are clustered by model year, make, and model (* $p<0.05$). All dollar amounts are adjusted to 2017 USD. Columns 2, 4, and 6 refine columns 1, 3, and 5 respectively by including self-reported credit history as a proxy for unobserved financial responsibility. The “excellent” self-reported credit history category is the baseline category and is omitted from regression columns 2, 4, and 6. Gasoline prices and regional fixed effects are at the Petroleum Administration for Defense District (PADD) level, dividing the fifty states into five districts. These regressions control for many vehicle and demographic characteristics that are not shown here—see Table A.3 in the Appendix for results showing additional controls.

Table 5: Heterogeneous response to gasoline price changes based on loan APR quartile

Dependent variable: MPG **Real APR Quartile (Q1 = lowest real APRs)**	(1) **Q1**	(2) **Q2**	(3) **Q3**	(4) **Q4**	(5) **Cash Buyers**
Gasoline price (PADD monthly average, $/gal)	1.866*	1.162*	0.895*	0.757*	1.635*
	(0.375)	(0.378)	(0.224)	(0.178)	(0.374)
Implied lifetime fuel cost increase ($)	4,671	5,699	6,141	6,273	4,744
Implied lifetime fuel cost increase ($) *(with 15% VMT reduction)*	770	1,490	1,802	1,934	925
Observations	58,436	52,873	55,994	52,892	151,571
R^2	0.544	0.536	0.546	0.599	0.573

Notes: Standard errors in parentheses are clustered by model year, make, and model (* $p<0.05$). All dollar amounts are adjusted to 2017 USD. Columns 1-4 divide the main regression sample into subsamples based on real APR quartile, where Q1 has the lowest real APRs and Q4 has the highest real APRs. Column 5 runs a similar regression over a subsample from the Ipsos survey who indicated that they paid cash for their vehicle and did not use financing. All regressions include model year, month, and year fixed effects. Gasoline prices are at the Petroleum Administration for Defense District (PADD) level, dividing the fifty states into five districts. The second row of the table calculates the average implied increase in discounted lifetime fuel costs assuming a persistent $1 gasoline price increase and that each consumers' purchased fuel economy increased by the amount indicated in the first row of the table. These implied fuel cost increases also assume that consumers do not reduce their lifetime vehicle miles traveled. The third row repeats the implied lifetime fuel cost change calculations assuming that consumers reduce annual vehicle miles traveled by 15 percent. These regressions control for many vehicle and demographic characteristics that are not shown here—see Table A.4 in the Appendix for results showing additional controls.

Table 6: Linear probability model estimates with hybrid/gasoline vehicle siblings

Dependent variable: Purchased hybrid (1 = Yes)	(1)	(2)	(3)	(4)	(5)
Loan APR, inflation-adjusted (percent)	-0.00286	-0.00217	-0.00212*	-0.00203*	-0.00282*
	(0.00178)	(0.00149)	(0.000986)	(0.000972)	(0.00112)
Self-reported credit history (“excellent” is omitted category)					
Buyer credit history - good (1 = Yes)	-0.00634	-0.0141*	-0.0149*	-0.0171*	-0.0134*
	(0.00703)	(0.00514)	(0.00467)	(0.00469)	(0.00470)
Buyer credit history - bad (1 = Yes)	-0.0241	-0.0235	-0.0239*	-0.0270*	-0.0191
	(0.0128)	(0.0121)	(0.00990)	(0.00922)	(0.0102)
Buyer credit history - none (1 = Yes)	-0.0749*	-0.0429*	-0.0474*	-0.0437*	-0.0424*
	(0.0184)	(0.0178)	(0.0165)	(0.0156)	(0.0164)
Fixed effects:					
Model year				✓	✓
Month			✓	✓	✓
Year			✓	✓	
PADD region					✓
Vehicle sibling		✓	✓	✓	✓
Observations	23,598	23,598	23,598	23,598	23,598
R^2	0.665	0.764	0.771	0.783	0.774

Notes: Standard errors in parentheses are clustered by model year, make, and model (* p<0.05). All dollar amounts are adjusted to 2017 USD. The “excellent” self-reported credit history category is the baseline category and is omitted from all regressions. Gasoline prices and regional fixed effects are at the Petroleum Administration for Defense District (PADD) level, dividing the fifty states into five districts. These regressions control for many vehicle and demographic characteristics that are not shown here—see Table A.6 in the Appendix for results showing additional controls.

A Appendix

A.1 Theoretical Model of A Consumer's Optimal MPG Choice

A.1.1 Model Description

This section describes a two-good model that illustrates how consumers' cost of credit may contribute to the energy efficiency gap. I extend the model described in Levinson (2019).

Consider a representative consumer who gets utility from two goods—driving (i.e., miles driven m) and a numeraire good x. The consumer is going to purchase a car and is considering a menu of options, all of which are identical except for fuel their economy (e). The cost of buying a car is determined by two elements:

1. The purchase price, given by:

$$p(e), \text{ with } p'(e) > 0 \text{ and } p''(e) > 0.$$[47]

2. The financing cost associated with purchasing the car, given by:

$$f(p(e)) = \lambda \cdot f_g(p(e)) + (1 - \lambda) \cdot f_b(p(e)), \text{ with}$$

$$\lambda \in [0, 1], \quad f_b' > f_g', \quad f_i'' \geq 0, \quad f_i(0) = 0 \; for \; i \in \{b, g\}$$

In item 2 above, λ represents a "cost of credit" parameter; f_g and f_b are financing cost functions for someone with good and bad credit, respectively, and λ creates a weighted mix of these two functions based on a consumer's creditworthiness. Thus, the higher λ is, the better financing terms are offered and the less it costs to borrow money. The lower λ is, the more credit-constrained a buyer is (on the extensive margin) due to high borrowing costs. The conditions imposed on f_g and f_b ensure that a "bad credit" borrower has higher financing costs at all amounts borrowed than a "good credit" borrower. These conditions also ensure that borrowing costs are weakly convex (i.e., borrowing costs ratchet up faster as a consumer borrows more money).[48] For simplicity, I refer to the total cost to purchase a car, $c(e)$, as follows:

[47] As a car's fuel efficiency increases, it becomes more expensive to upgrade to an even more efficient car.

