EI @ Haas WP 201

Pain at the Pump: The Differential Effect of Gasoline Prices on New and Used Automobile Markets

Meghan R. Busse, Christopher R. Knittel
and Florian Zettelmeyer

December 2009

This paper is part of the Energy Institute at Haas (EI @ Haas) Working Paper Series. EI @ Haas is a joint venture of the Haas School of Business and the UC Energy Institute that brings together research and curricular programs on energy business, policy and technology commercialization.

Energy Institute at Haas
2547 Channing Way, # 5180
Berkeley, California 94720-5180
http://ei.haas.berkeley.edu

Pain at the Pump: The Differential Effect of Gasoline Prices on New and Used Automobile Markets*

Meghan R. Busse
Northwestern University and NBER

Christopher R. Knittel
University of California, Davis and NBER

Florian Zettelmeyer
Northwestern University and NBER

December 2009

First version: October 2008

*We are grateful for helpful comments from Severin Borenstein, Igal Hendel, Ryan Kellogg, Jorge Silva-Risso, Scott Stern and seminar participants at the ASSA, Iowa State, Ohio State, Triangle Resource and Environmental Economics seminar, Purdue, UC Berkeley, Yale, MIT, University of British Columbia, University of Toronto, Cornell, Northwestern University, Chicago Federal Reserve Bank, University of Chicago, Texas A&M, and the University of Rochester. We also thank participants at the NBER 2008 Winter IO conference. We thank the University of California Energy Institute (UCEI) for financial help in acquiring data. Busse and Zettelmeyer gratefully acknowledge the support of NSF grants SES-0550508 and SES-0550911. Knittel thanks the Institute of Transportation Studies at UC Davis for support.

Addresses for correspondence: E-mail: m-busse@kellogg.northwestern.edu, crknittel@ucdavis.edu, f-zettelmeyer@kellogg.northwestern.edu

Pain at the Pump: The Differential Effect of Gasoline Prices on New and Used Automobile Markets

Abstract

The dramatic increase in gasoline prices from close to $1 in 1999 to $4 at their peak in 2008 made it much more expensive for consumers to operate an automobile. In this paper we investigate whether consumers have adjusted to gasoline price changes by altering what automobiles they purchase and what prices they pay. We investigate these effects in both new and used car markets. We find that a $1 increase in gasoline price changes the market shares of the most and least fuel-efficient quartiles of *new* cars by +20% and -24%, respectively. In contrast, the same gasoline price increase changes the market shares of the most and least fuel-efficient quartiles of *used* cars by only +3% and -7%, respectively. We find that changes in gasoline prices also change the relative prices of cars in the most fuel-efficient quartile and cars in the least fuel-efficient quartile: for *new* cars the relative price increase for fuel-efficient cars is $363 for a $1 increase in gas prices; for used cars it is $2839. Hence the adjustment of equilibrium market shares and prices in response to changes in usage cost varies dramatically between new and used markets. In the new car market, the adjustment is primarily in market shares, while in the used car market, the adjustment is primarily in prices. We argue that the difference in how gasoline costs affect new and used automobile markets can be explained by differences in the supply characteristics of new and used cars.

1 Introduction

Fuel costs make up a large and increasing share of the total cost of using an automobile. The dramatic increase in gasoline prices from below $1 in early 1999 to $4 at their peak in 2008 made it much more expensive for consumers to operate an automobile. For example, an average driver of a full-size SUV spent as little at $758 per year on gasoline at early-1999 gasoline prices; at mid-2008 prices this driver would have had to spend up to $2968 to travel the same distance in the same car.[1]

Paying more for using a car when gasoline prices increase, however, is not inevitable. Consumers can adjust to these usage cost changes by taking advantage of the variety in fuel efficiency of available automobiles. For example, a full-size SUV owner who would have spent $2968 for gasoline at mid-2008 prices could have reduced that amount to $2148 by replacing her full-size SUV with a smaller SUV, or to $1470 by switching from her SUV to a small car.[2]

In this paper we investigate whether the change in gasoline prices did, in fact, alter which automobiles consumers purchased and what prices they paid. We investigate both new and used car markets; while average transaction prices in the used market are lower, there are about twice as many used cars as new cars sold each year in the U.S.[3] To analyze these two markets we combine data on local gasoline prices and data on model-specific fuel efficiency with transaction data from a 20% sample of U.S. new car dealers from 1999 to 2008. These dealers sell both new and used vehicles.

We find that a $1 increase in gasoline price changes the market shares of the most and least fuel-efficient quartiles of *new* cars by +20% and -24%, respectively. In contrast, the same gasoline price increase changes the market shares of the most and least fuel-efficient quartiles of *used* cars by only +3% and -7%, respectively. We find that changes in gasoline prices also change the relative prices of cars in the most fuel-efficient and least fuel-efficient quartiles: for *new* cars the relative price increase for fuel-efficient cars is $363 for a $1 increase in gas prices; for used cars it is $2839. Hence, the adjustment of equilibrium market shares and prices in response to changes in usage cost varies dramatically between new and used markets. In the new car market, the adjustment is primarily in market shares, while in the used car market, the adjustment is primarily in prices.

The size of this difference seems surprising because the cars, the consumers, and the retailers

[1] This uses the standard assumption that consumers drive 12,000 miles per year. The average fuel-efficiency of full-size SUVs is 15.2 miles per gallon. The average national gasoline price during the first quarter of 1999 was $0.96 and during the second quarter of 2008 was $3.76.

[2] This uses the average fuel-efficiencies for full-size SUVs (15.2 MPG), entry SUVs (21 MPG), and entry compact cars (30.7 MPG). See Table 8 for average fuel efficiency by car segment.

[3] There are 10-16 million new and 20-35 million used cars sold in the U.S. per year.

are fairly similar in the two markets measured in our sample. All the transaction data in our sample come from new car dealers. The used cars sold at these dealerships are a positive selection of used cars, making them not incomparable to new cars. For example, on average, a used car in our sample sells for $15,582 compared to $25,515 for a new car. The consumers in our sample who buy used cars are also not dissimilar to those who buy new cars. For example, on average, a used car buyer comes from a census block group with a median household income of $50,826 instead of a median income of $58,130 for new car buyers. Finally, new and used cars are sold at exactly same retailers in our data; at many of these dealerships, the same salesperson sells both new and used cars.

We argue that the dramatic difference in how usage cost affects new and used automobile markets can be explained by differences in the *supply* of new and used cars. New cars are supplied by auto manufacturers while the supply of used cars arises ultimately from used car owners. This means that the outside options of new and used car suppliers, in the event that either decides not to sell a car, differ very fundamentally. For manufacturers, there is no value to the car other than the profit opportunity of selling it. The manufacturer's reservation price—and thereby its decision to sell—will be unaffected by gasoline prices. For used car owners, however, the outside option is to keep the car and drive it themselves. A used car owner's decision to sell, therefore, will depend on a comparison of the usage costs and prices of his or her current car and of the candidate replacement car. Rising gasoline prices will increase the usage cost disadvantage of fuel-inefficient cars, increasing the incentives of their owners to sell them (and vice versa for fuel-efficient cars). This means that while rising gasoline prices should shift the *demand* in new and used car markets similarly, the effect on *supply* should differ between new and used car markets. The supply of *new* cars should be largely unaffected by changing gasoline prices while the supply of *used* cars should shift when gasoline prices change.

The empirical results we find in this paper are consistent with what we would expect given these supply differences in the two markets. We find that in new car markets, changes in usage costs result in larger market share changes than price changes, which is what we would expect, we argue below, if changes in the market equilibrium are driven primarily by changes in demand. In contrast, we find that prices in used car markets adjust by more than they do in new car markets. This is because demand and supply are both shifting in the used car market in a way that amplifies price effects and dampens quantity effects.

In this paper, we estimate short-run equilibrium effects. For the car industry, the short-run horizon is measured in months, a time frame during which a manufacturer's offering of models is fixed, its model-specific production capacity is largely fixed, as are a number of input arrangements (labor contracts, in particular). Over a longer horizon, say a year or two, some of these aspects become more flexible (models can be tweaked, some capacity can be altered). Only over a long-run horizon (several years), can a manufacturer introduce fundamentally different models into its product offering.

Our paper makes two primary contributions. First, our paper provides rare empirical evidence on how usage costs affect equilibrium outcomes in durable goods markets. Furthermore, since we observe outcomes in both new and used markets, we can investigate these effects—and potential differences in these effects—in new versus used markets. In particular, our paper shows that the effect of usage cost changes can differ dramatically for goods that have identical usage cost, similar retail outlets, and similar demand structures, based only on the inherent differences in supply between new and used markets. Second, our paper speaks to the difficulty of car manufacturers to adapt to volatile gasoline prices. Since consumers are sensitive to gasoline prices in choosing between types of automobiles, rapid changes in gasoline prices dramatically complicate car development and production planning. The scale of this problem during 2008 has been substantial enough to make top auto executives give up their historic opposition to gasoline price taxes: some executives have suggested that Congress should consider a variable gasoline tax that would create a $4 floor for retail gasoline prices.[4]

This paper proceeds as follows. In the next section, we describe the intuition for how a change in gasoline prices might affect the new and used markets for cars. In Section 3, we describe the data used in the paper. Section 4 is the main body of the paper. It describes the empirical specifications used to investigate the effect of gasoline price on the prices and market shares in the new and used car markets, and reports the results of those estimations. Section 5 investigates the robustness of our base results. Section 6 provides supporting evidence for our findings in Section 4, and Section 7 concludes.

2 Gasoline prices and new and used car markets

In this section, we discuss the intuition for what effect gasoline prices would be likely to have on the demand and the supply of both new and used cars.

[4] "General Motors Corp. Chief Executive Officer Rick Wagoner said Tuesday that increasing the federal gasoline tax to guarantee a minimum price of $4 a gallon is an idea 'worthy of consideration.' " (Washington Times, March 19, 2009). " 'We need more expensive gasoline to change consumer behavior,' Mr. [Mike] Jackson [CEO of Autonation, the largest U.S. dealership chain] said. Otherwise, Americans will continue to favor big vehicles, not matter what kind of fuel-economy standards the government imposes on auto makers. Four dollars a gallon, he added, 'is a good start.' " (Wall Street Journal, March 5, 2009)

2.1 Gasoline price and car demand

Because cars are durable goods, potential customers must consider in their purchase decision not only the initial cost of acquiring a car, but also the ongoing costs of operating the car. An increase in the price of gasoline will increase the usage cost for all (gasoline-powered) automobiles. Exactly how much the cost-per-mile increases for a particular model, however, depends on the characteristics of the model; the larger and heavier a vehicle, and the greater its horsepower, the greater effect a given gasoline price increase will have on its costs of usage.

If there were sufficiently attractive substitutes for cars as a whole, we might expect across-the-board increases in usage costs to decrease demand for all car models. For what is probably the vast majority of car owners, however, abandoning car ownership entirely is unlikely to be a realistic option.[5] If this is the case, the demand for cars as a whole will be fairly insensitive to changes in gasoline prices, although demand for particular models might not be. Specifically, in both the new car and used car markets, we would expect to see demand increase for fuel-efficient cars and decrease for fuel-inefficient cars when gasoline prices increase.

Although we have just argued that the effect of gasoline prices on demand should be very similar for new and used cars, we find—as described in the introduction—very different equilibrium effects in the two markets. Since the equilibrium outcomes are the result of the interaction between supply and demand, this suggest that there are important supply-side differences between new and used cars. We turn now to considering how gasoline prices affect new car supply.

2.2 Gasoline price and new car supply

As described in the introduction, in this paper we find that changes in gasoline prices affect the *market shares* of new cars more than they affect the *prices* of new cars. In this subsection, we consider the role of new car supply in determining these equilibrium outcomes.[6]

We would not expect gasoline prices to have a large *direct* effect on new car production or production costs because gasoline is not an important input in the production of automobiles. (For example, one direct effect gasoline prices could have is on the costs of transporting cars from production plants to dealerships. In addition, gasoline prices are closely linked with oil prices, which could affect the costs of some of the petroleum-based inputs to cars, such as plastics. However,

[5] There are, of course, exceptions: customers in dense urban areas, who have access to public transportation or car-sharing arrangements such as ZipCar.

[6] New cars are supplied by auto manufacturers via a network of legally separate but captive retail dealerships. The equilibrium effects of a gasoline price on new car sales and prices depend on the combined response in this supply chain. In other words, the observed equilibrium effects at the retail level represent the net effect of the manufacturer and dealer responses together.

gasoline- or petroleum-related costs make up a fairly small fraction of the total costs of producing a car.) In light of this, the equilibrium effects of a gasoline price change will be determined by how a shifting demand curve interacts with a supply side that is little affected by a gasoline price change.

As gasoline prices change, this interaction will sweep out a locus of equilibrium price and market share combinations.[7] The shape of this locus will be determined by three primary factors: first, the shape of the manufacturer's marginal cost curve; second, the nature of competition in the market for new automobiles; third, the shape of the marginal revenue curve the manufacturer faces. In this subsection, we discuss these three attributes, paying particular attention to how they would affect the shape of the "equilibrium locus." Since our empirical results find a fairly flat equilibrium locus—prices change by much less than market shares when gasoline prices change—we will focus in this subsection on how these three attributes can lead to such an outcome.

2.2.1 Marginal costs of new car production

The simplest supply relationship that would generate a flat "equilibrium locus" would be a perfectly competitive market with constant (or nearly constant) marginal cost and any one of a variety of well-behaved demand curves. Indeed, in the simplest "textbook" case of perfect competition, the equilibrium price always equals a constant marginal cost, and the entire effect of a change in demand is expressed in a changed equilibrium quantity.

How closely does new car supply match this very simple model? Many of the costs of producing cars are fixed. Assembly plants and their required capital equipment are fixed costs. Union labor contracts make labor largely a fixed cost as well, since manufacturers must pay nearly their full wage bill whether or not workers are assembling cars. The fixed nature of many of the costs of production suggest that, for volumes below the maximum capacities of the assembly plants, marginal costs are likely to be small relative to the average total costs of production, and also fairly flat since the remaining incremental costs are likely to be true per-unit costs. Under many models of competition the flatter the marginal cost curve is, the flatter the equilibrium locus will be.[8]

Another characteristic of new car production that would lead to flat marginal cost curves would be flexibility in the output capacity of automobile production plants. There are two reasons to

[7]In a perfectly competitive market where demand was shifting as supply was fixed, this equilibrium locus would be the supply curve. Under other models of competition, the supply curve does not exist as such, and the equilibrium locus is a different object.

[8]A cost structure with large fixed costs and constant marginal costs is not consistent, strictly speaking, with a perfectly competitive market. However, an oligopoly model of competition, such as Cournot, or a differentiated goods or contestable market model would give this outcome.

believe that output capacities have some flexibility. First, vehicle manufacturers have historically responded to increases in vehicle demand by running plants for more weeks or for additional shifts (Bresnahan and Ramey 1994). While they may have to pay higher labor rates, marginal costs are likely to remain low nevertheless. Second, there have been recent advances in assembly line technology which allows manufacturers to quickly change the mix of vehicles that are produced on any given assembly line. Vehicles built on the same assembly line can vary considerably in terms of fuel efficiency, and thus vary in terms of whether demand increases or decreases with changes in gas prices. For example, BMW builds their large X5 SUV, and their small Z4 roadster on the same assembly line in Spartanburg, SC.[9] In another example, Honda can build the compact Civic on the same assembly line that builds the Ridgeline pickup and the Acura MDX SUV. In 2008, the last year in our sample, the Civic was in highest fuel-efficiency quartile of cars while the Acura MDX was in the lowest fuel-efficiency quartile. This means that in response to changes in gasoline prices, Honda can quickly shift production from a vehicle in the lowest quartile in terms of fuel efficiency to one in the top quartile.[10]

Overall, we conclude that new car production should probably not be modeled with strictly constant marginal costs, or with complete flexibility. However, fairly flat marginal cost and somewhat flexible capacity limits are probably the best characterization for considering most incremental changes in production. To the extent that this is true, this attribute would contribute to our finding a larger effect of gasoline prices on new car market shares than on new car prices.