[48] Also, note that being a cash buyer or the recipient of a 0% APR loan can be represented as a special case in which $\lambda = 1$ and $f_g(p(e)) = 0$ for all e.

$$c(e) = p(e) + f(p(e)), \text{ with } c'(e) > 0, c''(e) > 0.^{49}$$

The consumer first chooses a car to purchase and then spends their remaining income on driving and on the numeraire good. I assume that the consumer has income Y to spend on the purchase/financing of the car, driving, and the numeraire good. For simplicity, I consider the consumer's problem as a one-shot decision, where income, expenditures, etc., over the life of ownership of the car are discounted to present value amounts. I also assume that gasoline prices (g) are constant during this period.[50] Thus, the price of driving equals the price of gasoline divided by the fuel economy of the car that is chosen ($\frac{g}{e}$).[51]

The consumer has quasilinear preferences of the following form:

$$U(m, x) = v(m) + x \tag{A.1}$$

I assume that $v(m)$ is defined from the family of constant relative risk aversion (CRRA) utility functions, so $v(m)$ is strictly increasing and strictly concave.[52,53] Given these preferences, the consumer chooses e and m to solve the following utility maximization problem:

$$\max_{(e,\, m)} v(m) + x \quad \text{subject to} \tag{A.2}$$
$$Y = x + \frac{g}{e} \cdot m + c(e).$$

A.1.2 Comparative Statics

Figure A.2 depicts a simplified version of the consumer's problem in which only two car choices are available—an efficient car with high MPG and an inefficient car with low MPG. The buyer with a low cost of creditin the figure faces two possible budget sets based on the choice of car, the steeper of which corresponds to the low-MPG car (i.e., it costs less upfront

[49] The fact that $c(e)$ is strictly increasing and strictly convex in e follows from the chain rule.

[50] Assuming constant gasoline prices for calculation of future fuel costs is common in the literature—see, for example, Busse et al. (2013). Also, evidence suggests that consumers believe future gasoline prices will not change from current prices (Allcott, 2011; Anderson et al., 2013).

[51] I also assume that there is no "outside option" for the consumer and that they will purchase a car.

[52] Assume the consumer's risk aversion parameter is $\rho \geq 1$. The family of CRRA utility functions is defined as follows:

$$v(m) = \begin{cases} \frac{m^{1-\rho}-1}{1-\rho} & \text{if } \rho \neq 1 \\ log(m) & \text{if } \rho = 1 \end{cases}$$

[53] Quasilinear preferences and CRRA utility over miles driven are assumed for model tractability.

but costs more per mile to drive).[54] The example quasilinear indifference curve (i_ℓ) shows an optimal bundle in which the low cost of credit consumer chooses the high-MPG car.

Now consider a buyer with a high cost of credit who is identical to the previous buyer except for λ, which is smaller for the less creditworthy buyer. The dashed lines in Figure A.2 illustrate a downward shift of both budget sets for the buyer with a higher cost of credit due to increasing financing costs associated with purchasing each car. Further, note that the high-MPG car budget set shifts downward by *more* than that of the low-MPG car, since the high-MPG car costs more to purchase and thus also costs more to finance. As the figure shows, this shift can cause the optimal bundle for the high cost of credit consumer (indicated on indifference curve i_h) to shift to the low-MPG car despite having the same income and preferences as the low cost of credit buyer.

Next, let's revisit the consumer's utility maximization problem from equation (A.2) and analyze more generally how the optimal choice of energy efficiency changes with λ, the cost of credit parameter. Intuition from the 2-car version of the problem depicted in Figure A.2 suggests that as λ increases and a buyer's cost of credit decreases, the optimal choice of energy efficiency should increase.

First order conditions (FOC) for an interior solution (indicated with asterisks) are as follows:

$$\{m\}\colon \quad v'(m^*) - \frac{g}{e^*} = 0 \implies g = e^* \cdot v'(m^*) \tag{A.3}$$

$$\{e\}\colon \quad \frac{m^* \cdot g}{(e^*)^2} - c'(e^*) = 0 \implies g = \frac{(e^*)^2 \cdot c'(e^*)}{m^*} \tag{A.4}$$

Combining equations (A.3) and (A.4) and simplifying yields:

$$m^* \cdot v'(m^*) = e^* \cdot c'(e^*) \tag{A.5}$$

[54]For simplicity, assume this buyer has $\lambda = 0$ and is either paying with cash or obtaining a 0% loan, so they do not face any financing costs.

Using the Implicit Function Theorem, I rewrite equation (A.5) as an implicit function of λ and set it equal to zero:

$$h(e^*, m^*; \lambda) = e^*(\lambda) \cdot c'(e^*(\lambda)) - m^*(\lambda) \cdot v'(m^*(\lambda)) = 0 \tag{A.6}$$

To determine how e^* changes as λ changes, I take the total derivative of equation (A.6) with respect to λ (the goal is to determine the sign of the term in bold, $\frac{de^*}{d\lambda}$):

$$\frac{dh}{d\lambda} = \frac{\partial h}{\partial e^*} \cdot \frac{\mathbf{de}^*}{\mathbf{d}\boldsymbol{\lambda}} + \frac{\partial h}{\partial m^*} \cdot \frac{dm^*}{d\lambda} + \frac{\partial h}{\partial \lambda}$$

Next, I derive $\frac{dh}{d\lambda}$:[55]

$$\frac{dh}{d\lambda} = \overbrace{\left[e^*(\lambda) \cdot c''(e^*(\lambda)) + c'(e^*(\lambda))\right]}^{\equiv A\ (+)} \cdot \frac{de^*}{d\lambda} - \overbrace{\left[m^*(\lambda) \cdot v''(m^*(\lambda)) + v'(m^*(\lambda))\right]}^{\equiv B\ (\leq 0)} \cdot \frac{dm^*}{d\lambda} + \underbrace{\left[e^*(\lambda) \cdot \left(f_g'(p(e^*(\lambda))) \cdot p'(e^*(\lambda)) - f_b'(p(e^*(\lambda))) \cdot p'(e^*(\lambda))\right)\right]}_{\equiv C\ (-)} = 0 \tag{A.7}$$