2.2.2 Competition in new car market

The nature of competition in the market for new cars will also affect how equilibrium prices and quantities change in response to gasoline-price-induced changes in demand. Generally speaking, the more competitive a market is, the flatter the equilibrium locus will be. By this we mean that a change in demand will affect equilibrium quantities more relative to equilibrium prices the more competitive the market is.[11]

The market for new cars is probably best described as an oligopoly. There are about 12 car

[9] "BMW subtracts to add flexibility in S.C." (Automotive News, June 5, 2006)

[10] "Adaptability helps Honda weather industry changes" (Automotive News, June 8, 2009)

[11] One way to think of this would be to compare three markets with the same demand curve and the same industry marginal cost curve. Suppose one market is a perfectly competitive market; in this market the industry marginal cost curve would be the supply curve. Suppose one market is a monopoly; in this market, the industry marginal cost curve would be the monopolist's marginal cost curve. Suppose the last market is a Cournot oligopoly; in this market, the industry marginal cost curve would be the aggregation of the individual oligopolists' marginal cost curves. For well-behaved demand and marginal cost curves, as the demand curve shifts, the "equilibrium locus" will be flattest for the perfectly competitive market, will get steeper as the number of Cournot oligopolists decrease, and will be steepest for the monopoly market.

manufacturers in the world who produce mass market cars.[12] To almost all consumers, cars are differentiated products, but they are products that can substitute for each other, at least within categories. One argument in support of their substitutability is that most new car buyers start out with a consideration set that includes several cars, often from multiple manufacturers. Since automobile manufacturers set prices model-by-model, the intensity of price competition will be determined not at the firm level, but at the model level, depending on how substitutable customers find the offerings in the category of car they are considering.

Overall, since oligopolistic interaction yields the middle outcome for the flatness of the equilibrium locus (namely, steeper than perfect competition would yield, flatter than monopoly would yield), the larger the number of meaningful competitors for a particular model, the more competitive price setting will be for that model, and the more this attribute will contribute to our empirical finding that the response to gasoline price changes in the new car market is primarily in market shares rather than prices.

2.2.3 Marginal revenue for new cars

In section 2.1, we discussed how the demand for new cars is affect by gasoline prices. In this subsection, we discuss the *shape* of the demand curve for new cars, since—for a firm with market power—this will determine the marginal revenue and thereby factor into the firm's supply decision.

While economists often, for convenience, think in terms of linear or constant elasticity demand curves, this will almost always be an approximation of what demand is in an actual market. When demand decreases for a firm with market power, the firm has to decide what the optimal response is to that change in demand. Should the firm lower its price in an attempt to keep sales quantities at or near their former levels? Or should it keep its price high in order to preserve its profit margin, even if that means losing incremental unit sales? (A firm whose demand increases faces a mirror image set of questions. Namely, what is the best way to exploit this opportunity for increased profits: by raising prices, and thereby increasing profit margins, or by keeping prices the same, and reaping the rewards as increased sales?) With a particular demand curve specified, one can answer this question precisely. In general terms, what the firm should consider is the size and elasticity of its marginal consumers compared to those of its inframarginal consumers. Suppose, for example, that the demand for a particular car model is made up of a large number of buyers who are price insensitive (e.g. people who are quite likely to buy a Mustang or an Escalade or a

[12] Into such a category, we would place General Motors, Ford, Chrysler, Honda, Toyota, Nissan, Mazda, Hyundai, Kia, Volkswagen, Mitsubishi, and Subaru. Many of these companies own multiple nameplates; e.g. Lexus is owned by Toyota; Volvo is owned by Ford; etc.

Prius whether or not the price goes up or down by a few hundred dollars) and a small number of people who are price sensitive buyers. If this is the case, then the manufacturer should consider carefully whether it is worthwhile to trade inframarginal profit for incremental unit sales or vice versa. For example, if gasoline prices increase, demand may fall for a (low-MPG) Escalade, but this may be primarily among price sensitive incremental customers. GM may decide that lowering the price of the Escalade in order to keep the incremental customers may not be worth the sacrifice of inframarginal profit that would require. This is the kind of example that would contribute to our finding of a larger effect of gasoline prices on new car market shares than on new car prices.

Overall, it is difficult for us to make a general conclusion about how important this is in contributing to the flatness of the equilibrium locus for new cars. This is because we don't observe demand directly, and because this attribute is likely to vary across individual car models. However, we find it very plausible that new car manufacturers consider this tradeoff, and that at least some vehicles could have demand curves that would lead manufacturers to prefer to maintain prices rather than preserve market share.

2.3 Gasoline price and used car supply

Supply in the used car market is very different from supply in the new car market because the fundamental source of used cars is individual drivers, not firms. In order for a car to make its way into the used car market, that car's current owner has to decide to sell it, trade it in, or return it rather than keeping it at the end of a lease. In most cases, the current owner replaces his or her current car with another car, either from the new or used market. As a consequence, the used car supply decision depends in part on how sensitive individual drivers are to the price of gasoline, and on how that affects their relative valuations of the cars they currently own and cars that they might buy instead. In considering the effect of gasoline prices on the equilibrium in the used car market, we therefore have to consider the effects on both potential suppliers and potential buyers of used cars.

Consider a potential seller and a potential buyer of a particular fuel-inefficient used car. If the gasoline price increases by some amount, then the *per-mile* cost of driving that particular car increases by the same amount for both drivers.[13] If the two drivers have approximately the same driving habits, then one might expect the effect of the gasoline price increase on the buyer and the seller to be symmetric: for both the current owner and the potential buyer, the increased cost of usage for the current owner of that car will exactly equal the increased cost of usage for the

[13] Technically, fuel consumption per mile can be affected by how aggressively a driver drives a car, but we abstract from such differences here.

potential buyer if she buys the car. Taking this logic one step further, if most drivers have similar driving habits (or if a large enough number of marginal buyers and sellers have similar driving habits), then the demand curve for a used car should shift inward by roughly the same amount that the supply curve for that car shifts outward (at least in the area of the demand and supply curves where equilibrium occurs).[14] If this were the case, then the prices of a particular used car should adjust to reflect the value of the fuel expenditure disadvantage (or advantage) that car has, given the new gasoline prices. This suggests that we should see large effects of gasoline price changes on the *prices* of used cars, but small changes in *market shares*.

What would we expect to see if drivers instead are very heterogeneous in their usage intensities? It would still be the case that an increase in gasoline prices would increase the *per-mile* driving costs of any given car by the same amount for all drivers. However, the valuation of a particular car would change by different amounts for different drivers. For a driver with a long daily commute, the costs of owning a large, fuel-inefficient SUV would rise by much more than the costs of owning that same vehicle would rise for a non-commuter. Similarly, the advantage of owning a smaller, more fuel-efficient car relative to the large SUV would increase by more for that same long-commuting driver than for the non-commuter. If there is enough such heterogeneity, and if the usage cost changes are large enough relative to the transactions costs of a used car transaction, then an increase in gasoline prices might cause a substantial increase in used car transactions, especially at the extremes of the fuel price distribution where the gains to trade are the largest.

A second difference between the supply of new cars and the supply of used cars is that a large fraction of wholesale transactions in used cars go through independent auctions, unaffiliated with the car manufacturers who are the upstream suppliers (and price-setters) in the new car market. Auctions are a major clearinghouse for wholesale used cars and are ubiquitously available throughout the country. (For example, Manheim, which is the largest operator of used car auctions in the U.S., has about 100 sites throughout the U.S.) Auctions are generally held every week, and 1,000-3,000 cars might be transacted in a typical week. This means that for car dealers, used cars are convertible into cash, and vice versa, at auction-determined prices on a weekly basis. One might expect that such a mechanism would reflect changes in equilibrium market conditions quite quickly, and would thereby help move the prices of used cars sold at car dealerships fairly quickly to a new, market-clearing equilibrium price that reflected changes in gasoline prices. While this adjustment in the transaction prices of used cars may not happen as quickly in sales between private parties,

[14] This discussion abstracts from changes in scrappage rates due to changes in gasoline prices. Li, Timmins, and von Haefen (forthcoming) find that scrappage rates for fuel inefficient vehicles increase as gasoline prices rise. This would imply that the change in prices is a lower bound on the shift in demand as a result of changes in gasoline prices.

the data used in this paper are from used car sales at car dealerships, making that the relevant distribution channel here.

Overall, our finding that, in used car markets, the equilibrium prices are more affected by gasoline price changes than are the equilibrium market shares is consistent with relatively homogeneous driving behavior (at least among marginal buyers and sellers) and a wholesale market that effectively propagates price adjustments.

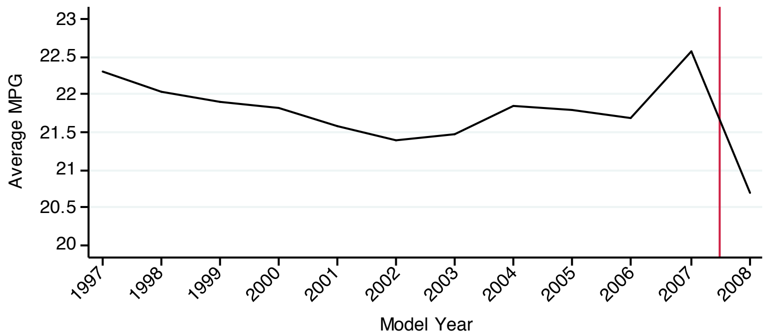
2.4 Literature review

There is a long-standing literature investigating the determinants of automobile sales. (The earliest papers we have found pre-date World War II.) There is also a large literature, dating from the first energy crisis that investigates the relationship between fuel efficiency and gasoline prices. Our paper is also related to more recent literatures on automobile demand estimation, and on the role of gasoline prices in car choices. Our results with respect to market shares are closely related to estimation of demand for automobiles. A number of discrete choice demand models exist for which mileage, or an estimate of dollars per mile, is a characteristic in the indirect utility function.[15] Typically, the influence of gasoline prices is not the focus of these papers. Exceptions are papers by Klier and Linn (2008), Sawhill (2008), and Langer and Miller (2008). Klier and Linn (2008) estimate an aggregate data logit model using monthly sales data for new cars from 1970 to 2007. Consistent with our results, they find that fuel economy increases by 1.08 MPG for a dollar increase in gasoline prices. Sawhill (2008) estimates the implicit discount rate that consumers use when trading off upfront costs with future fuel costs. Using aggregate market share data, he finds significant heterogeneity in this utility parameter; however it is uncertain whether the heterogeneity is also measuring the variation in miles driven across consumers.[16] Langer and Miller (2008) capture one component that is related to our price results. They look at how automobile incentives respond to gasoline prices. They have data on listed rebates and incentives, but do not observe the extent to which consumers take advantage of these incentives or how they are shared between consumers and dealers.

[15] For example, see such seminal papers as Goldberg (1995) and Berry, Levinsohn, and Pakes (1995).

[16] Sawhill (2008) has data on the distribution of miles driven across the population which allows him to match a population moment, however he is not able to match correlations between a consumer's discount rate and miles driven.

Figure 1: Average MPG of available cars by model year



3 Data

We combine several types of data for this analysis. Our main data contain automobile transactions from a sample of 20% of all dealerships in the U.S. from September 1, 1999 to June 30, 2008. The data were collected by a major market research firm, and include every new car and used car transaction within the time period for the dealers in the sample. For each transaction we observe the exact vehicle purchased, the price paid for the car, the dealer's cost of obtaining the car from the manufacturer, information on any vehicle that was traded in, and (census-based) demographic information on the customer. We discuss the variables used in each specification later in the paper.

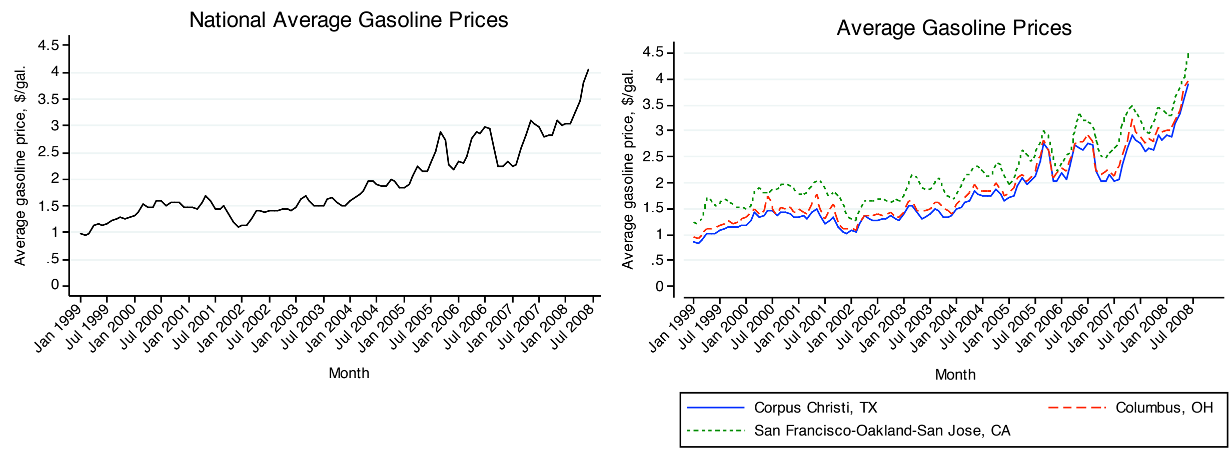
We supplement these transaction data with data on car models' fuel consumption and data on gasoline prices. The fuel consumption data are from the Environmental Protection Agency (EPA). As the fuel consumption measure for each car model we use the "EPA Combined Fuel Economy" which is a weighted average of the EPA Highway (45%) and City (55%) Vehicle Mileage. As shown in Figure 1, the average MPG of models available for sale in the United States shows a pattern of slow decline in the first part of our sample period, and some increase in the latter part.[17] Overall, however, the average MPG of available models (not sales-weighted) stays between 21.5 and 22.5 miles per gallon for the entire decade.[18]

We also use gasoline price data from OPIS (Oil Price Information Service) which cover January 1997 to June 2008. OPIS obtains gasoline price information from credit card and fleet fuel card "swipes" at a station level. We purchased monthly station level data for stations in 15,000 ZIP codes. Ninety-eight percent of all new car purchases in our transaction data are made by buyers

[17] The sharp decline in MPG observed in 2008 coincides with a change in how the EPA calculates MPG.

[18] While *vehicles* changed fairly little in terms of average fuel efficiency over this period, this does not mean that there was no improvement in technology to make *engines* more fuel-efficient. The average horsepower of available models increased substantially over the sample years, a trend that pushed toward higher fuel consumption, working against any improvements in fuel efficiency technology. See Knittel (2009) for a discussion of these issues and estimates of the rate of technological progress over this time period.

Figure 2: Monthly average gasoline prices (national and by DMA)



who reside in one of these ZIP codes.

Since our aim is to estimate the effect of gasoline prices on transactions, we need to match the gasoline price (which we observe at station level) to the location of a car buyer (which we observe at ZIP-code level). Althought we could aggregate station-level data to ZIP-codes, this may not be a good approach for two reasons. First, we only observe a small number of stations per ZIP-code, which may lead to measurement error.[19] Second, consumers are likely to react not only to the gasoline prices in their own ZIP-code but also to gasoline prices outside their immediate neighborhood. This is especially true if price changes that are specific to individual ZIP-codes are transitory in nature. As a result, we measure gasoline price by averaging the prices for basic grade over all stations in each local market (as defined by Nielsen Designated Market Areas, or "DMAs" for short). There are 210 DMAs. Examples are "San Francisco-Oakland-San Jose, CA," "Charlotte, NC," and "Ft. Myers-Naples, FL." Later we investigate the sensitivity of our results to different ways of aggregating gasoline prices (see section 5.3).

To get a sense of the variability of gasoline prices, we graph monthly national average gasoline prices. As shown in Figure 2 (left panel), there is substantial variation in gasoline prices within our sample period. Between 1999 and 2008, average national gasoline prices were as low as \$1 and as high as \$4. While gasoline prices were generally trending up during this period there are certainly months where gasoline prices fall.

There is also substantial regional variation in gasoline prices. The right panel of Figure 2 illustrates this by comparing three DMAs: Corpus Christi, TX; Columbus, OH; and San Francisco-

[19]In our data, the median ZIP code reports data from 3 stations on average over the months of the year. More than 25% of ZIP-codes have only one station reporting.

Oakland-San Jose, CA. California gasoline prices are substantially higher than prices in Ohio (which are close to the median) and Texas (which are low). While the three series generally track each other, in some months the series are closer together and in other months they are farther apart, reflecting the cross-sectional variation in the data.

To create our final dataset, we draw a 10% random sample of all transactions. After combining the three datasets this leaves us with a new car dataset of 1,866,366 observations and a used car dataset of 1,264,092 observations. Table 6 presents summary statistics for the two datasets.

4 Main results

In this section, we estimate the effect of gasoline prices on the market shares of cars of different levels of fuel efficiency and the associated equilibrium price effects. We estimate these effects first for the new car market and then for the used car market.

4.1 New car market shares

We first investigate the effect of gasoline prices on new car market shares.

4.1.1 Specification and variables

At the most basic level, our approach is to model the effect of covariates on equilibrium price and quantity outcomes. We do this using a reduced form approach. In completely generic terms, this would mean regressing observed quantities (Q), or some function of Q, on demand covariates (X^D) and supply covariates (X^S):

$$Q = \alpha_0 + \alpha_1 X^D + \alpha_2 X^S + \nu \tag{1}$$

In this case, the estimated $\hat{\alpha}$s would neither estimate parameters of the demand curve nor of the supply curve, but would instead estimate the effect of each covariate on the equilibrium Q, once demand and supply responses were both taken into account.

What we estimate in practice is a variant of this. First, we choose to focus on market share as an outcome variable rather than unit sales because this controls for the substantial aggregate fluctuation in car sales over the year. Our demand covariates are gasoline prices (the chief variable of interest), customer demographics, and variables describing the timing of the purchase, all described in greater detail below. We also include region-specific year fixed effects and region-specific month-of-year fixed effects. Supply covariates should presumably reflect costs of production of new cars (raw materials, labor, energy, etc.). We expect that these vary little within the region-specific year and within the region-specific month-of-year fixed effects that are already included in the specification. Furthermore, short- to medium-run manufacturing and pricing decisions for automobiles are not made on the basis of small changes to manufacturing costs. While we realize that almost any model of profit maximization an economist would write down would have pricing and production depend on costs, our interactions with executives responsible for these decisions at car manufacturers indicate that this is not the way short- to medium-run pricing and manufacturing decisions are made in practice.

This leaves us with the following specification. We estimate the effect of gasoline prices on market shares of models of different fuel efficiencies using a series of linear probability models that can be written as:

$$I_{irt}(j \in K) = \gamma_0 + \gamma_1 \text{GasolinePrice}_{it} + \gamma_2 \text{Demog}_{it} + \gamma_3 \text{PurchaseTiming}_{jt} + \tau_{rt} + \mu_{rt} + \epsilon_{ijt} \quad (2)$$

$I_{irt}(j \in K)$ is an indicator that equals 1 if transaction i in region r on date t for car type j was for a car in class K. A "car type" in our sample is the interaction of make, model, model year, trim level, doors, body type, displacement, cylinders, and transmission (for example, one "car type" in our data is a 2003 Honda Accord EX 4-door sedan with a 4-cylinder 2.4-liter engine and automatic transmission). We consider two different classes in this section, namely fuel efficiency quartiles and segments (e.g., midsize, SUV, compact).[20,21] The variable of primary interest is *GasolinePrice*, which is specific to the month in which the vehicle was purchased and to the DMA of the buyer.[22]

We use an extensive set of controls. First, we control for a wide range of demographic variables ($Demog_{it}$), namely the income, house value and ownership, household size, vehicles per household, education, occupation, average travel time to work, English proficiency, and race of buyers by using census data at the level of "block groups," which, on average, contain about 1100 people.[23] We also control for a series of variables that describe purchase timing ($PurchaseTiming_{jt}$). These variables include: a dummy variable, *EndOfYear*, that equals 1 if the car was sold within the last 5 days of the year; a dummy variable, *EndOfMonth*, that equals 1 if the car was sold within the last 5 days

[20] In previous versions we have considered subsegments (e.g., entry compact, premium compact, mini SUV, compact SUV). These results are available from the authors.

[21] Our results do not depend on the linear probability specification; we obtain nearly identical results with a multinomial logit model (see section 5.5).

[22] Another potential approach is to use a variable that represents gasoline price expectations, perhaps based on futures prices for crude oil. One might argue on theoretical grounds that this is the price customers should use in calculating the usage cost of a durable good. In practice, however, during the time period of our sample futures prices for crude oil are quite highly correlated with current gasoline prices, reducing the statistical power from such an exercise. As a result, we have not undertaken this approach.

[23] One might argue that our specification should not hold the demographics of buyers constant for the following reason: Any change in market shares of fuel-efficient vs. fuel-inefficient cars due to changes in demographics associated with fuel price changes can legitimately be considered to be part of the short-run equilibrium market share effect of changing gasoline prices. We have estimated all of our sales specifications without demographic covariates and find that our qualitative results are robust to the exclusion of the demographic variables.

of the month and a dummy variable, *WeekEnd*, that specifies whether the car was purchased on a Saturday or Sunday. If there are volume targets or sales on weekends or near the end of the month or the year, we will absorb their effects with these variables. $PurchaseTiming_{jt}$ also includes fixed effects for the difference between the model year of the car and the year in which the transaction occurs. This distinguishes between whether a car of the 2000 model year, for example, was sold in calendar 2000 or in calendar 2001. Finally, we include year, τ_{rt}, and month-of-the-year, μ_{rt}, fixed effects corresponding to when the purchase was made. Both year and month-of-the-year fixed effects are allowed to vary by the geographic region (29 throughout the U.S.) in which the car was sold. This takes into account that year-over-year and seasonal preferences for specific car classes may vary by region of the country. To examine the robustness of our results to which components of variation in the data are used to identify the effect of gasoline prices, we repeat our estimation with a series of different fixed effect specifications in Section 5.1.

Finally, note that our estimates should be interpreted as estimates of the short-run effects of gasoline prices. By "short-run" we mean effects on market shares and prices over the time horizon in which manufacturers would be unable to change the configurations of cars they offer in response to gasoline price changes. Defined this way, the short-run horizon is several years at least. Persistently higher gasoline prices would presumably cause manufacturers to change the kinds of vehicles they choose to produce, as U.S. manufacturers did in the 1970s at the time of the first oil price shock.[24] The nature of our data, its time span, and our empirical approach are all unsuited to estimating what the long-run effects of gasoline price would be on market shares and prices. The short-run estimates are nevertheless useful, we believe, both because short-run effects are important in the short-to-medium term (especially if financial solvency is an issue) and because they yield some insight into the size of the pressures to which manufacturers are responding as they move towards the long run.

4.1.2 Market share results

We first consider the effect of gasoline prices on the market shares of different classes of fuel efficiency. Specifically, we classify all transactions in our sample by the fuel efficiency quartile (based on the EPA Combined Fuel Economy MPG rating for each model) into which the purchased car type falls. Quartiles are re-defined each year based on the distribution of all models *offered* (as opposed to the distributions of vehicles sold) in that year. Table 7 reports the quartile cutoffs and mean MPG within quartile for all years of the sample. (Note that the effect of a change in

[24]As gasoline prices began to fall in the early 1980s, CAFE standards also affected manufacturer offerings.

the EPA rating system can be seen in the abrupt change between 2007 and 2008. Our estimates include fixed year effects which capture level shifts in the EPA rating system.)

In order to estimate Equation 2 with car class defined by MPG quartile, we define four different dependent variables. The dependent variable in the first estimation is "1" if the purchased car is in fuel efficiency quartile 1, "0" otherwise. The dependent variable in the second estimation is "1" if the purchased car is in fuel efficiency quartile 2, "0" otherwise, and so on. To account for correlation in the errors due to either supply or demand factors, we cluster the standard errors at the DMA level.

The full estimation results are reported in Table A-1. The gasoline price coefficients (γ_1) for each specification are presented below.[25] We also report the standard errors of the estimates, and the average market share of each MPG quartile in the sample period. (Note that the quartiles are based on the distribution of available models while the market share is sales-weighted, which is why market shares need not be 25% for each quartile.) Combining information in the first and third column, we report in the last column the percentage change in market share that the estimated coefficient implies would result from a $1 increase in gasoline prices.

Fuel Efficiency	Coefficient	SE	Mean market share	% Change in share
MPG Quartile 1 (least fuel-efficient)	-0.05**	(0.0049)	20.90%	-23.9%
MPG Quartile 2	-0.014**	(0.004)	21.20%	-6.60%
MPG Quartile 3	-0.0065*	(0.0029)	23.70%	-2.74%
MPG Quartile 4 (most fuel-efficient)	0.07**	(0.005)	34.20%	20.5%

These results suggest that a $1 increase in gasoline price decreases the market share of cars in the least fuel-efficient quartile by 5 percentage points, or 23.9%. Conversely, we find that a $1 increase in gasoline price increases the market share of cars in the most fuel-efficient quartile by 7 percentage points, or 20.5%. This provides evidence that higher gasoline prices are associated with the purchase of more fuel-efficient cars. Notice that these estimates do not simply reflect an overall trend of increasing gasoline prices and increasing fuel efficiency; since we control for region-specific year fixed effects, all estimates rely on within-year, within-region variation in gasoline prices and associated purchases.[26]

Next we consider the effect of gasoline prices on the market shares of different car classes as defined by industry segments. The industry uses a standard classification of eight segments: "Compact Car" (e.g., Toyota Corolla), "Midsize Car" (e.g., Honda Accord), "Luxury Car" (e.g., Lexus LS430), "Sporty Car" (e.g., Mitsubishi Eclipse), "Sport Utility Vehicle (SUV)" (e.g., Jeep

[25] Two asterisks (**) signifies significance at the .01 level, * signifies significance at the .05 level and + at the .10 level. We do not restrict the γs to sum to zero; the sum equals -0.0001.

[26] Nor are the results due to seasonal correlations between gasoline prices and the types of cars purchased at different times of year, since the regressions control for region-specific month-of-year fixed effects.

Grand Cherokee), "Pickup" (e.g., Ford F150), "Van" (e.g., Toyota Sienna), and "Fullsize Car" (e.g., Ford Crown Victoria). We estimate the specification in Equation 2 for each of seven segments (we exclude full-size cars since very few of them are sold). The dependent variable in the first estimation is "1" if the purchased car is a "Compact Car," "0" otherwise. We proceed similarly for the other segments.

The full estimation results are reported in Table A-2. The relevant estimates of the fuel price coefficient from these specifications are presented below. In addition to the coefficient estimates, the table reports the standard errors (clustered again at the DMA level) and the average market shares of each segment over the sample period. The last column of the table presents the percent change in market share of each segment implied by a $1 increase in gasoline prices.

Segment	Coefficient	SE	Mean Market Share	% Change in Share
Compact Car	0.042**	(0.0041)	17.40%	24.14%
Midsize Car	0.016**	(0.0028)	20.30%	7.88%
Luxury Car	-0.0016	(0.0026)	4.00%	-4.00%
Sporty Car	0.0052**	(0.0015)	9.40%	5.53%
SUV	-0.039**	(0.0035)	28.00%	-13.93%
Pickup	-0.016**	(0.0032)	14.30%	-11.19%
Van	-0.0069**	(0.0018)	6.70%	-10.30%

These results show an outflow of consumers from SUVs, pickups, and vans (which are the lowest fuel-efficiency segments; see Table 8). These segments lose 3.9, 1.6, and 0.7 percentage points of market share, respectively, which corresponds to 13.9%, 11.2%, and 10.3% reductions of the respective market shares. The largest segment market share change is the gain of 4.2 percentage points, a 24.1% increase, for compact cars, the most fuel-efficient segment. Midsize cars also increase their market share by 1.6 percentage points, a 7.9% gain. The market share of sporty cars also increases. While this might seem surprising, this category contains many small 2-door coupes, some with fuel efficiency close to that of compact cars. We find no statistically significant effect for luxury cars. One possible reason for this is that luxury cars both gain and lose as a result of gasoline price changes. For example, one could imagine that some buyers opt for a luxury sedan instead of a luxury SUV if gasoline prices increase, while others substitute from a luxury sedan to a more economical midsize car in response to the same gasoline price increase. An alternative explanation is that fuel efficiency is simply not a decision criterion for the purchase of luxury cars, or that buyers who buy such cars are fairly insensitive to the price of gasoline, perhaps because they are wealthier than the average car buyer.

Summary

Overall, we find both statistically and economically significant effects of gasoline prices on new car market shares as measured either by fuel efficiency quartiles or by segments. This is particularly true for the "extremes," measured as the most fuel-efficient and least fuel-efficient quartiles, where market share shifts by more than 20% in response to a \$1 increase in gasoline prices.

4.2 New car prices

While market share is one important piece of the impact of gasoline prices on automobile manufacturers, the effect on price is necessary to complete the picture. The previous subsection showed, for example, that market shares of SUVs fall substantially when gas prices increased. We would like to know whether this happened despite manufacturers offering large price discounts, or whether manufacturers offered little price response. In this section, we investigate the effect of gasoline prices on the transaction prices paid by buyers for new cars of varying fuel efficiencies.

4.2.1 Specification and variables

As in section 4.1.1 our approach is to estimate the reduced form effect of gasoline prices on the equilibrium prices of new cars of different fuel efficiencies. The reduced form analog of Equation 1 for price is:

$$P = \beta_0 + \beta_1 X^D + \beta_2 X^S + \eta \tag{3}$$

As with Equation 1, the $\hat{\beta}$s will measure neither parameters of the demand curve, nor parameters of the supply curve, but instead the estimated short run effects of the covariates on equilibrium prices. In practice, we estimate the following equation, which contains the same controls, with one addition, as we used in Equation 2:

$$\begin{aligned} P_{irjt} = \lambda_0 + \boldsymbol{\lambda_1}(\text{GasolinePrice}_{it} \cdot \text{MPG Quartile}_j) + \lambda_2 \text{Demog}_{it} + \\ \lambda_3 \text{PurchaseTiming}_{jt} + \delta_j + \tau_{rt} + \mu_{rt} + \epsilon_{ijt} \end{aligned} \tag{4}$$

The price variable recorded in our dataset is the pre-sales tax price that the customer pays for the vehicle, including factory installed accessories and options, and including any dealer-installed accessories contracted for at the time of sale that contribute to the resale value of the car.[27] Conceptually, our price variable should measure the customer's total wealth outlay for the car. In

[27]Dealer-installed accessories that contribute to the resale value include items such as upgraded tires or a sound system, but would exclude options such as undercoating or waxing.

order to capture this, we make two modifications to the price variable from our dataset. First, we subtract off the manufacturer-supplied cash rebate to the customer if the car is purchased under a such a rebate, since the manufacturer pays that amount on the customer's behalf. Second, we subtract from the purchase price any profit the customer made on his or her trade-in (or add to the purchase price any loss made on the trade-in). The price the dealer pays for the trade-in vehicle minus the estimated wholesale value of the vehicle (as booked by the dealer) is called the *TradeInOverAllowance*. Dealers are willing to trade off profits made on the new vehicle transaction and profits made on the trade-in transaction, which is why the *TradeInOverAllowance* can be either positive or negative. When a customer loses money on the trade-in transaction, part of his or her payment for the new vehicle is an in-kind payment with the trade-in vehicle. By subtracting the *TradeInOverAllowance* we adjust the negotiated (cash) price to include this payment.