I relabel three large terms in equation (A.7) as A, B, and C, respectively. Based on the assumptions of the model, A is unambiguously positive and C is unambiguously negative. Under the assumption of CRRA utility for $v(m)$ with $\rho \geq 1$, we also have $B \leq 0$.[56] Rearranging equation (A.7), I solve for $\frac{de^*}{d\lambda}$ using simplified notation:

$$\frac{de^*}{d\lambda} = \frac{dm^*}{d\lambda} \cdot \frac{B}{A} - \frac{C}{A} \tag{A.8}$$

Now the goal is to sign $\frac{de^*}{d\lambda}$. To start, notice that $\frac{C}{A}$ is negative, so $-\frac{C}{A}$ adds a positive term to the right hand side of equation (A.8). Thus, if $\frac{dm^*}{d\lambda} \cdot \frac{B}{A} \geq 0$, then we can conclude that $\frac{de^*}{d\lambda} > 0$.

Consider first the case in which $B = 0$, which is true if $v(m) = log(m)$. In this case, $\frac{dm^*}{d\lambda} \cdot \frac{B}{A} = 0$, so $\frac{de^*}{d\lambda} = -\frac{C}{A} > 0$.

[55] For $\frac{\partial h}{\partial \lambda}$, note that $c'(e^*(\lambda)) = p'(e^*(\lambda)) \cdot \left[1 + \lambda \cdot f_g'(p(e^*(\lambda))) + (1-\lambda) \cdot f_b'(p(e^*(\lambda)))\right]$.

[56] If $\rho = 1$, then $m^*(\lambda) \cdot v''(m^*(\lambda)) + v'(m^*(\lambda)) = -m^* \cdot (m^*)^{-2} + (m^*)^{-1} = 0$.
If $\rho > 1$, then $m^*(\lambda) \cdot v''(m^*(\lambda)) + v'(m^*(\lambda)) = -\rho \cdot m^* \cdot (m^*)^{-\rho-1} + (m^*)^{-\rho} = (m^*)^{-\rho} \cdot (1-\rho) < 0$.

Next, consider the case in which $B < 0$.[57] Additionally, assume the following:

$$\frac{de^*}{d\lambda} \cdot \frac{dm^*}{d\lambda} > 0 \tag{A.9}$$

The assumption in inequality (A.9) says that optimal fuel efficiency and miles driven must move in the same direction with respect to changes in λ (i.e., $\frac{de^*}{d\lambda}$ and $\frac{dm^*}{d\lambda}$ must have the same sign). This is a reasonable assumption—looking at FOC equations (A.3) and (A.4), one can see that m^* is increasing in e^*. Moreover, an increase in e^* effectively lowers the price of driving, so consumers should want to drive more as fuel efficiency increases, all else equal. If this were not the case, the demand curve for driving would be upward sloping.

Inequality (A.9) implies that $\frac{de^*}{d\lambda}$ and $\frac{dm^*}{d\lambda}$ must both be negative or both be positive.[58] Assume for the sake of contradiction that both are negative. Then we have the following:

$$\underbrace{\frac{de^*}{d\lambda}}_{(-)} = \underbrace{\overbrace{\frac{dm^*}{d\lambda}}^{(-)} \cdot \overbrace{\frac{B}{A}}^{(-)} - \overbrace{\frac{C}{A}}^{(-)}}_{(+)} \qquad \Longrightarrow\!\Longleftarrow \tag{A.10}$$

This leaves us with a negative number equal to a positive number, which is a contradiction. As a result, we must have:

$$\frac{de^*}{d\lambda} = \frac{dm^*}{d\lambda} \cdot \frac{B}{A} - \frac{C}{A} > 0$$