In Equation 4, P_{irjt} is the above-defined price for transaction i in region r on date t for car j, and the control variables are as described in section 4.1.1 (page 14). For the price specification, we also control for detailed characteristics of the vehicle purchased by including "car type" fixed effects (δ_j).[28]

We estimate how gasoline prices affect the transaction prices paid for cars of different fuel efficiencies. One might think that since higher gasoline prices make car ownership more expensive, higher gasoline prices will lead to lower negotiated prices for all cars. However, this would ignore the results of the previous subsection, which show that as gasoline prices increase, some cars experience sales increases and others decreases. It would thus not be surprising if the transaction prices of the most fuel-efficient cars were to increase as a result of a gasoline price increase. To capture this, we estimate separate coefficients for the *GasolinePrice* variable, depending on the fuel economy quartile into which car j falls; the quartiles are redefined each model year, as described in section 4.1.2.[29]

4.2.2 New car price results

The full results from estimating Equation 4 are presented in Table A-3. The gasoline price coefficients are as follows:

Variable	Coefficient	SE
GasolinePrice*MPG Quart 1 (least fuel-efficient)	-236**	(74)
GasolinePrice*MPG Quart 2	-74+	(40)
GasolinePrice*MPG Quart 3	6.9	(30)
GasolinePrice*MPG Quart 4 (most fuel-efficient)	127**	(43)

[28]For a definition of "car type" see page 14.

[29]We obtain similar results if we estimate four separate regressions, thereby relaxing the constraint that the parameters associated with the other covariates are equal across fuel efficiency quartiles.

These estimates indicate that a \$1 increase in gasoline price is associated with a lower negotiated price of cars in the least fuel-efficient quartile (by \$236) but a higher price of cars in the most fuel-efficient quartile by (\$127). Overall, the change in negotiated prices appears to be monotonically related to fuel efficiency. Note that this is an equilibrium price effect; it is the net effect of the manufacturer price response, any change in consumers' willingness to pay, and the change in the dealers' reservation price for the car.

One way to think about the magnitude of the estimated effect is as follows. The estimated coefficients imply that when gasoline prices increase by \$1, the difference between the average prices for the most and least fuel-efficient quartiles grows by \$363 (\$127 + \$236) . The average MPG in the least fuel-efficient quartile during the sample period is 16.2, while the average MPG in the most fuel-efficient quartile is 27.9. In 12,000 miles of driving (an oft-used measure for annual mileage), a car with MPG of 16.2 would require 741 gallons of gasoline, while a car with MPG of 27.9 would consume 430 gallons, a difference of 311 gallons. Thus the estimated price difference between the two quartiles arising from a \$1 increase in gasoline prices equals the difference in fuel expenditures between average vehicles in the two quartiles for approximately *1.2 years* of driving.

We also estimate Equation 4 separately for each segment. To estimate the effect of gasoline prices for cars of different fuel efficiencies, we interact gasoline price with *segment-specific* MPG quartiles for each model year (rather than quartiles defined over the entire set of cars available in the U.S. in a particular model year). The full results of this approach are reported in Table A-4. One might expect to find the same pattern segment-by-segment as we found in Table A-3, namely that new car prices decrease the most for the least fuel-efficient quartile (Quartile 1), and less for more fuel-efficient cars, with the most fuel-efficient cars' prices perhaps rising. This is roughly the pattern we see for most of the segments, especially if we confine ourselves to comparing by above- and below-median fuel efficiency.[30]

[30]For compact cars, prices increase in the most fuel-efficient segment of compact cars by \$225 when gasoline prices go up by \$1, and fall or only rise little for other quartiles. The prices of luxury cars, SUVs, and pickups all fall for vehicles in the bottom half of the fuel efficiency distribution for their respective segments, by as much as \$764 per \$1 increase in gasoline prices (Quartile 1 luxury cars). The most fuel-efficient luxury cars and SUVs see their prices rise by \$370 and \$235, respectively, in response to a \$1 price increase, while pickups have no statistically significant effect for above-median fuel efficiency pickups.

Midsize and sporty cars do not match this pattern. Prices for midsize cars in the most fuel-efficient quartile *fall* by \$160 when gasoline prices increase by \$1, and fall by \$470 and \$198 in the two above-median fuel efficiency quartiles for sporty cars. The results for the midsize segment may due to the fact that this segment sees both inflows and outflows when gasoline prices rise, gaining from SUVs and pickups when gasoline prices rise, and losing to compact cars. This would make the net effects in the different quartiles of the segment hard to predict. We do not have an explanation why sporty cars show such opposite results to what we expected. Finally, vans behave as expected in three out of four quartiles (prices are unaffected in the most fuel-efficient quartiles, and fall by \$393 in quartile 2). However, prices show some weak signs of being higher in the least fuel-efficient quartile when gasoline prices increase by \$1 (an increase of \$243, albeit not significant at a 10% level). This may be due to increased usage of carpooling vans in response to increased gasoline prices.

Summary

Overall, we find that prices for fuel-efficient new cars rise when gasoline prices increase and that prices for fuel-inefficient cars fall. The difference in the average change in new car price between the most and least fuel-efficient quartiles when gasoline price increases by $1 is $363. This difference is equal to 1.2 year's worth of the difference between the fuel expenditure increases implied by a $1 gasoline price increase for the most and least fuel-efficient quartiles.

4.3 Used car market shares

In this subsection, we begin by considering the effect of gasoline prices on used car market shares. In the next subsection, we consider the effect on used car prices. We estimate the same specifications as we used to estimate the new car results, namely Equation 2 in this subsection and Equation 4 in the next, but using data from used car transactions at the same dealerships at which we observe new car transactions. As in Section 4, we look at the market share effects of gasoline prices first by MPG quartiles and then by segments.

The full results of market share effects of gasoline prices by MPG quartiles are reported in Table A-5. The gasoline price coefficients are as follows:

Fuel Efficiency	Coefficient	SE	Mean share	% Change in share
MPG Quartile 1 (least fuel-efficient)	-0.016*	(0.0074)	24.10%	-6.64%
MPG Quartile 2	-0.019**	(0.006)	21.00%	-9.05%
MPG Quartile 3	0.026*	(0.012)	25.90%	10.04%
MPG Quartile 4 (most fuel-efficient)	0.01	(0.009)	28.90%	3.46%

The results at the extremes of the fuel-efficiency distribution are both smaller in magnitude and weaker in statistical significance than the analogous results for new cars. For new cars, market share changes were quite consistently related to gasoline price, with the most fuel-efficient quartile showing the largest increase (7 percentage points) and the least fuel-efficient quartile showing the largest decrease (5 percentage points) in conjunction with gasoline price increases. For used cars, the most fuel-efficient quartile shows no statistically significant effect of gasoline price changes while the least fuel-efficient quartile shows a much smaller (1.6 percentage point) decline than for new cars.

If we look at market share effects by segment, we also find smaller (and statistically weaker) results for used cars than we found for new cars. The full estimation results are reported in Table A-6. The fuel price coefficients from the segment-based regressions are as follows.

Segment	Coefficient	SE	Mean Mkt Share	% Change in Share
Compact Car	0.0028	(0.0048)	13.98%	2.00%
Midsize Car	0.035**	(0.0096)	25.59%	13.68%
Luxury Car	-0.0069+	(0.0038)	10.31%	-6.69%
Sporty Car	-0.0038**	(0.0014)	4.71%	-8.07%
SUV	-0.013+	(0.0074)	24.53%	-5.30%
Pickup	-0.016**	(0.0043)	14.07%	-11.37%
Van	0.0021	(0.0047)	6.81%	3.08%

In the used car results, compact cars and SUVs—which had the largest market share effects for new cars—show no statistically significant effect of gasoline prices on market shares (at the 5% level). Nor do vans and luxury cars. There are three segments that do show statistically significant effects. Midsize cars show an increase of 3.5 percentage points in response to an increase in gasoline price of $1, a 13.7% increase in market share. This is substantially larger than the effect estimated for *new* midsize cars. Sporty cars are estimated to lose 0.38 percentage points of market share, a 8.1% loss. This is an effect of comparable magnitude to the effect for new sporty cars, but of opposite sign. Finally, pickups are estimated to lose 1.6 percentage points, or 11.4% of their market share, when gasoline prices rise by $1. This is the only segment whose new and used results are quite close.

Summary

Overall, we find much less evidence among used cars than among new cars of an adjustment in market shares of cars of different fuel efficiencies in response to fuel prices. A particularly striking aspect of the contrast is the much smaller effect at the extremes of fuel efficiency—for the first and fourth quartiles when the data are categorized by quartile, and for compact cars and SUVs when the data are categorized by segment. These were the classes in which the results were largest for new cars. In Section 2, we speculated that we might see little market share response to gasoline prices because a large volume of used cars passes through a wholesale auction. If this auction is effective at assigning market-clearing prices to cars, then the resulting price adjustments would counteract any gain customers might hope to make by trading cars of different fuel efficiencies in order to reduce fuel expenditures.

If our hypothesis of the market clearing effects of wholesale auctions is true, then we also ought to see much greater adjustment in price in the used car market than in the new car market. It is to this we turn next.

4.4 Used car prices

In this section, we estimate the effect of gasoline prices on the transaction prices of used cars. We do so by estimating the same specification we used for new car prices, namely Equation 4, using instead our used car transaction data. All the control variables are the same; in particular, we observe all the same car characteristics for used cars that we do for new cars, so the "car type" definition is the same. The definition of the dependent variable is almost the same as that used for new cars. A customer who is buying a used car can use a trade-in in the transaction, just as a buyer of a new car can, so the price definition subtracts the *TradeInOverAllowance* just as it does for new cars. However, used cars never have customer rebates offered, so there is no need to subtract that amount from the reported transaction price.

As we did for new cars, we begin by estimating the effect of gasoline prices on used car prices separately by the MPG quartile of the used car being purchased. The full results are reported in Table A-7. The gasoline price coefficients are as follows:

Variable	Coefficient	SE
GasolinePrice*MPG Quart 1 (least fuel-efficient)	-1073**	(40)
GasolinePrice*MPG Quart 2	-900**	(58)
GasolinePrice*MPG Quart 3	118*	(53)
GasolinePrice*MPG Quart 4 (most fuel-efficient)	1766**	(51)

The estimated coefficients imply that when gasoline prices increase by $1, the transaction prices of the least fuel-efficient quartile of used cars falls by $1073. This is 4.5 times the size of the $236 effect estimated for the least fuel-efficient quartile of new cars. Prices in the next least fuel-efficient segment are estimated to fall by nearly as much, namely $900. On the other end of the fuel efficiency distribution, the prices of the most fuel-efficient quartile of used cars is estimated to increase by $1766 for each $1 increase in gasoline prices, an effect that is fourteen times the size of the effect estimated for new cars ($127).

The fact that the magnitude of the effects of gasoline price on car prices is so much larger for used cars than for new cars provides evidence for the final piece of our supposition in Section 2; namely that we would see a response to gasoline prices primarily in *market shares* for new cars (and less in prices) and primarily in *prices* for used cars (and less in market shares). The reasons we anticipated that we might see a large response in prices for used cars were twofold. First, used cars can be easily traded at high-volume, widely-available auction markets, promoting rapid price adjustment. Second, the change in the willingness-to-accept of the sellers of used cars (who are themselves the current drivers of those used cars) is likely to be similar to the change in willingness-to-pay of the buyers of used cars (who will become the drivers of those used cars), as long as the marginal buyer and seller have similar driving habits.

Next we look within segments. The full results are reported in Table A-8. Here we see the same results within segment as we saw for used cars as a whole. Namely, for most of the segments, used car prices fall by the most for the least fuel-efficient cars in the segment, and rise by the most for the most fuel-efficient cars in the segment.[31]

Summary

Overall, we see a very large effect of gasoline price changes on used car prices. The pattern that prices fall the most for the least fuel-efficient cars and rise the most for the most fuel-efficient cars appears quite strongly whether we look at all used cars together, or look within segments. Furthermore, the effects are much larger than the effects for new car prices, from 4.5 to 14 times as large, depending on which results are compared.[32]

4.5 Discount rates and energy efficiency: an aside

Our investiation of the link between usage cost and prices of durable goods is related to an earlier literature that investigates consumers' willingness-to-pay for energy efficient durable goods. For example, the seminal work of Hausman (1979) investigates consumers' choices among air conditioners of different energy efficiencies. Hausman estimates consumer discount rates in excess of 20% when considering the upfront price of the appliance versus ongoing electricity savings. Related studies have also found high discount rates for consumers making such choices.

Although this issue is not the focus of our paper, the estimates we have presented so far allow us to make a rough calculation of the implied discount rate for consumers making the "upfront durable price" vs. "on-going energy cost" trade-off for automobiles.

[31]This is true for the compact segment; for the luxury car segment (where the results show the greatest contrast between quartiles: prices for the least fuel-efficient luxury cars fall by $3560 and rise by $1319 for the most fuel-efficient cars); for the sporty cars; for SUVs (which show the second largest contrast of all the segments, with prices for the least fuel-efficient SUVs falling by $1681, prices in the third quartile rising by $808, and prices in the most fuel-efficient quartile rising by $1639 for every $1 increase in gasoline prices); and finally, for pickups. The only exception to this pattern is vans, where prices actually *rise* for cars of below median fuel efficiency. We speculate that part of this result is do to increased demand for commercial vans for the purpose of carpooling.

[32]Our estimates suggest that changes in gasoline prices are associated with changes in the relative price of new vs. used cars. Specifically, we find that the price of a fuel-efficient new car falls relative to the price of a used car of the same fuel-efficiency when gasoline prices increase. In these circumstances we might expect, therefore, to see an increase in the share of purchases of fuel-efficient cars that are purchases of a new car. Conversely, we find that the price of a new fuel-*in*efficient car increases relative to the price of a fuel-inefficient used car as gasoline prices increase, suggesting a decrease in the share of purchases of fuel-inefficient cars that are new car purchases. In unreported results (available from the authors) we find that a $1 increase in gasoline prices is associated with an increase of 3.5 percentage points in the share of compact car transactions that are for new cars (a 5.4% change), 2.6 percentage points for sporty cars (a 4.7% change), and 1 percentage point for luxury cars (a 1.7% change). Conversely, the new car share falls by 2.1 percentage points for SUVs (a 3.3% change), and 2.7 percentage points for vans (a 4.5% change). (The results are not statistically significant for midsize cars or pickups). These effects are consistent with what we would expect given the predicted relative price change.

In Section 4.2.2, we calculated that the increase in the price difference between the most and least fuel-efficient quartiles of cars associated with a $1 increase in gasoline prices was very close to the difference in increased fuel expenditure between the most and least fuel-efficient quartiles of cars for a single year of driving. If we perform the same calculation for the estimated price effects for used car, the $2839 increase in the difference between the most and the least fuel-efficient quartile of cars reflects fuel expenditure savings associated with driving the average car in the most fuel-efficient quartile instead of the average car in the least fuel-efficient quartile for 9 years.