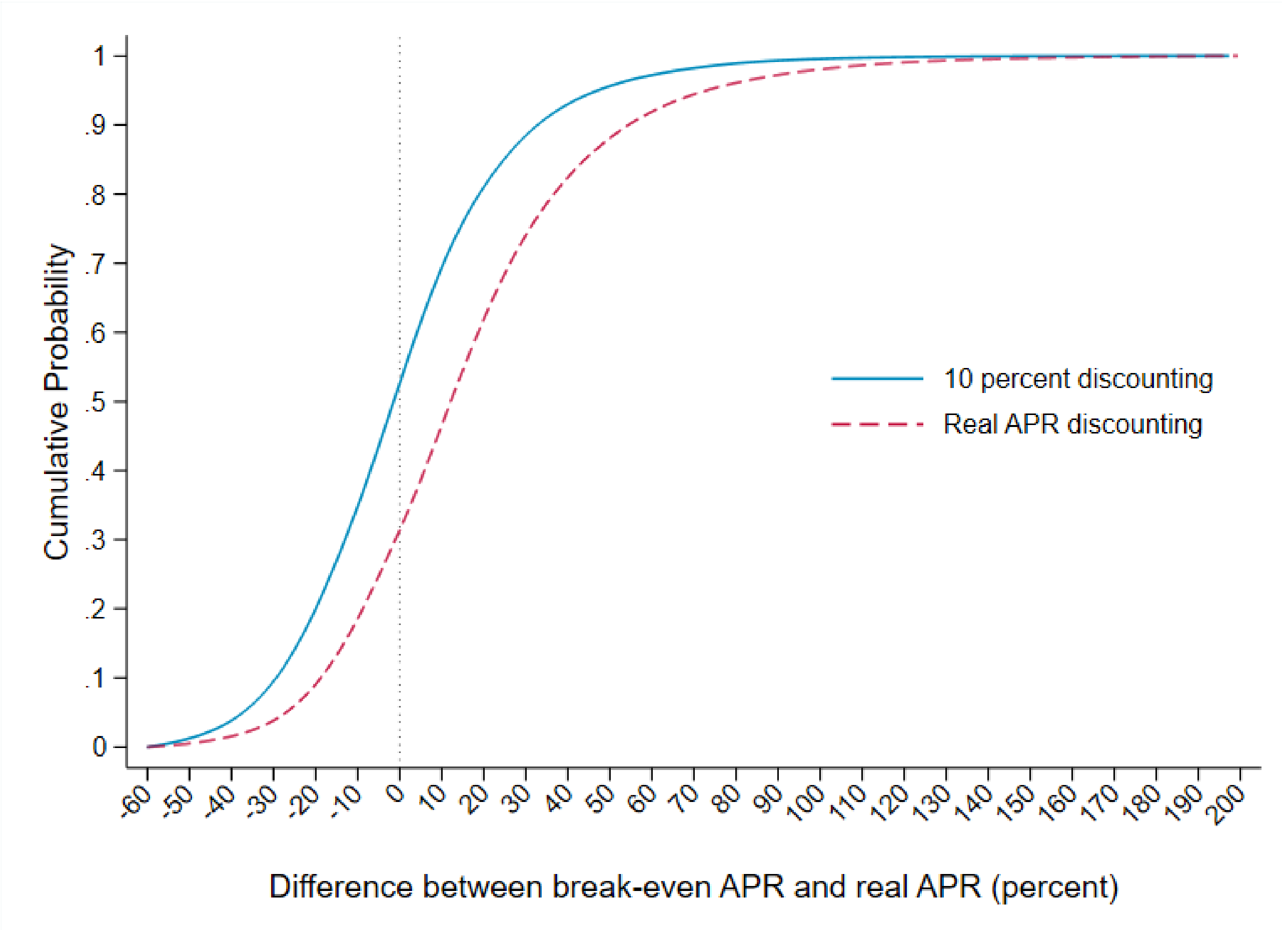
Thus, under reasonable assumptions, the model predicts that $\frac{de^*}{d\lambda} > 0$. This means that consumers with a comparatively lower cost of credit should purchase more fuel-efficient cars, all else equal. Additionally, this simple model underscores why income can be an imperfect proxy for credit constraints when analyzing consumer choices to invest in energy efficiency. As the model illustrates, it is quite possible to have two consumers with identical incomes and driving preferences but differing optimal investment levels in energy efficiency.

[57] This is the case if $v(m)$ is CRRA with $\rho > 1$.

[58] $\frac{de^*}{d\lambda}$ and $\frac{dm^*}{d\lambda}$ cannot both be zero because the right hand side of equation (A.8) would still be positive in that case, which is a contradiction.

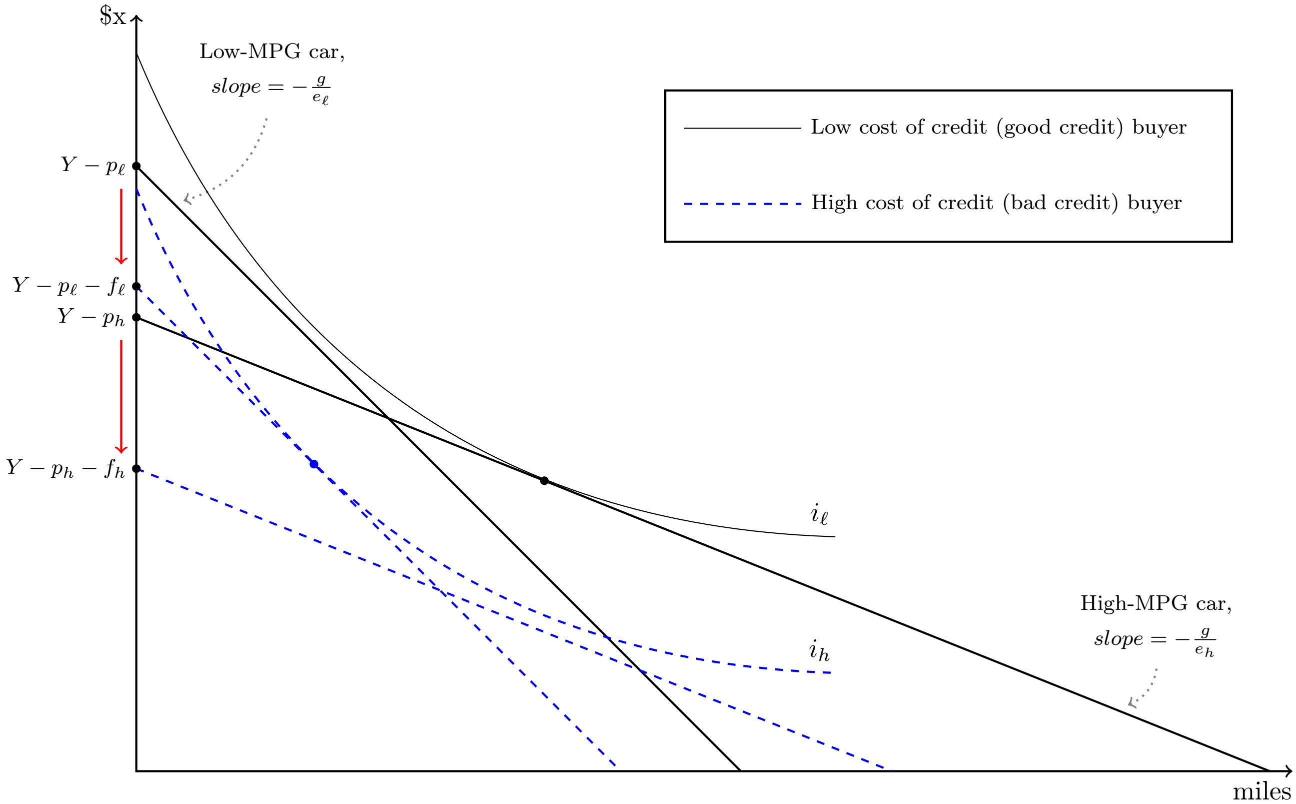
A.2 Appendix Figures

Figure A.1: Gap between consumer break-even APR and real APR – 1-MPG increase with alternative MPG cost



Notes: This figure shows empirical cumulative distribution functions (using 10% discounting and real APR discounting, respectively) of the difference between each consumer's break-even APR for profitable fuel efficiency investment and the actual real APR they obtained for their auto loan. The data, assumptions, and method used to calculate the break-even APR for each consumer are described in Section 3. The portions of the CDFs that lie above zero on the horizontal axis represent consumers who—on a purely financial basis—are leaving money on the table by not investing in more fuel efficiency. This figure uses $631 as the cost of an additional MPG, which is an approximate implied willingness-to-pay using estimates and average vehicle characteristics from Leard et al. (2023b). Though this figure assumes a higher per-MPG cost than Figure 3, there is still a large portion of the distribution of buyers who would profit from investing in additional fuel economy.