To better understand this, we perform a number of similar back-of-the-envelope calculations. If we continue to use 12,000 miles driven as the baseline and a real interest rate of 3 percent, it takes nearly 10 years of fuel savings to recuperate the increase in upfront costs. Increasing the number of miles driven to 15,000 per year implies an "undiscounted" time frame of over 7 years and roughly 8 years if we discount. How many annual miles are needed for the change in relative prices to reflect a "three year payback" period? Nearly 29,000 per year.[33]

Alternatively, we can ask at what discount rate does the price difference reflect the savings in fuel costs given typical survival and driving patterns of used cars? For this we use the National Highway and Transportation Safety Associations's estimates of survival rates and miles driven for cars and trucks as reported in Lu (2006). The median age of used cars in our data is 3 years. We use the median age of used cars in our sample (three) and the average of the survival rates and miles driven across cars and trucks, weighted by the proportion of trucks in our sample, to calculate expected miles driven over the lifespan of the typical used car. Under these assumptions, the $2839 change in relative prices imply a real discount rate of below 1.1 percent. While a thorough understanding of this is beyond the scope of this paper, these simple back-of-the-envelope calculations suggest an *over*-reaction to changes in fuel costs when consumer trade-off upfront costs with usage costs. This contrasts with the results of work which has suggested that consumers have high discount rates when choosing energy efficiency levels.[34]

5 Robustness

In this section we explore the robustness of our results. First, we analyze whether our results are robust to changing the component of variation in the data that is used to identify the effect of gasoline prices. Second, we allow the response to gasoline price to differ by the level and prior direction of gasoline prices to see whether we are ignoring important response heterogeneity in

[33]Three year payback periods are often used in policy analyses as a way to capture high consumer discount rates.

[34]An over-reaction is consistent with recent work by Gicheva, Hastings, and Villas-Boas (2007) which finds consumers over-react relative to the predictions of a permanent income hypothesis model to changes in gasoline prices.

our estimates. Third, we analyze the robustness of our findings to the aggregation of gasoline prices. Fourth we analyze whether we should treat gasoline prices as being endogenous. Fifth, we examine whether our results depend on our use of a linear probability model to estimate market share changes in response to gasoline prices.

5.1 Source of variation

We now re-estimate the original specifications in this paper with a series of different fixed effects. Recall that all specifications so far control for region-specific year and region-specific month-of-year fixed effects. This means that the estimated gasoline price effects are identified by within-year, region-specific market share or price changes which deviate from region-specific seasonal effects.

In order to investigate the robustness of theses estimates, we estimate a specification without any year or month-of-year (seasonal) fixed effects. (In our original specification (Equation 2) we captured regional effects by the fact that seasonal dummies were region-specific. To continue to account regional variation we include region fixed effects for the 29 regions.) Next, we estimate a specification with region-specific seasonal effects but without year fixed effects. The results from these two more parsimonious specifications show whether we are missing an important source of variation due to the extensive set of fixed effects used in our base specification. Finally, we estimate a specification with *more* detailed time fixed effects, by replacing the region-specific year fixed effects with region-specific quarter fixed effects. These results allow us to increase our confidence that our estimated effects are not driven by the generally upward-trending gasoline prices in our sample period.

Table 1 shows the results of these three specification for new and used cars. For comparison, the table repeats the estimates of the original specification in Equation 2.

The coefficients on the gasoline price variable are remarkably robust to which fixed effects are included. Consider first the new car estimates in the upper panel of Table 1. In our original specification we found that a $1 increase in gasoline prices decreased the market share of the least fuel-efficient cars (MPG Quartile 1) by 5 percentage points. Omitting time and and then both time and seasonal fixed effects changes this estimate by only little, to 4.6 and then 4.8 percentage points, respectively. Similarly, we originally found that a $1 increase in gasoline prices increased the market share of the most fuel-efficient cars (MPG Quartile 4) by 7 percentage points. Omitting time and/or seasonal fixed effects decreases our estimate to no lower than 5.4 percentage points. Including more granular time fixed effects than in our original specification by using region-specific quarter fixed effects also has a modest effect; we find a market share decrease of 6.5 percentage points for the least fuel-efficient cars and a market share increase of 8 percentage points for the most

Table 1: Effect of time and seasonal fixed effects in market share specification†

Specification	Time FE	Seasonal FE	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
New Cars						
Most Parsimonious (Region FE only)	–	–	-.048** (.0043)	-0.0035 (0.0046)	-0.0078** (0.003)	0.059** (0.0061)
More Parsimonious	–	Month-of-year × Region	-0.046** (0.0042)	-0.0022 (0.0042)	-0.0062* (0.0028)	0.054** (0.0055))
Base (original)	Year × Region	Month-of-year × Region	-0.05** (0.0049)	-0.014** (0.004)	-0.0065* (0.0029)	0.07** (0.005)
Richer	Quarter × Region	Month-of-year × Region	-0.065** (0.0067)	-0.024** (0.0063)	0.0093* (0.0042)	0.08** (0.0067)
Used Cars						
Most Parsimonious (Region FE only)	–	–	-0.02** (0.0057)	-0.009+ (0.0046)	0.014* (0.0066)	0.015* (0.0059)
More Parsimonious	–	Month-of-year × Region	-0.02** (0.0048)	-0.0077* (0.0038)	0.012* (0.0053)	0.016** (0.0048)
Base (original)	Year × Region	Month-of-year × Region	-0.016* (0.0074)	-0.019** (0.006)	0.026* (0.012)	0.01 (0.009)
Richer	Quarter × Region	Month-of-year × Region	-0.022* (0.0095)	-0.022* (0.01)	0.035 (0.024)	0.0092 (0.023)

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.

fuel-efficient cars. The market share estimates for used cars, reported in the lower panel of Table 1, are similarly consistent across changes in the included fixed effects. Overall, we conclude that the results from our original specification seem robust to which component of time and seasonal variation in the data is used to identify the effect of gasoline prices on the market shares of cars of different fuel efficiency. In all reported fixed effect specifications, we find that the market shares of new cars react more to gasoline price changes than do the market shares of used cars.

We investigate the robustness of our price results by estimating a comparable set of specifications. First, we eliminate all time and seasonal fixed effects from our original price specification (Equation 4), while retaining regional fixed effects. Next, we include region-specific seasonal effects but no year fixed effects. Finally, we include region-specific quarter effects in addition to region-specific seasonal effects. The estimation results are reported in Table 2.

The results in Table 2 show that our price estimates are also robust to changing how much variation in the data is absorbed by fixed effects versus used to identify the effect of gasoline price changes. This is especially true if what we compare across specifications is the estimated change in relative prices of the first and fourth quartile cars implied by a $1 increase in gasoline prices. This estimate is reported in the last column of Table 2. Although the individual quartile coefficients are affected by changes in which fixed effects are used, if we focus on the last column, the estimated relative price effects are very similar across specifications. For new cars, a $1 increase in gasoline

Table 2: Effect of time and seasonal fixed effects in price specification†

Specification	Time FE	Seasonal FE	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4	Price change Quar 1 to 4
New Cars							
Most Parsimonious (Region FE only)	–	–	-513** (82)	-359** (43)	-275** (33)	-147** (38)	$366
More Parsimonious	–	Month-of-year × Region	-245** (74)	-86* (41)	-14 (36)	103* (46)	$348
Base (original)	Year × Region	Month-of-year × Region	-236** (74)	-74+ (40)	6.9 (30)	127** (43)	$363
Richer	Quarter × Region	Month-of-year × Region	-124 (79)	30 (55)	108* (46)	218** (58)	$342
Used Cars							
Most Parsimonious (Region FE only)	–	–	-1117** (38)	-969** (58)	28 (51)	1649** (55)	$2766
More Parsimonious	–	Month-of-year × Region	-778** (41)	-639** (62)	365** (58)	1995** (60)	$2773
Base (original)	Year × Region	Month-of-year × Region	-1073** (40)	-900** (58)	118* (53)	1766** (51)	$2839
Richer	Quarter × Region	Month-of-year × Region	-1208** (59)	-1040** (73)	-25 (70)	1646** (65)	$2854

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.

price increases the price of the most fuel-efficient cars (Quartile 4) relative to the most fuel-inefficient cars (Quartile 1) by $342 to $366 across all specifications. For used cars, the equivalent numbers are $2766 to $2854 across all specifications. Hence, used cars are estimated to experience much larger price adjustments than new cars when gasoline prices change, whichever set of fixed effects we use.

In summary, these estimates show that our findings are robust to which component of the variation in the data is used to estimate the effect of gasoline prices.

5.2 Heterogeneity in gasoline price response

So far we have used the gasoline price for the month of the transaction in the buyer's DMA as our measure of *GasolinePrice*. In doing so we are disallowing heterogeneity in the response to gasoline prices. In this subsection, we investigate two types of heterogeneity that might exist. First, we investigate whether the response to gasoline prices differs by the absolute price of gasoline. For example, does a $1 increase in gasoline prices have a different effect on market shares and car prices when gasoline currently costs $1.50 per gallon from when it costs $3.50 per gallon? Second, we investigate whether the response to gasoline price differs by whether gasoline prices have been consistently rising or falling in prior periods. For example, is the effect of a $1 gasoline price increase larger if gasoline prices have been increasing over the previous three months than if they have been flat or declining?

To answer the first question we repeat all of the main results in Section 4 using *GasolinePrice* interacted with indicators for whether the gasoline price falls in the range "<$1.50," "$1.50-$2.50," "$2.50-$3.50," or ">$3.50." The purpose is to see whether there is an inflection point of gasoline prices at which the effects suddenly kick in, or at which they grow much larger. News reports have posited that there is a gasoline price "threshold" above which consumers change their behavior more dramatically.[35] Summarizing over many results, we find that gasoline prices do have somewhat different effects at different price levels, but there is little evidence of a sudden inflection. See Tables A-12 and A-13 for a summary of these results; full results are available from the authors.

To answer the second question we also repeat the main results of this section interacting *GasolinePrice* with an indicator variable that records whether gasoline prices went up monotonically in the previous three months, went down monotonically in the previous three months, or had some kind of mixed pattern. These results also show some heterogeneity in the gasoline price response but do not have a consistent enough pattern to draw conclusions about systematic differences in effects under the three conditions. See Tables A-14 and A-15 for a summary of these results; full results are available from the authors.

5.3 Gasoline price aggregation

Next, we investigate the robustness of our findings to the aggregation of gasoline prices. Recall that, although we know the ZIP-code of each buyer, we chose to aggregate gasoline prices at the level of local markets (defined by DMAs). The advantage of using the higher level of aggregation is that we reduce the possibility of measurement error that could arise from our observing only a small number of stations per ZIP-code. The higher level of aggregation also allows consumers to react not only to the gasoline prices in their local ZIP-code but also to gasoline prices in a broader area. At the same time, however, we eliminate some of the cross-sectional variation that less aggregate data would allow us to use.

One could also make the argument that we should use a more aggregate measure of gasoline prices than the DMA-level prices we have used so far. This is because consumers may be more likely to notice gasoline price changes once the gasoline price changes have affected a large area and are thus reported in the media; alternatively, local price variation may contain more transitory price shocks that do not enter into the long run forecasts of gasoline prices over the life of the car.

[35] For example, an article in Automotive News on 5/22/08 entitled "Ford: $3.50 gasoline was tipping point for sales shift" states: "The segment shifts [away from SUVs and Pickups] 'really started to move' when gasoline prices hit $3.50 a gallon, [Ford CEO Alan] Mulally said. 'It seemed to us that we reached a tipping point where customers began shifting away from these vehicles at an accelerated rate,'...."

To investigate whether our conclusions depend of the level of aggregation of gasoline prices, we re-estimate our original MPG quartile specifications (Equations 2 and 4) using a less aggregated and a more aggregated measure of gasoline prices. We use 4-digit ZIP-code level gasoline price as our less aggregated measure. We use this instead of 5-digit ZIP-code level price because too many 5-digit ZIP-codes have too few gas stations to calculate a reliable average.[36] For our more aggregated measure, we average the prices for basic grade over all stations in each "Petroleum Administration for Defense District" (PADD). PADDs are the standard geographical classification used by the Energy Information Administration. A PADD's boundaries are defined such that they delineate a region in which supply is homogenous. There are five PADDs: East Coast, Midwest, Gulf Coast, Rockies, and West Coast. There remains substantial variation in gasoline prices across PADDs: not only are prices in some PADDs higher than in other PADDs, there is also variation in the magnitude of the difference (not reported).

The full results are reported in Tables A-9 and A-10. We find that the coefficients on gasoline prices in the 4-digit ZIP code aggregation are similar to those in our (original) DMA aggregation but somewhat smaller in magnitude. This is consistent with some measurement error occurring in the 4-digit ZIP code aggregation. If we aggregate gasoline prices at the PADD level, most coefficient estimates in the market share regression are unchanged. In the price regression we find some increases in magnitude for new cars.

Overall, we would reach exactly the same conclusion about the difference between the reaction of new and used markets to gasoline price changes if we aggregated gasoline prices within 4-digit ZIP code or within PADD instead of within DMAs.

5.4 Endogeneity

So far we have assumed that gasoline prices are uncorrelated with the error term in the market share and price specifications. In this subsection, we relax that assumption.

It seems unlikely that such a correlation would arise due to reverse causality; this is because U.S. gasoline prices depend on world oil prices and refinery margins and these are unlikely to be influenced by the yearly sales of cars in the U.S. However, there are other potential sources of endogeneity which may taint our coefficient estimates. First, there could be local variations in economic conditions that are correlated with local variations in gasoline prices. If the changes in economic conditions change what cars people buy or how much they are willing to spend on them, then our gasoline price coefficients will capture (in part) cyclical effects on car sales and prices.

[36] In our data, the median 4-digit ZIP code reports data from 11.5 stations on average over the months of the year, up from 3 for 5-digit ZIP codes.

Second, gasoline tax changes might be endogenous to economic conditions which also affect car sales and prices. Third, changes in gasoline prices could cause income shocks in local areas (say, areas with refineries or with car plants) and these income shocks may drive car sales and prices.

One way to address the potential endogeneity of gasoline prices would be to use a more aggregate measure of gasoline price; this would make it less likely that local shocks leads to correlation between gasoline prices and the error term in the market share and price specifications. The specification using PADD-level gasoline prices (described in the previous section and reported in Tables A-9 and A-10) does exactly this.

A second approach we take is to use world oil price as an instrument for gasoline prices at the PADD level. Clearly, world oil prices are correlated with regional fuel prices. At the same time, it seems highly unlikely that local or regional variation in economic conditions, gasoline tax changes, or income shocks would have a meaningful effect on world oil prices. To allow for some variation by PADD in the correlation with world oil prices, we use as instruments world oil prices interacted with PADD dummies.

The results of these two approaches are reported in Tables 3 and 4. For easier comparison we also report our original DMA-level specification (which uses OLS).

Table 3: OLS and IV results in market share specification†

	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
New Cars				
DMA-level gas prices OLS (original)	-.05** (.0049)	-.014** (.004)	-.0065* (.0029)	.07** (.005)
PADD-level gas prices OLS	-.05** (.0048)	-.014** (.0049)	-.0078* (.0032)	.072** (.0051)
PADD-level gas prices IV	-.054** (.0063)	.0027 (.0088)	-.012* (.0048)	.063** (.0098)
Used Cars				
DMA-level gas prices OLS (original)	-.016* (.0074)	-.019** (.006)	.026* (.012)	.01 (.009)
PADD-level gas prices OLS	-.018* (.0078)	-.022** (.0063)	.03* (.013)	.0099 (.0093)
PADD-level gas prices IV	-.0089 (.015)	-.027** (.0099)	.055** (.02)	-.019 (.015)

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.

We have already concluded that the OLS regression with PADD-level gasoline prices yields similar market share estimates but somewhat larger price estimates compared to the original OLS regression with DMA-level gasoline prices. The PADD-level IV estimates of the effect of gasoline prices on *market share* are similar to the PADD-level OLS estimates. We find, however, that the estimates of the effect of gasoline prices on car *prices* are generally larger in the PADD-level IV specification than in the PADD-level OLS specification. This can be seen in Table 4.

Table 4: OLS and IV results in price specification†

	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
New Cars				
DMA-level gas prices OLS (original specif.)	-236** (74)	-74+ (40)	6.9 (30)	127** (43)
PADD-level gas prices OLS	-352** (74)	-70+ (37)	45 (30)	163** (34)
PADD-level gas prices IV	-466** (24)	-49* (23)	57* (23)	250** (20)
Used Cars				
DMA-level gas prices OLS (original specif.)	-1073** (40)	-900** (58)	118* (53)	1766** (51)
PADD-level gas prices OLS	-1108** (40)	-936** (58)	124* (49)	1830** (48)
PADD-level gas prices IV	-1302** (22)	-1084** (23)	97** (22)	1995** (22)

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.