Figure A.2: Optimal fuel economy choice with 2-car example (high-MPG vs. low-MPG)



Notes: This figure illustrates how consumers' cost of credit can inhibit investment in fuel economy (a detailed explanation of the model that inspires this figure is available in Section A.1). In this simple model, a consumer is choosing between two vehicles that are identical except for fuel economy—the high-MPG car gets e_h MPG and costs p_h, while the low-MPG car gets e_ℓ MPG and costs p_ℓ (with $e_h > e_\ell$ and $p_h > p_\ell$). Assuming constant gasoline prices (g) and income (Y), the high-MPG car is more expensive upfront but cheaper to drive per-mile and the low-MPG car is cheaper upfront but more expensive to drive per-mile. The consumer chooses a car to purchase and allocates their remaining income between driving (represented by miles on the horizontal axis) and a numeraire good x (the vertical axis). The solid lines show an example indifference curve (i_ℓ) for a buyer with a low cost of credit (i.e., someone who is paying cash or obtains 0% financing and thus does not face any financing costs) whose optimal bundle includes purchasing the high-MPG car. However, a buyer with a high cost of credit with identical preferences faces the same price per-mile for each car but also faces higher costs of purchasing either car due to financing charges, causing the downward shift of each budget set shown by the dashed lines and red arrows. Moreover, the cost of purchasing the high-MPG car increases by more than that of the low-MPG car, since total financing charges are increasing in the amount borrowed (i.e., $f_h > f_\ell$) and $p_h > p_\ell$. As the figure demonstrates, this causes the otherwise identical consumer with a higher cost of credit to shift their optimal bundle (on indifference curve i_h) to the low-MPG car instead of the high-MPG car that the buyer with a low cost of credit chose.

A.3 Appendix Tables

Table A.1: Loan APR and fuel economy choice (controls shown)

Dependent variable: miles per gallon (MPG)	(1)	(2)	(3)	(4)	(5)	(6)
Loan APR, inflation-adjusted (percent)	-0.132*	-0.0512*	-0.0537*	-0.0549*	-0.0520*	-0.0544*
	(0.0166)	(0.0111)	(0.0111)	(0.0110)	(0.0111)	(0.0109)
Loan amount ($1000s)	0.00539	0.0113*	0.0114*	0.0115*	0.0120*	0.0119*
	(0.00287)	(0.00304)	(0.00302)	(0.00304)	(0.00283)	(0.00280)
Loan length (months)	0.00535*	-0.00778*	-0.00840*	-0.00863*	-0.00855*	-0.00880*
	(0.00229)	(0.00221)	(0.00221)	(0.00223)	(0.00223)	(0.00218)
Purchase price ($1000s)	0.132*	0.135*	0.139*	0.139*	0.135*	0.139*
	(0.0189)	(0.0191)	(0.0200)	(0.0199)	(0.0193)	(0.0200)
Gasoline price (PADD monthly average, $/gal)	-0.660*	0.861*	1.177*	1.744*		
	(0.177)	(0.207)	(0.247)	(0.327)		
Buyer expected annual miles (1000s)	0.0190*	0.0245*	0.0248*	0.0254*	0.0258*	0.0255*
	(0.00460)	(0.00443)	(0.00443)	(0.00441)	(0.00444)	(0.00434)
Vehicle weight (1000 lbs)	3.043*	3.065*	2.971*	2.975*	3.082*	2.969*
	(1.020)	(1.006)	(1.008)	(1.006)	(1.006)	(0.996)
Engine liters	-0.634	-0.0884	-0.0779	-0.0786	-0.101	-0.0883
	(0.378)	(0.369)	(0.369)	(0.370)	(0.368)	(0.367)
Education dummy (1 = Has bachelors degree)	0.384*	0.414*	0.415*	0.422*	0.425*	0.424*
	(0.0560)	(0.0539)	(0.0532)	(0.0530)	(0.0539)	(0.0531)
Lives in urban area (1 = Yes)	-0.0245	-0.0998*	-0.113*	-0.145*	-0.167*	-0.165*
	(0.0371)	(0.0338)	(0.0333)	(0.0348)	(0.0341)	(0.0350)
Household income ($1000s)	0.000220	0.000588	0.000604*	0.000566	0.000572	0.000625*
	(0.000314)	(0.000303)	(0.000299)	(0.000297)	(0.000297)	(0.000290)
Household size (number of people)	0.0991*	0.0793*	0.0777*	0.0786*	0.0786*	0.0772*
	(0.0226)	(0.0229)	(0.0225)	(0.0224)	(0.0228)	(0.0221)
Buyer race dummy (1 = White)	0.279*	0.496*	0.506*	0.526*	0.496*	0.492*
	(0.0901)	(0.0788)	(0.0766)	(0.0764)	(0.0664)	(0.0653)
Buyer age (years)	0.0170*	0.00900*	0.00844*	0.00858*	0.00904*	0.00853*
	(0.00380)	(0.00368)	(0.00363)	(0.00363)	(0.00368)	(0.00362)
Constant	39.42*	37.26*	35.72*	34.13*	39.68*	39.30*
	(7.415)	(6.715)	(6.726)	(6.476)	(6.906)	(6.923)
Fixed effects:						
Model year		✓	✓	✓	✓	✓
Month		✓	✓		✓	
Year			✓			
Month-by-year				✓		
PADD region					✓	
PADD region-by-month-by-year						✓
Observations	369,425	369,425	369,425	369,425	369,425	369,425
R^2	0.525	0.543	0.545	0.546	0.544	0.548

Notes: Standard errors in parentheses are clustered by model year, make, and model (* p<0.05). All dollar amounts are adjusted to 2017 USD. Gasoline prices and regional fixed effects are at the Petroleum Administration for Defense District (PADD) level, dividing the fifty states into five districts. Controls not shown include vehicle horsepower, torque, length, width, height, wheelbase, engine cylinders, body style dummies (e.g., sedan, SUV, convertible), and drive type dummies (e.g., front wheel drive, all wheel drive).