Overall, a potential endogeneity between gasoline prices and the error terms of the market share and price regressions does not change our basic finding that new and used markets react very differently to changes in gasoline prices. Controlling for endogeneity does suggest, however, that our original specification may have underestimated the magnitude of the gasoline price effect on car prices. The effect of gasoline prices on market shares is largely unaffected by our two approaches to control for endogeneity.

5.5 Alternative market share specification

As our last robustness check we address potential limitations of the linear probability model we have used to estimate the effect of gasoline prices on markets shares. One might be concerned that the linear probability model does not constrain the estimates in the market share regressions to add up to 1.[37] To address this we reestimate our basic MPG quartile specification (Equation 2) with a multinomial logit ("mlogit" in Stata) which estimates the probability that, conditional on purchase, a car falls into MPG Quartile 1, 2, 3, or 4 (all variables and controls are the same as those specified in Equation 2). In Table 5 we compare the gasoline price coefficients estimated for the linear probability model with the marginal effects in probability associated with a $1 increase in gasoline prices as estimated by the multinomial logit. Full estimation results are reported in Table A-11.

[37] In fact, the market shares predicted by the linear probability results in section 4 come very close to summing to 1, despite no constraint to do so.

Table 5: mlogit marginal effects in market share specification†

	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
New Cars				
LPM	-.05**	-.014**	-.0065*	.07**
	(.0049)	(.004)	(.0029)	(.005)
mlogit	-.053**	-.012**	-.004	.069**
	(.0047)	(.0038)	(.0027)	(.005)
Used Cars				
LPM	-.016*	-.019**	.026*	.01
	(.0074)	(.006)	(.012)	(.009)
mlogit	-.017*	-.020**	.025*	.012
	(0.007)	(0.006)	(0.012)	(0.0085)

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs in parentheses. The SEs in the LPM are robust and clustered at the DMA level. The SE of the marginal effects in mlogit are derived using the Delta-method in Stata's "margins" command.

The table shows that the estimated marginal effects for the multinomial logit are nearly identical to those estimated in the linear probability model. We conclude that our quartile results do not depend on our use of the linear probability model.

6 Supplementary Evidence

In Section 4 of the paper we established the main result of the market share and price effects of gasoline price changes in both the new and used car markets. In this section, we explore supplementary evidence that sheds some additional light on what is happening in each of these markets. The supplementary evidence comes from looking at dealer inventories and trade-ins.

6.1 Inventories

In Section 4, we found that when gasoline prices increase, new car transactions shift toward fuel-efficient cars and away from fuel-inefficient cars, while used car transactions exhibit little of this effect. What does this change in fuel-efficiency mix mean for upstream supply, particularly of new cars? If new car production is extremely flexible, then manufacturers will be able to respond by changing their production mix to match the transaction mix. If production is not very flexible, however, we would expect to see increased inventories of fuel-inefficient new cars and declining inventories of fuel-efficient new cars.

In our data, we can observe one inventory-related measure, called "days to turn." Days to turn counts the number of days that a specific vehicle was on a dealer's lot before it sold. Higher average days to turn for a particular class of cars indicates that the dealer is carrying higher inventory levels of that car.

In order to investigate inventory effects, we estimate the effect of gasoline prices on days to turn by MPG quartiles (the specification and results are reported in Table A-16). We find much larger changes in days to turn in response to gasoline price changes for new than for used cars. For new cars, the estimated coefficients imply that a $1 increase in gasoline price is associated with a 12-day increase in days to turn for cars in the least fuel-efficient quartile, a 17.6% increase from the sample mean of 68.3 days. Conversely, we find that the same gasoline price increase reduces by 5.4 days the time that a car in the most fuel-efficient quartile remains on the lot, a 10.8% decrease relative to an average of 50.2 days. In contrast, for used cars, higher gasoline prices have no statistically significant effect on days to turn for either the least or the most fuel-efficient quartile. The only statistically significant change in days to turn occurs for used cars in the second most fuel-inefficient MPG quartile; days to turn increases by 1.5 days, or 3.2%.

These results are consistent with our description in Section 2 of the operation of new and used car markets and thus complements our earlier market share and price results.

6.2 Comparison of purchased cars and trade-in MPG

One of the unique features of our data, among papers addressing similar topics, is that we observe transactions for individual cars, including what car—if any—was traded in as part of the transaction. This means that for the approximately 40% of new and used transactions that involve a trade-in, we can see what a customer purchases compared to what that same customer purchased at some point in the past. This allows us to perform analysis that is in the spirit of a within customer analysis.[38]

In regressions described and reported in Table A-17, we estimate the effect of gasoline prices on the MPG of the newly purchased car, *conditioning on the trade-in car* used in the transaction. (It is this last element that makes this a "quasi-within-customer" analysis.) We find that higher gasoline prices are associated with greater fuel efficiency of the new car relative to the trade-in. The estimated coefficient implies that a $1 increase in the gasoline price leads customers to increase the fuel efficiency of their new car relative to their trade-in by 0.94 miles per gallon.[39] For used cars, we find that a $1 gasoline price increase increases the fuel efficiency of the newly purchased used car relative to the trade-in by 0.48 miles per gallon.

[38] We cannot do an exact within customer model because we do not observe multiple new car purchases by the same customer. We also do not know when a trade-in was purchased because a given model year is usually available for long over a year (as long as 18 months is not uncommon). Furthermore, we cannot tell if the trade-in was originally purchased new or used.

[39] Because of the included year fixed effects, this coefficient does *not* measure merely changes in consumers' MPG tastes over time.

In terms of the previous results, this tells us, we believe, something about the demand for new and used cars. In Section 4.1 we showed that the market share of new cars shifted generally away from fuel-inefficient cars and towards fuel-efficient cars. The results of this subsection suggest that part of the reason for this is that, when gasoline prices increase, customers choose to purchase more fuel-efficient new cars relative to cars they have purchased in the past.[40]

Similarly, while we did not observe very consistent market share changes for used cars, we did observe in Section 4.4 that prices for used cars shifted quite reliably to higher prices for fuel-efficient cars and lower prices for fuel-inefficient cars when gasoline prices increased. These results suggest that part of the reason for this is that used car buyers are choosing more fuel-efficient used cars when gasoline prices increase relative to cars they have purchased before.

6.3 Actual cash value of trade-ins

A final piece of supplementary evidence we can examine are the amounts that dealers book as the "actual cash value" of trade-ins they receive. While a dealer might wish to manipulate the *price* paid to the customer for his or her trade in, the "actual cash value" is the dealer's internal assessment of the value of the vehicle. In this number, the dealer is trying to approximate the price for which he could have purchased—or could sell—the car at auction. We are interested in how the "actual cash value" of cars of different fuel efficiencies varies with gasoline prices.

In regressions described and reported in Table A-18, we estimate the effect of gasoline prices on the "actual cash value" of trade-ins of different fuel efficiencies. The estimated effects of gasoline prices on actual cash values are similar to the results obtained for the gasoline price effect on used car prices, reported on page 23. The first three quartiles of the actual cash value results are in almost all cases within $100-300 of the used car price results.[41] This result is consistent with our argument that prices adjust fairly rapidly in the used car market, thanks to a well-functioning wholesale market, and that used car buyers and sellers may well adjust their values of particular used cars quite similarly since both care about the change in usage costs. In the results we have

[40] This presumes that the sample of cars with trade-ins are comparable to the overall sample. In unreported specifications, we have separately estimated our main price and market share specifications from Section 4 for transactions with and without trade-ins. The results are qualitatively similar and often not statistically significantly different. When they are different, market shares are slightly more responsive to gasoline prices when the consumer is trading in a vehicle.

[41] There is one interesting exception to actual cash values and used transaction car prices showing very similar adjustment, which is the most fuel-efficient quartile of trade-in cars. There the estimated effects of gasoline price on actual cash values are $1275 (for trade-ins used to buy new cars) and $778 (for trade-ins used to buy used cars) which are $500-$1000 less that the $1766 estimated effect of a $1 gasoline price increase on the price of the most fuel-efficient used car. One story that would explain this would be that when gasoline prices rise, customers are particularly interested in buying a good, fuel-efficient used car from dealers, and that dealers are able to mark up such cars in their retail transactions above what the actual market (auction) price is for such cars.

reported, we have seen that prices for used car retail transactions and for dealer's estimated cost of traded-in cars adjust similarly to gasoline prices. If we had access to data on auction transactions, we would expect to see similar adjustments in those prices.

7 Concluding remarks

In this paper we have investigated the effect of gasoline prices on market shares and prices of cars of different fuel efficiencies in both the used and new car markets. We have found statistically and economically significant effects in both markets. In new car markets, we find the largest effects in market shares. We estimate the market share of the most fuel-efficient quartile to increase by 20% when gasoline prices increase by $1, and the market share of the most fuel-inefficient quartile to decrease by 24%. Furthermore, we estimate market shares of very fuel-efficient or very fuel-inefficient segments to adjust by 10-24% when gasoline prices increase by $1. Transaction prices for new cars also change in response to gasoline prices, typically on the order of several hundred dollars, generally increasing for fuel-efficient cars while decreasing for fuel-inefficient cars. In one benchmarking calculation, we showed that the predicted difference in transaction prices arising from a gasoline price increase was approximately the size of 1.2 year's worth of fuel expenditure savings from buying a more fuel-efficient car.

In used car markets, we also estimate that market shares and prices of used cars respond to changes in gasoline prices, but the relative magnitude of these two effects is very different. In used car markets, our estimates of the effect of gasoline prices on market shares is much less consistently statistically significant. Notably, the most extreme quartiles and segments in terms of fuel efficiency usually show no statistically significant effect of gasoline prices on market shares; even for segments and quartiles that are statistically significant, the effects are in most cases smaller than 10% changes in market share. Used car prices, on the other hand, show much larger effects of gasoline price changes than do new car prices; in many cases, by an order of magnitude. When looking at all used cars together, the transactions prices of the least fuel-efficient used cars are estimated to fall by $1073 when gasoline prices rise by $1, while the prices of the most fuel-efficient used cars are estimated to rise by $1766, a difference of more than $2800. This difference is equivalent to more than nine years' worth of fuel expenditure savings from driving the average car in the most fuel-efficient rather than least fuel-efficient quartile. If we look within segment, this same pattern holds across almost all the segments, in some cases with even larger price effects.

We believe that there are several things we learn from these results. First, these results help us understand at least part of what has happened in the U.S. auto industry over the past several years to bring it into its current state of difficulty. One might argue that the auto industry has experienced a "perfect storm" that included a credit crunch and a major recession as well as historically large increases in gasoline prices. While this paper cannot address all of these contributing factors, we believe we have learned something about the role of gasoline prices. We have shown that the industry has responded with fairly small price adjustments, which has meant that market shares have fallen, especially for the large SUVs and pickups that have recently been the most profitable vehicles for manufacturers. More generally, since consumers are sensitive to gasoline prices in choosing between types of automobiles, rapid changes in gasoline prices dramatically complicate car development and production planning. For example, the time period covered in this study ended with a steep rise in gasoline prices from $2 to $4 per gallon between early-2005 and mid-2008. This coincided with the Ford F-150 pickup truck losing its decades-long position as the best-selling vehicle in the U.S. to the Honda Civic. In response U.S. auto firms scrambled to develop plans for competitive, smaller cars. And then suddenly over the second half of 2008, gas prices tumbled back down towards $2 per gallon. That auto industry executives would, in light of this, argue gasoline prices to be fixed at $4, giving up long-standing opposition to gasoline taxes, suggests just how costly such turbulence must be for production and planning.

Second, our results show a contrast between how markets for new and for used durable goods respond to differences in the ongoing usage costs of the good. We argue that the dramatic difference in how usage cost affects new and used automobile markets can be explained by differences in the *supply* of new and used cars. For the auto manufacturers who supply new cars, a new car has no value other than the profit opportunity of selling it. The new car manufacturer must decide what is the most profitable price at which to offer the car, which will depend on how gasoline prices have affect the demand for the car. In contrast, the outside option for a used car owner who is considering selling a car is to keep the car and continue driving it. This means that the outside option of new and used car suppliers differs fundamentally. A used car seller must consider how gasoline prices have affected not only the usage costs of his or her current car, but also of the car he or she is considering as a replacement. Most importantly, used car sellers are facing buyers who have exactly the same usage cost considerations, reducing the potential gains from trading vehicles in the used car market in response to fuel price changes. This—combined with an efficient wholesale market for used cars—appears to lead to rapid price adjustment for used cars, while new car manufacturers choose not to change prices, and experience market share changes instead.

We believe that these results yield both specific insights into car markets and important general insights into the functioning of new and used markets for durable goods when there is a change in ongoing usage costs.

References

Berry, S., J. Levinsohn, and A. Pakes (1995): "Automobile Prices in Market Equilibrium," *Econometrica*, 63(4), 841–890.

Bresnahan, T. F., and V. A. Ramey (1994): "Output Fluctuations at the Plant Level," *Quarterly Journal of Economics*, 109(3), 593–624.

Gicheva, D., J. Hastings, and S. Villas-Boas (2007): "Revisiting the Income Effect: Gasoline Prices and Grocery Purchases," Working Paper 13614, National Bureau of Economic Research.

Goldberg, P. K. (1995): "Product Differentiation and Oligopoly in International Markets: The Case of the U.S. Automobile Industry," *Econometrica*, 63(4), 891–951.

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

Klier, T., and J. Linn (2008): "The Price of Gasoline and the Demand for Fuel Efficiency: Evidence from Monthly New Vehicles Sales Data," University of Illinois at Chicago.

Knittel, C. R. (2009): "Automobiles on Steroids: Product Attribute Trade-offs and Technological Progress in the Automobile Sector," Working Paper 15162, National Bureau of Economic Research.

Langer, A., and N. Miller (2008): "The Effect of Retail Gasoline Prices on Automobile Price Incentives," University of California, Berkeley.

Li, S., C. Timmins, and R. von Haefen (forthcoming): "How Do Gas Prices Affect Fleet Fuel Economy?," *American Economic Journal: Economic Policy*.

Lu, S. (2006): "Vehicle Survivability and Travel Mileage Schedules," Working Paper DOT HS 809 952, NHTSA Technical Report.

Sawhill, J. W. (2008): "Are Capital and Operating Costs Weighted Equally in Durable Goods Purchases? Evidence from the US Automobile Market," University of California, Berkeley.