Table A.2: Self-reported credit history and loan APR (controls shown)

Dependent variable: Loan APR	(1)	(2)
Self-reported credit history (“excellent” is omitted category)		
Buyer credit history - good (1 = Yes)	1.416*	1.410*
	(0.0186)	(0.0186)
Buyer credit history - bad (1 = Yes)	5.290*	5.283*
	(0.0686)	(0.0685)
Buyer credit history - none (1 = Yes)	2.446*	2.439*
	(0.0877)	(0.0875)
Loan amount ($1000s)	-0.0399*	-0.0406*
	(0.00112)	(0.00113)
Loan length (months)	0.0354*	0.0357*
	(0.000689)	(0.000691)
Purchase price ($1000s)	0.0161*	0.0159*
	(0.000977)	(0.000968)
Education dummy (1 = Has bachelors degree)	-0.334*	-0.336*
	(0.0122)	(0.0122)
Lives in urban area (1 = Yes)	-0.106*	-0.0868*
	(0.0158)	(0.0158)
Household income ($1000s)	-0.000634*	-0.000591*
	(6.53e-05)	(6.53e-05)
Household size (number of people)	0.0309*	0.0303*
	(0.00561)	(0.00557)
Buyer race dummy (1 = White)	-0.417*	-0.417*
	(0.0198)	(0.0197)
Buyer age (years)	-0.00233*	-0.00249*
	(0.000490)	(0.000488)
Financing arranged by dealer (1 = Yes)	-0.385*	-0.385*
	(0.0180)	(0.0181)
Constant	2.083*	2.010*
	(0.0951)	(0.114)
Fixed effects:		
Month-by-year	✓	
PADD region-by-month-by-year		✓
Observations	240,224	240,220
R^2	0.309	0.312

Notes: Standard errors in parentheses are clustered by model year, make, and model (* p<0.05). All dollar amounts are adjusted to 2017 USD. Columns 1 and 2 show regressions of APR on self-reported credit history. The “excellent” self-reported credit history category is the baseline category and is omitted from all regressions.

Table A.3: Self-reported credit history as a proxy for unobserved financial literacy (controls shown)

Dependent variable: miles per gallon (MPG)	(1)	(2)	(3)	(4)	(5)	(6)
Loan APR, inflation-adjusted (percent)	-0.0509*	-0.0269*	-0.0531*	-0.0287*	-0.0517*	-0.0287*
	(0.0117)	(0.0119)	(0.0117)	(0.0117)	(0.0117)	(0.0118)
Self-reported credit history (“excellent” is omitted category)						
Buyer credit history - good (1 = Yes)		-0.323*		-0.327*		-0.311*
		(0.0508)		(0.0508)		(0.0497)
Buyer credit history - bad (1 = Yes)		-0.560*		-0.565*		-0.536*
		(0.102)		(0.0990)		(0.101)
Buyer credit history - none (1 = Yes)		-0.804*		-0.800*		-0.771*
		(0.125)		(0.124)		(0.122)
Loan amount ($1000s)	0.00884*	0.0113*	0.00892*	0.0114*	0.00946*	0.0118*
	(0.00347)	(0.00354)	(0.00344)	(0.00350)	(0.00323)	(0.00331)
Loan length (months)	-0.00611*	-0.00639*	-0.00673*	-0.00704*	-0.00685*	-0.00711*
	(0.00243)	(0.00245)	(0.00241)	(0.00243)	(0.00243)	(0.00245)
Purchase price ($1000s)	0.136*	0.134*	0.140*	0.138*	0.136*	0.134*
	(0.0194)	(0.0193)	(0.0202)	(0.0201)	(0.0195)	(0.0195)
Gasoline price (PADD monthly average, $/gal)	0.899*	0.903*	1.217*	1.217*		
	(0.216)	(0.216)	(0.256)	(0.256)		
Buyer expected annual miles (1000s)	0.0241*	0.0252*	0.0245*	0.0255*	0.0254*	0.0263*
	(0.00452)	(0.00455)	(0.00453)	(0.00455)	(0.00453)	(0.00456)
Vehicle weight (1000 lbs)	3.229*	3.211*	3.135*	3.115*	3.247*	3.230*
	(1.029)	(1.028)	(1.031)	(1.030)	(1.029)	(1.028)
Engine liters	-0.0638	-0.0603	-0.0538	-0.0501	-0.0722	-0.0688
	(0.375)	(0.375)	(0.375)	(0.375)	(0.374)	(0.374)
Education dummy (1 = Has bachelors degree)	0.418*	0.392*	0.419*	0.393*	0.428*	0.403*
	(0.0614)	(0.0597)	(0.0604)	(0.0586)	(0.0611)	(0.0594)
Lives in urban area (1 = Yes)	-0.105*	-0.102*	-0.117*	-0.113*	-0.173*	-0.170*
	(0.0373)	(0.0374)	(0.0373)	(0.0373)	(0.0386)	(0.0386)
Household income ($1000s)	0.000614	0.000454	0.000605	0.000446	0.000597	0.000443
	(0.000352)	(0.000355)	(0.000349)	(0.000351)	(0.000346)	(0.000348)
Household size (number of people)	0.0873*	0.0912*	0.0860*	0.0899*	0.0857*	0.0894*
	(0.0262)	(0.0264)	(0.0259)	(0.0260)	(0.0260)	(0.0262)
Buyer race dummy (1 = White)	0.455*	0.435*	0.466*	0.446*	0.454*	0.436*
	(0.0770)	(0.0760)	(0.0752)	(0.0741)	(0.0650)	(0.0641)
Buyer age (years)	0.00998*	0.00815*	0.00943*	0.00758*	0.0101*	0.00834*
	(0.00383)	(0.00378)	(0.00377)	(0.00373)	(0.00383)	(0.00378)
Constant	38.19*	38.25*	36.66*	36.72*	40.70*	40.77*
	(6.760)	(6.754)	(6.769)	(6.763)	(6.938)	(6.934)
Fixed effects:						
Model year	✓	✓	✓	✓	✓	✓
Month	✓	✓	✓	✓	✓	✓
Year			✓	✓		
PADD region					✓	✓
Observations	220,195	220,195	220,195	220,195	220,195	220,195
R^2	0.542	0.542	0.544	0.544	0.543	0.543

Notes: Standard errors in parentheses are clustered by model year, make, and model (* $p<0.05$). All dollar amounts are adjusted to 2017 USD. Columns 2, 4, and 6 refine columns 1, 3, and 5 respectively by including self-reported credit history as a proxy for unobserved financial responsibility. The “excellent” self-reported credit history category is the baseline category and is omitted from regression columns 2, 4, and 6. Gasoline prices and regional fixed effects are at the Petroleum Administration for Defense District (PADD) level, dividing the fifty states into five districts. Controls not shown include vehicle horsepower, torque, length, width, height, wheelbase, engine cylinders, body style dummies (e.g., sedan, SUV, convertible), and drive type dummies (e.g., front wheel drive, all wheel drive).

Table A.4: Heterogeneous response to gasoline price changes based on credit constraints (controls shown)

Dependent variable: miles per gallon (MPG)	(1)	(2)	(3)	(4)	(5)
Real APR Quartile (Q1 = lowest real APRs)	**Q1**	**Q2**	**Q3**	**Q4**	**Cash Buyers**
Gasoline price (PADD monthly average, $/gal)	1.866*	1.162*	0.895*	0.757*	1.635*
	(0.375)	(0.378)	(0.224)	(0.178)	(0.374)
Loan APR, inflation-adjusted (percent)	0.222*	-0.182	-0.0730	-0.0299*	
	(0.0886)	(0.130)	(0.100)	(0.00761)	
Buyer credit history - bad (1 = Yes)	-1.080*	-0.472	-0.518*	-0.265*	
	(0.215)	(0.338)	(0.200)	(0.0810)	
Buyer credit history - good (1 = Yes)	-0.480*	-0.212*	-0.266*	-0.174*	
	(0.121)	(0.0962)	(0.0760)	(0.0591)	
Buyer credit history - none (1 = Yes)	-0.817*	-1.012*	-0.511*	-0.623*	
	(0.257)	(0.298)	(0.237)	(0.119)	
Loan amount ($1000s)	0.0153*	0.00921	0.00936*	0.00916*	
	(0.00360)	(0.00670)	(0.00374)	(0.00429)	
Loan length (months)	-0.0101*	-0.00591	-0.00333	-0.00815*	
	(0.00411)	(0.00488)	(0.00294)	(0.00282)	
Purchase price ($1000s)	0.152*	0.165*	0.125*	0.107*	0.170*
	(0.0231)	(0.0269)	(0.0176)	(0.0125)	(0.0189)
Buyer expected annual miles (1000s)	0.0355*	0.0192*	0.0248*	0.0215*	0.0212*
	(0.00676)	(0.00771)	(0.00598)	(0.00387)	(0.00792)
Vehicle weight (1000 lbs)	3.626*	4.057*	2.724*	2.136*	5.170*
	(1.412)	(1.300)	(0.959)	(0.816)	(1.292)
Engine liters	0.232	0.507	-0.0670	-0.917*	1.132*
	(0.493)	(0.532)	(0.377)	(0.249)	(0.516)
Education dummy (1 = Has bachelors degree)	0.291*	0.469*	0.345*	0.377*	0.534*
	(0.0647)	(0.0835)	(0.0737)	(0.0668)	(0.0689)
Lives in urban area (1 = Yes)	-0.0596	-0.159	-0.160*	-0.0547	-0.156*
	(0.0781)	(0.0813)	(0.0616)	(0.0609)	(0.0582)
Household income ($1000s)	1.21e-05	0.000235	0.000681	0.00102*	-0.000263
	(0.000487)	(0.000539)	(0.000474)	(0.000410)	(0.000288)
Household size (number of people)	0.124*	0.116*	0.0949*	0.0378	0.167*
	(0.0361)	(0.0427)	(0.0437)	(0.0243)	(0.0332)
Buyer race dummy (1 = White)	0.398*	0.557*	0.425*	0.348*	0.136
	(0.0859)	(0.126)	(0.0996)	(0.0689)	(0.0908)
Buyer age (years)	0.00714	0.00948	0.00790	0.00700*	-0.00443
	(0.00410)	(0.00592)	(0.00407)	(0.00320)	(0.00519)
Constant	31.03*	40.24*	37.68*	41.49*	40.35*
	(7.982)	(9.103)	(6.143)	(4.297)	(9.309)
Observations	58,436	52,873	55,994	52,892	151,571
R^2	0.551	0.536	0.546	0.596	0.573

Notes: Standard errors in parentheses are clustered by model year, make, and model (* p<0.05). All dollar amounts are adjusted to 2017 USD. Columns 1-4 divide the main regression sample into subsamples based on real APR quartile, where Q1 has the lowest real APRs and Q4 has the highest real APRs. Column 5 runs a similar regression over a subsample from the Ipsos survey who indicated that they paid cash for their vehicle and did not use financing. The "excellent" self-reported credit history category is omitted from all regressions. All regressions include model year, month, and year fixed effects. Gasoline prices are at the Petroleum Administration for Defense District (PADD) level, dividing the fifty states into five districts. Controls not shown include vehicle horsepower, torque, length, width, height, wheelbase, engine cylinders, body style dummies (e.g., sedan, SUV, convertible), and drive type dummies (e.g., front wheel drive, all wheel drive).