Table 6: Summary Statistics

	New Cars						Used Cars					
Variable	N	Mean	Median	SD	Min	Max	N	Mean	Median	SD	Min	Max
GasolinePrice	1866366	2	1.8	0.67	0.77	4.8	1264092	2.1	1.9	0.69	0.77	4.7
MPG	1866366	23	22	5.7	10	65	1264092	22	22	4.8	9.9	65
Price	1866366	25515	23295	10876	2576	195935	1264092	15582	14468	8504	1	181000
DaysToTurn	1801528	58	27	78	1	3859	1211535	47	25	74	1	6055
ModelYear	1866366	2004	2004	2.5	1997	2008	1264092	2001	2001	3.5	1985	2008
CarAge	1866366	0.79	1	0.46	0	3	1264092	4	4	2.6	0	24
TradeValue	796759	8619	6800	8107	-5350	198000	495083	5295	3000	6081	-3402	150000
PctWhite	1866366	0.72	0.82	0.26	0	1	1264092	0.7	0.81	0.28	0	1
PctBlack	1866366	0.082	0.024	0.16	0	1	1264092	0.11	0.028	0.2	0	1
PctAsian	1866366	0.05	0.02	0.087	0	1	1264092	0.038	0.013	0.07	0	1
PctHispanic	1866366	0.12	0.053	0.18	0	1	1264092	0.13	0.051	0.19	0	1
PctLessHighSchool	1866366	0.15	0.12	0.13	0	1	1264092	0.18	0.14	0.13	0	1
PctCollege	1866366	0.38	0.36	0.19	0	1	1264092	0.33	0.3	0.18	0	1
PctManagment	1866366	0.16	0.15	0.082	0	1	1264092	0.14	0.13	0.075	0	1
PctProfessional	1866366	0.22	0.22	0.097	0	1	1264092	0.2	0.19	0.092	0	1
PctHeath	1866366	0.016	0.012	0.018	0	1	1264092	0.019	0.014	0.02	0	1
PctProtective	1866366	0.02	0.016	0.021	0	1	1264092	0.021	0.017	0.021	0	1
PctFood	1866366	0.041	0.035	0.031	0	1	1264092	0.046	0.04	0.033	0	1
PctMaintenance	1866366	0.028	0.021	0.029	0	1	1264092	0.032	0.025	0.031	0	1
PctHousework	1866366	0.027	0.024	0.021	0	1	1264092	0.028	0.025	0.022	0	1
PctSales	1866366	0.12	0.12	0.046	0	1	1264092	0.12	0.11	0.045	0	1
PctAdmin	1866366	0.15	0.15	0.053	0	1	1264092	0.16	0.16	0.054	0	1
PctConstruction	1866366	0.049	0.042	0.039	0	1	1264092	0.056	0.049	0.041	0	1
PctRepaitn	1866366	0.036	0.033	0.027	0	1	1264092	0.04	0.037	0.027	0	1
PctProduction	1866366	0.063	0.049	0.053	0	1	1264092	0.075	0.061	0.059	0	1
PctTransportation	1866366	0.051	0.044	0.038	0	1	1264092	0.059	0.053	0.039	0	1
Income	1866366	58130	53199	26246	0	200001	1264092	50826	46580	22231	0	200001
MedianHHSize	1866366	2.7	2.7	0.52	0	9.4	1264092	2.7	2.7	0.51	0	8.5
MedianHouseValue	1866366	178431	144800	131866	0	1000001	1264092	145079	121674	102666	0	1000001
VehPerHousehold	1866366	1.8	1.9	0.38	0	7	1264092	1.8	1.8	0.39	0	7
PctOwned	1866366	0.72	0.8	0.23	0	1	1264092	0.7	0.77	0.24	0	1
PctVacant	1866366	0.062	0.042	0.076	0	1	1264092	0.067	0.047	0.075	0	1
TravelTime	1866366	27	27	6.7	0.91	200	1264092	27	26	6.8	1	200
PctUnemployed	1866366	0.047	0.037	0.043	0	1	1264092	0.053	0.041	0.046	0	1
PctBadEnglish	1866366	0.044	0.016	0.078	0	1	1264092	0.045	0.014	0.08	0	1
PctPoverty	1866366	0.084	0.057	0.085	0	1	1264092	0.1	0.072	0.095	0	1
Weekend	1866366	0.25	0	0.44	0	1	1264092	0.26	0	0.44	0	1
EndOfMonth	1866366	0.25	0	0.43	0	1	1264092	0.21	0	0.41	0	1
EndOfYear	1866366	0.022	0	0.15	0	1	1264092	0.017	0	0.13	0	1
TradeOdometer	632689	71181	64224	44632	1	250000	385625	93150	89903	48514	1	250000

Table 7: New car fuel economy quartile cutoffs

Modelyear	MPG Q1 Mean	25th Pctile	MPG Q2 Mean	50th Pctile	MPG Q3 Mean	75th Pctile	MPG Q4 Mean
1999	16.0	18.3	20.1	22.2	23.3	24.7	27.7
2000	16.2	18.3	19.9	21.8	23.1	24.3	27.6
2001	16.0	17.7	19.3	21.2	22.7	24.2	27.7
2002	15.9	17.4	19.1	21.2	22.5	24.1	27.6
2003	15.8	17.4	19.3	21.3	22.6	24.1	27.7
2004	16.3	17.8	19.4	21.2	22.7	24.5	28.4
2005	16.2	18.3	19.8	21.6	22.8	24.5	28.3
2006	16.4	17.8	19.3	21.2	22.5	24.3	28.2
2007	17.1	18.7	20.4	21.8	23.4	25.3	29.4
2008	15.6	17.3	18.5	20.1	21.5	23.2	26.6

Table 8: Examples of cars in segments and subsegments

Segment	Avg. MPG	Subsegment	Avg. MPG	Example
Compact Car	29.1	Entry Compact Car	30.7	Hyundai Accent, Toyota Yaris
		Premium Compact Car	28.8	Honda Civic, Ford Focus
Midsize Car	24.4	Entry Midsize Car	25.0	Pontiac G6, VW Jetta
		Premium Midsize Car	24.1	Honda Accord, Ford Fusion, Nissan Altima
Luxury Car	21.4	Entry Luxury Car	22.4	BMW 3-Series, Acura TSX
		Mid Luxury Car	21.3	BMW 5-Series, Volvo V70
		Premium Luxury Car	18.7	BMW 7 Series, Lexus LS Series
Sporty Car	23.4	Sporty Car	24.2	VW Golf GTI, Ford Mustang
		Premium Sports Car	21.2	Chevrolet Corvette, Porsche 911
		Luxury Sports Car	18.8	BMW 6 Series, Mercedes SL-Class
SUV	18.6	Entry SUV	21.0	Honda CRV, Ford Escape
		Midsize SUV	18.1	Toyota 4Runner, Dodge Durango
		Fullsize SUV	15.2	GMC Yukon, Toyota Sequoia
		Luxury SUV	16.8	Acura MDX, Cadillac Escalade
Pickup	17.6	Compact Pickup	18.9	Ford Ranger, Dodge Dakota
		Light Duty Fullsize Pickup	16.2	Ford F150, Chevrolet Silverado 1500
Van	19.2	Compact Van	20.2	Honda Odyssey, Dodge Grand Caravan
		Fullsize Van	15.5	Dodge Ram Van 2500, Ford Club Waron E-150

Table Appendix

Table A-1: New Cars: Market share results, fuel efficiency quartiles†

	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
FuelPrice	-.05**	-.014**	-.0065*	.07**
	(.0049)	(.004)	(.0029)	(.005)
PctLessHighSchool	.034*	.025*	-.023+	-.036*
	(.015)	(.01)	(.012)	(.017)
PctCollege	-.056**	.018	.017	.021
	(.012)	(.011)	(.011)	(.017)
Income	2.8e-08	3.5e-07**	2.4e-07*	-6.1e-07**
	(9.0e-08)	(9.4e-08)	(1.0e-07)	(1.1e-07)
MedianHHSize	.016**	.0061*	-.006	-.016**
	(.0032)	(.0026)	(.0047)	(.006)
MedianHouseValue	7.3e-08*	3.1e-08+	1.2e-08	-1.2e-07**
	(3.0e-08)	(1.6e-08)	(9.3e-09)	(4.1e-08)
VehiclePerHH	.049**	.0033	-.029**	-.023
	(.014)	(.0036)	(.0057)	(.018)
TravelTime	-.000048	-.00029**	-.00027*	.00061*
	(.0002)	(.000098)	(.00013)	(.00025)
Weekend	-.019**	-.0036*	-.0012	.024**
	(.0018)	(.0015)	(.0016)	(.0021)
EndOfMonth	.0057**	.004**	.0035**	-.013**
	(.001)	(.0011)	(.001)	(.0013)
EndOfYear	-.0037	-.0056*	-.0016	.011**
	(.0026)	(.0023)	(.0027)	(.0037)
Observations	1866008	1866008	1866008	1866008
R-squared	0.033	0.010	0.009	0.039

[*] significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.
Not reported: Region × year, region × month-of-year, and car age fixed effects. We also don't report house ownership, occupation, english proficiency, and race of buyers.

Table A-2: New Cars: Market share results, segments†

	Compact	Midsize	Luxury	Sporty	SUV	Pickup	Van
FuelPrice	.042**	.016**	-.0016	.0052**	-.039**	-.016**	-.0069**
	(.0041)	(.0028)	(.0026)	(.0015)	(.0035)	(.0032)	(.0018)
PctLessHighSchool	-.029	-.026	.063**	-.019**	-.016	.041**	-.014*
	(.022)	(.017)	(.01)	(.0045)	(.013)	(.014)	(.0056)
PctCollege	.011	-.034*	.055**	-.0044	.07**	-.11**	.0086
	(.017)	(.013)	(.0099)	(.0036)	(.017)	(.016)	(.0054)
Income	-3.0e-07**	-3.8e-07**	8.7e-07**	7.2e-08*	2.9e-07**	-4.4e-07**	-1.1e-07**
	(1.0e-07)	(8.6e-08)	(1.2e-07)	(2.8e-08)	(9.8e-08)	(1.2e-07)	(2.6e-08)
MedianHHSize	-.0084+	-.0042	-.033**	-.00043	.013**	.013**	.02**
	(.0047)	(.0041)	(.0024)	(.0012)	(.0035)	(.0035)	(.0036)
MedianHouseValue	-5.6e-08+	-1.1e-07**	2.0e-07**	-7.2e-09	4.4e-08	-5.2e-08**	-2.0e-08**
	(2.9e-08)	(1.4e-08)	(2.1e-08)	(4.9e-09)	(3.1e-08)	(1.2e-08)	(6.3e-09)
VehiclePerHH	-.0059	-.024**	-.022**	.0053**	.0061	.047**	-.0064+
	(.012)	(.0068)	(.0052)	(.0015)	(.0081)	(.0065)	(.0034)
TravelTime	.00037	.00031	-.0008**	.000015	.00012	.000095	-.00011+
	(.00023)	(.0002)	(.00016)	(.000092)	(.00018)	(.00017)	(.000065)
Weekend	.012**	.011**	-.013**	-.002*	.004**	-.01**	-.0021**
	(.0015)	(.0019)	(.0019)	(.00082)	(.0013)	(.0019)	(.0006)
EndOfMonth	-.014**	-.00059	.0086**	-.0024	.0046*	.00087	.0025**
	(.0014)	(.0017)	(.0013)	(.0016)	(.0019)	(.00092)	(.00064)
EndOfYear	.0041	.013**	-.013**	-.0058**	.0017	.001	-.00019
	(.0025)	(.0031)	(.0023)	(.0019)	(.0032)	(.0023)	(.0015)
Observations	1866008	1866008	1866008	1866008	1866008	1866008	1866008
R-squared	0.026	0.017	0.053	0.007	0.018	0.061	0.009

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.

Not reported: Region × year, region × month-of-year, and car age fixed effects. We also don't report house ownership, occupation, english proficiency, and race of buyers.

Table A-3: New Cars: Price results, fuel efficiency quartiles†

Variable	Coefficient/SE
FuelPrice*MGP Quart 1	-236** (74)
FuelPrice*MGP Quart 2	-74+ (40)
FuelPrice*MGP Quart 3	6.9 (30)
FuelPrice*MGP Quart 4	127** (43)
PctLessHighSchool	196** (75)
PctCollege	46 (53)
Income	0.0011** (0.00035)
MedianHHSize	25* (11)
MedianHouseValue	0.00017* (0.000078)
VehiclePerHH	-121** (37)
TravelTime	-0.27 (0.9)
Weekend	-12+ (6)
EndOfMonth	-135** (4.4)
EndOfYear	-79** (17)
Observations	1866008
R-squared	0.054

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses. Not reported: Region × year, region × month-of-year fixed effects, car type, and car age fixed effects. We also don't report house ownership, occupation, english proficiency, and race of buyers.

Table A-4: New Cars: Price results, fuel efficiency quartiles by segment†

	Compact	Midsize	Luxury	Sporty	SUV	Pickup	Van
FuelPrice*MGP Quart 1	13 (68)	70 (80)	-764** (242)	256+ (142)	-242** (73)	-378** (95)	243 (180)
FuelPrice*MGP Quart 2	87* (42)	78* (39)	-147 (109)	249* (125)	-336** (50)	-238** (72)	-393** (123)
FuelPrice*MGP Quart 3	-57+ (30)	41 (35)	65 (86)	-470** (115)	66 (59)	83 (66)	-92 (73)
FuelPrice*MGP Quart 4	225** (45)	-160** (42)	370** (83)	-198** (76)	283** (43)	-63 (88)	-14 (68)
PctLessHighSchool	332** (97)	94 (98)	-197 (202)	-31 (276)	101 (129)	385** (120)	21 (166)
PctCollege	-175** (46)	-5 (57)	-43 (163)	-376* (158)	235** (90)	-39 (134)	-131 (122)
Income	0.00066 (0.00042)	-0.00084* (0.00039)	0.0011 (0.00095)	0.0019 (0.0017)	0.0016** (0.0005)	0.0019** (0.00073)	0.001 (0.0011)
MedianHHSize	-9.6 (11)	67** (16)	-72+ (37)	-61 (48)	41+ (23)	61** (20)	42+ (23)
MedianHouseValue	0.00017 (0.0001)	-0.000082 (0.0001)	0.00029* (0.00013)	0.00058** (0.00017)	0.00016 (0.00013)	-0.00013 (0.00013)	0.0003 (0.0002)
VehiclePerHH	-99** (23)	-134** (45)	22 (84)	-40 (62)	-163** (56)	-171** (36)	-98* (50)
TravelTime	0.18 (0.66)	0.027 (1)	-3.9* (1.9)	0.22 (2)	0.85 (1.1)	2.6* (1.3)	2.5 (1.8)
Weekend	-17* (8)	11 (8.9)	-12 (18)	-12 (23)	-23** (7.8)	6.2 (15)	-32* (16)
EndOfMonth	-85** (7.9)	-112** (8.6)	-219** (16)	-122** (36)	-138** (9.4)	-152** (11)	-157** (14)
EndOfYear	-53* (24)	-92** (25)	-42 (49)	-47 (82)	-116** (38)	-59 (46)	-49 (51)
Observations	324017	377978	174572	73681	522717	267296	125747
R-squared	0.046	0.061	0.090	0.070	0.067	0.061	0.086

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.
Not reported: Region × year, region × month-of-year fixed effects, car type, and car age fixed effects. We also don't report house ownership, occupation, english proficiency, and race of buyers.

Table A-5: Used Cars: Market share results, fuel efficiency quartiles†

	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
FuelPrice	-0.016* (0.0074)	-0.019** (0.006)	0.026* (0.012)	0.01 (0.009)
PctLessHighSchool	0.011 (0.015)	0.039** (0.012)	-0.029 (0.027)	-0.021 (0.024)
PctCollege	-0.041* (0.017)	0.0096 (0.016)	-0.012 (0.021)	0.044* (0.022)
Income	-5.2e-07** (1.3e-07)	3.7e-07** (7.2e-08)	6.0e-07** (1.5e-07)	-4.5e-07** (1.4e-07)
MedianHHSize	0.014** (0.004)	-0.002 (0.0031)	-0.0057+ (0.0031)	-0.0066 (0.004)
MedianHouseValue	4.5e-08* (1.9e-08)	9.8e-08** (1.1e-08)	-4.2e-08* (1.7e-08)	-1.0e-07** (2.9e-08)
VehiclePerHH	0.048** (0.01)	-0.0089+ (0.0052)	-0.037** (0.0061)	-0.0027 (0.014)
TravelTime	0.00014 (0.00024)	-0.0003* (0.00014)	-0.00036+ (0.00021)	0.00052 (0.00033)
Weekend	-0.0053* (0.0021)	-0.0086** (0.0025)	0.0045 (0.0028)	0.0095** (0.0028)
EndOfMonth	0.0036 (0.0024)	-0.00073 (0.0013)	0.00088 (0.0023)	-0.0037+ (0.0022)
EndOfYear	-0.012** (0.0039)	0.004 (0.0041)	0.004 (0.0042)	0.0045 (0.0045)
Observations	1263940	1263940	1263940	1263940
R-squared	0.030	0.013	0.015	0.023

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.
Not reported: Region × year, region × month-of-year, and car age fixed effects. We also don't report house ownership, occupation, english proficiency, and race of buyers.