Table A.5: Hybrid-gasoline sibling pairs in Ipsos data

Make	**Model**	# **Hybrids**	# **Non-hybrids**
Acura	ILX	22	139
Acura	MDX	28	129
Acura	RLX	17	81
Audi	Q5	10	436
Buick	Lacrosse	89	237
Buick	Regal	39	312
Chevrolet	Malibu	172	410
Chevrolet	Silverado	22	1913
Chevrolet	Tahoe	23	625
Ford	Escape	201	247
Ford	Fusion	520	734
GMC	Sierra	20	2054
GMC	Yukon	12	333
GMC	Yukon Denali	17	194
Honda	Accord	361	694
Honda	Civic	348	1532
Hyundai	Sonata	681	1074
Infiniti	Q50	47	101
Infiniti	QX60	28	183
Kia	Optima	247	5369
Lexus	ES	346	580
Lexus	GS	17	316
Lexus	NX	87	144
Lexus	RX	464	373
Lincoln	MKZ	293	214
Mercury	Mariner	29	116
Mercury	Milan	51	68
Nissan	Altima	91	209
Nissan	Pathfinder	10	150
Subaru	Crosstrek	193	321
Toyota	Avalon	249	349
Toyota	Camry	393	870
Toyota	Highlander	509	840
Toyota	RAV4	611	192
Volkswagen	Jetta	157	485
TOTAL		**6,404**	**17,194**

Table A.6: Linear probability model estimates with hybrid/gasoline vehicle siblings (controls shown)

Dependent variable: Purchased hybrid (1 = Yes)	(1)	(2)	(3)	(4)	(5)
Loan APR, inflation-adjusted (percent)	-0.00286	-0.00217	-0.00212*	-0.00203*	-0.00282*
	(0.00178)	(0.00149)	(0.000986)	(0.000972)	(0.00112)
Self-reported credit history ("excellent" is omitted category)					
Buyer credit history - good (1 = Yes)	-0.00634	-0.0141*	-0.0149*	-0.0171*	-0.0134*
	(0.00703)	(0.00514)	(0.00467)	(0.00469)	(0.00470)
Buyer credit history - bad (1 = Yes)	-0.0241	-0.0235	-0.0239*	-0.0270*	-0.0191
	(0.0128)	(0.0121)	(0.00990)	(0.00922)	(0.0102)
Buyer credit history - none (1 = Yes)	-0.0749*	-0.0429*	-0.0474*	-0.0437*	-0.0424*
	(0.0184)	(0.0178)	(0.0165)	(0.0156)	(0.0164)
Loan amount ($1000s)	0.00135*	0.00136*	0.00139*	0.00143*	0.00124*
	(0.000301)	(0.000292)	(0.000289)	(0.000283)	(0.000278)
Loan length (months)	-0.000117	-0.000562*	-0.000670*	-0.000792*	-0.000580*
	(0.000203)	(0.000170)	(0.000158)	(0.000159)	(0.000149)
Purchase price ($1000s)	0.00889*	0.0119*	0.0118*	0.0130*	0.0118*
	(0.00180)	(0.00186)	(0.00177)	(0.00180)	(0.00172)
Gasoline price (PADD monthly average, $/gal)	0.0120	0.0284	0.0393*	0.0202*	
	(0.0205)	(0.0145)	(0.00842)	(0.00790)	
Buyer expected annual miles (1000s)	0.00250*	0.00162*	0.00161*	0.00151*	0.00167*
	(0.000323)	(0.000260)	(0.000251)	(0.000231)	(0.000243)
Vehicle weight (1000 lbs)	0.994*	1.458*	1.445*	1.415*	1.469*
	(0.125)	(0.209)	(0.202)	(0.195)	(0.196)
Engine liters	-0.0233	-0.137*	-0.121	-0.131*	-0.133*
	(0.0590)	(0.0619)	(0.0638)	(0.0603)	(0.0626)
Education dummy (1 = Has bachelors degree)	0.0358*	0.0306*	0.0292*	0.0276*	0.0287*
	(0.00480)	(0.00474)	(0.00439)	(0.00429)	(0.00457)
Lives in urban area (1 = Yes)	0.0202*	0.00628	0.00479	0.00595	0.00485
	(0.00481)	(0.00372)	(0.00383)	(0.00360)	(0.00352)
Household income ($1000s)	6.12e-05	8.05e-05*	8.49e-05*	9.16e-05*	8.24e-05*
	(3.62e-05)	(2.98e-05)	(2.87e-05)	(2.81e-05)	(2.79e-05)
Household size (number of people)	0.00565*	0.00436*	0.00392*	0.00337*	0.00332*
	(0.00172)	(0.00133)	(0.00132)	(0.00131)	(0.00132)
Buyer race dummy (1 = White)	0.0113	0.00776	0.00947	0.00790	0.00990
	(0.00877)	(0.00621)	(0.00627)	(0.00591)	(0.00607)
Buyer age (years)	0.000580*	0.000362	0.000228	0.000269	0.000266
	(0.000246)	(0.000195)	(0.000165)	(0.000159)	(0.000169)
Constant	5.718*	9.522*	12.38*	10.37*	10.63*
	(1.167)	(2.753)	(2.913)	(3.174)	(3.271)
Fixed effects:					
Model year				✓	✓
Month			✓	✓	✓
Year			✓	✓	
PADD region					✓
Vehicle sibling		✓	✓	✓	✓
Observations	23,598	23,598	23,598	23,598	23,598
R^2	0.665	0.764	0.771	0.783	0.774

Notes: Standard errors in parentheses are clustered by model year, make, and model (* p<0.05). All dollar amounts are adjusted to 2017 USD. The "excellent" self-reported credit history category is the baseline category and is omitted from all regressions. Gasoline prices and regional fixed effects are at the Petroleum Administration for Defense District (PADD) level, dividing the fifty states into five districts. Controls not shown include vehicle horsepower, torque, length, width, height, wheelbase, engine cylinders, body style dummies (e.g., sedan, SUV, convertible), and drive type dummies (e.g., front wheel drive, all wheel drive).