Table A-6: Used Cars: Market share results, segments†

	Compact	Midsize	Luxury	Sporty	SUV	Pickup	Van
FuelPrice	0.0028	0.035**	-0.0069+	-0.0038**	-0.013+	-0.016**	0.0021
	(0.0048)	(0.0096)	(0.0038)	(0.0014)	(0.0074)	(0.0043)	(0.0047)
PctLessHighSchool	-0.02	-0.0016	0.059**	-0.014**	-0.021	0.023	-0.026**
	(0.016)	(0.017)	(0.016)	(0.004)	(0.017)	(0.016)	(0.0088)
PctCollege	0.021	-0.028	0.085**	-0.0076	0.048**	-0.093**	-0.025**
	(0.013)	(0.019)	(0.017)	(0.0049)	(0.015)	(0.015)	(0.0079)
Income	-2.0e-07	-2.7e-07+	1.1e-06**	1.4e-07**	-5.7e-08	-5.8e-07**	-1.1e-07
	(1.2e-07)	(1.5e-07)	(9.6e-08)	(3.8e-08)	(1.2e-07)	(7.5e-08)	(6.9e-08)
MedianHHSize	-0.0022	0.0018	-0.035**	0.0011	0.011**	0.0069*	0.016**
	(0.0029)	(0.0036)	(0.0029)	(0.00098)	(0.0028)	(0.0029)	(0.0025)
MedianHouseValue	-8.8e-08**	-1.3e-07**	2.3e-07**	-5.3e-09	7.1e-08**	-5.3e-08**	-2.8e-08*
	(1.9e-08)	(1.7e-08)	(2.0e-08)	(4.4e-09)	(2.1e-08)	(1.2e-08)	(1.1e-08)
VehiclePerHH	0.0062	-0.022**	-0.036**	0.0042+	0.0052	0.051**	-0.0082
	(0.0088)	(0.0076)	(0.0044)	(0.0023)	(0.0076)	(0.0051)	(0.0052)
TravelTime	0.00054*	-0.00021	-0.00066**	0.000071	0.00008	0.0002	-0.000025
	(0.00024)	(0.0002)	(0.00012)	(0.000058)	(0.0002)	(0.00014)	(0.0001)
Weekend	0.0043*	0.0052	-0.011**	0.00087+	0.0013	-0.00046	-0.00058
	(0.0021)	(0.0033)	(0.0022)	(0.00048)	(0.0021)	(0.0025)	(0.0016)
EndOfMonth	-0.0016	-0.0036	0.0056**	-0.00072	0.0033	-0.002	-0.00098
	(0.0026)	(0.0032)	(0.001)	(0.00047)	(0.002)	(0.0016)	(0.00077)
EndOfYear	-0.0027	0.0082+	0.00049	-0.0039*	0.0018	-0.0081**	0.0041+
	(0.0048)	(0.0047)	(0.0029)	(0.0017)	(0.0044)	(0.0028)	(0.0021)
Observations	1263940	1263940	1263940	1263940	1263940	1263940	1263940
R-squared	0.017	0.031	0.049	0.008	0.027	0.044	0.016

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.

Not reported: Region × year, region × month-of-year, and car age fixed effects. We also don't report house ownership, occupation, english proficiency, and race of buyers.

Table A-7: Used Cars: Price results, fuel efficiency quartiles†

Variable	Coefficient/SE
FuelPrice*MGP Quart 1	-1073** (40)
FuelPrice*MGP Quart 2	-900** (58)
FuelPrice*MGP Quart 3	118* (53)
FuelPrice*MGP Quart 4	1766** (51)
PctLessHighSchool	120 (95)
PctCollege	89 (80)
Income	.0026** (.00074)
MedianHHSize	-38 (25)
MedianHouseValue	.00065** (.00016)
VehiclePerHH	-178** (28)
TravelTime	-1.8+ (1.1)
Weekend	122** (11)
EndOfMonth	-106** (7.1)
EndOfYear	-23 (23)
Observations	1263857
R-squared	0.631

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses. Not reported: Region × year, region × month-of-year fixed effects, car type, and car age fixed effects. We also don't report house ownership, occupation, english proficiency, and race of buyers.

Table A-8: Used Cars: Price results, fuel efficiency quartiles by segment†

	Compact	Midsize	Luxury	Sporty	SUV	Pickup	Van
FuelPrice*MGP Quart 1	-792**	-317**	-3560**	-859**	-1681**	-983**	1104**
	(57)	(47)	(238)	(182)	(69)	(55)	(119)
FuelPrice*MGP Quart 2	270**	88**	19	440**	206**	-453**	671**
	(37)	(31)	(111)	(95)	(51)	(52)	(77)
FuelPrice*MGP Quart 3	303**	207**	643**	742**	808**	284**	-9
	(33)	(26)	(107)	(75)	(67)	(45)	(63)
FuelPrice*MGP Quart 4	346**	460**	1319**	703**	1639**	1510**	122*
	(29)	(40)	(95)	(98)	(63)	(53)	(56)
PctLessHighSchool	247**	25	95	-282	206+	-24	432*
	(91)	(105)	(237)	(323)	(116)	(131)	(204)
PctCollege	95	75	83	41	192	37	130
	(70)	(80)	(191)	(222)	(132)	(123)	(161)
Income	-.002**	-.00091	.0029**	.0026	.0031**	.000028	.00091
	(.00071)	(.00065)	(.00097)	(.002)	(.00087)	(.0011)	(.0013)
MedianHHSize	28	20	-175**	-11	8.3	-3.6	58
	(25)	(22)	(37)	(48)	(37)	(43)	(47)
MedianHouseValue	.00021	.000092	.00089**	.00089**	.00019	-.000013	.00021
	(.00014)	(.00012)	(.00014)	(.00025)	(.0002)	(.0002)	(.00022)
VehiclePerHH	-122**	-173**	-189**	-276**	-158**	-85+	-140**
	(29)	(28)	(59)	(69)	(41)	(44)	(53)
TravelTime	1.3	1.7+	-8.1**	-2	-.25	-.075	-1.2
	(1.1)	(.94)	(2.4)	(2.5)	(1.3)	(1.4)	(1.7)
Weekend	84**	1.0e+02**	166**	73*	145**	143**	104**
	(9.7)	(12)	(31)	(30)	(17)	(18)	(25)
EndOfMonth	-63**	-85**	-197**	-50	-144**	-107**	-79**
	(7.8)	(11)	(29)	(34)	(15)	(15)	(21)
EndOfYear	-33	-25	-132	-79	16	79	-87
	(38)	(30)	(88)	(104)	(41)	(50)	(68)
Observations	176614	323461	130296	59577	310026	177855	86028
R-squared	0.609	0.692	0.729	0.570	0.711	0.619	0.734

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.
Not reported: Region × year, region × month-of-year fixed effects, car type, and car age fixed effects. We also don't report house ownership, occupation, english proficiency, and race of buyers.

Table A-9: Effect of gasoline price aggregation in market share regression†

New Cars				
Gas Price Aggregation	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
4-digit ZIP	-.038** (.0081)	-.016** (.0039)	-.0041 (.0035)	.058** (.0084)
DMA (original specification)	-.05** (.0049)	-.014** (.004)	-.0065* (.0029)	.07** (.005)
PADD	-.05** (.0048)	-.014** (.0049)	-.0078* (.0032)	.072** (.0051)
Used Cars				
Gas Price Aggregation	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
4-digit ZIP	-.011 (.007)	-.016* (.0062)	.025* (.012)	.0018 (.008)
DMA (original specification)	-.016* (.0074)	-.019** (.006)	.026* (.012)	.01 (.009)
PADD	-.018* (.0078)	-.022** (.0063)	.03* (.013)	.0099 (.0093)

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.

Table A-10: Effect of gasoline price aggregation in price regression†

New Cars				
Gas Price Aggregation	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
4-digit ZIP	-219** (69)	-71* (33)	5 (30)	137** (43)
DMA (Base Case)	-236** (74)	-74+ (40)	6.9 (30)	127** (43)
PADD	-352** (74)	-70+ (37)	45 (30)	163** (34)
Used Cars				
Gas Price Aggregation	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
4-digit ZIP	-1080** (39)	-921** (59)	83 (74)	1615** (59)
DMA (Base Case)	-1073** (40)	-900** (58)	118* (53)	1766** (51)
PADD	-1108** (40)	-936** (58)	124* (49)	1830** (48)

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.

Table A-11: mlogit estimates (baseline is MPG Quartile 4) †

New Cars			
	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3
FuelPrice	-.48** (.036)	-.27** (.029)	-.23** (.018)
PctLessHighSchool	.25* (.11)	.23** (.084)	-.036 (.076)
PctCollege	-.38** (.11)	-.0079 (.1)	-.046 (.062)
Income	3.1e-06** (7.9e-07)	4.2e-06** (6.6e-07)	3.7e-06** (5.4e-07)
MedianHHSize	.13** (.029)	.071** (.024)	.015 (.034)
MedianHouseValue	7.6e-07* (3.1e-07)	5.4e-07* (2.1e-07)	4.2e-07* (1.7e-07)
VehiclePerHH	.32** (.12)	.089 (.065)	-.054 (.068)
TravelTime	-.0029+ (.0017)	-.0031** (.001)	-.0027** (.00098)
Weekend	-.17** (.014)	-.089** (.012)	-.076** (.0096)
EndOfMonth	.069** (.0077)	.059** (.008)	.055** (.0064)
EndOfYear	-.052* (.021)	-.061** (.02)	-.041* (.019)
Observations	1866008		
Log pseudolikelihood	-2482493.4		
Used Cars			
	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3
FuelPrice	-.12** (.044)	-.14** (.039)	.056 (.072)
PctLessHighSchool	.12 (.11)	.26* (.11)	-.047 (.17)
PctCollege	-.34** (.12)	-.12 (.11)	-.21 (.14)
Income	2.3e-08 (9.6e-07)	3.5e-06** (6.0e-07)	4.3e-06** (9.3e-07)
MedianHHSize	.092** (.023)	.014 (.025)	-.003 (.021)
MedianHouseValue	5.6e-07** (1.9e-07)	8.0e-07** (1.4e-07)	2.1e-07 (1.5e-07)
VehiclePerHH	.2* (.086)	-.026 (.072)	-.14* (.058)
TravelTime	-.0016 (.002)	-.0028+ (.0015)	-.003+ (.0017)
Weekend	-.059** (.014)	-.075** (.017)	-.016 (.018)
EndOfMonth	.027+ (.015)	.0093 (.0095)	.017 (.014)
EndOfYear	-.066* (.028)	.0025 (.028)	-.00083 (.026)
Observations	1263940		
Log pseudolikelihood	-1706051		

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (clustered at the DMA level) in parentheses.

Table A-12: New and Used Cars: Market share (quartile) results by gasoline price levels[†]

	New Cars			
	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
GasolinePrice (<1.5 dollar)	-.049** (.0067)	-.012* (.0056)	-.011* (.0046)	.071** (.0058)
GasolinePrice (1.5-2.5 dollars)	-.05** (.0062)	-.0092+ (.0049)	-.0087* (.0041)	.068** (.0054)
GasolinePrice (2.5-3.5 dollars)	-.05** (.0055)	-.011* (.0043)	-.0067+ (.0034)	.067** (.0047)
GasolinePrice (>3.5 dollars)	-.051** (.0059)	-.013* (.0058)	-.014** (.0035)	.078** (.0075)

	Used Cars			
	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
GasolinePrice (<1.5 dollar)	-.025** (.0089)	-.0079 (.0077)	.015 (.017)	.017 (.015)
GasolinePrice (1.5-2.5 dollars)	-.023** (.0083)	-.008 (.0069)	.013 (.016)	.018 (.015)
GasolinePrice (2.5-3.5 dollars)	-.022** (.0072)	-.0091 (.0056)	.011 (.014)	.02 (.012)
GasolinePrice (>3.5 dollars)	-.017 (.012)	-.023** (.0087)	.042* (.017)	-.0023 (.012)

[*] significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.
This table only reports the coefficients on gasoline prices.

Table A-13: New and Used Cars: Price results by gasoline price levels†

	New Cars, MPG Quartiles	Used Cars, MPG Quartiles
GasolinePrice(< 1.5)*MPG Quart 1	-266** (88)	-1366** (75)
GasolinePrice(1.5-2.5)*MPG Quart 1	-223* (100)	-1201** (62)
GasolinePrice(2.5-3.5)*MPG Quart 1	-225** (82)	-1112** (52)
GasolinePrice(> 3.5)*MPG Quart 1	-384** (75)	-1350** (65)
GasolinePrice(< 1.5)*MPG Quart 2	-130+ (66)	-1237** (107)
GasolinePrice(1.5-2.5)*MPG Quart 2	-110+ (64)	-1156** (85)
GasolinePrice(2.5-3.5)*MPG Quart 2	-110* (53)	-1009** (78)
GasolinePrice(> 3.5)*MPG Quart 2	-81 (49)	-954** (89)
GasolinePrice(< 1.5)*MPG Quart 3	-42 (41)	476** (92)
GasolinePrice(1.5-2.5)*MPG Quart 3	-57 (41)	417** (87)
GasolinePrice(2.5-3.5)*MPG Quart 3	-36 (34)	315** (74)
GasolinePrice(> 3.5)*MPG Quart 3	.22 (33)	227* (91)
GasolinePrice(< 1.5)*MPG Quart 4	82 (64)	2654** (167)
GasolinePrice(1.5-2.5)*MPG Quart 4	28 (70)	2454** (158)
GasolinePrice(2.5-3.5)*MPG Quart 4	58 (56)	2217** (109)
GasolinePrice(> 3.5)*MPG Quart 4	136** (47)	1903** (88)

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.
This table only reports the coefficients on gasoline prices.

Table A-14: New and Used Cars: Market share (quartile) results by gasoline price trends†

New Cars Results	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
GasolinePrice (3 months up)	-.052** (.0046)	-.016** (.0039)	-.0015 (.0028)	.07** (.0046)
GasolinePrice (3 months mixed)	-.051** (.005)	-.016** (.0042)	.00048 (.003)	.067** (.0049)
GasolinePrice (3 months down)	-.054** (.0054)	-.019** (.0047)	.004 (.0034)	.069** (.0053)
Used Cars Results	MPG Quartile 1	MPG Quartile 2	MPG Quartile 3	MPG Quartile 4
GasolinePrice (3 months up)	-.013+ (.0069)	-.018** (.0059)	.019+ (.011)	.011 (.0081)
GasolinePrice (3 months mixed)	-.01+ (.0062)	-.015* (.0058)	.012 (.0087)	.012+ (.0069)
GasolinePrice (3 months down)	-.0087 (.0068)	-.016* (.0063)	.012 (.0091)	.012 (.0076)

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.
This table only reports the coefficients on gasoline prices.

Table A-15: New and Used Cars: Price results by gasoline price trends†

	New Cars, MPG Quartiles	Used Cars, MPG Quartiles
GasolinePrice(3 mo up)*MPG Quart 1	-290** (80)	-1025** (42)
GasolinePrice(3 mo mixed)*MPG Quart 1	-312** (90)	-1094** (44)
GasolinePrice(3 mo down)*MPG Quart 1	-365** (99)	-1202** (51)
GasolinePrice(3 mo up)*MPG Quart 2	-110* (46)	-855** (61)
GasolinePrice(3 mo mixed)*MPG Quart 2	-135** (51)	-920** (63)
GasolinePrice(3 mo down)*MPG Quart 2	-143* (56)	-1003** (70)
GasolinePrice(3 mo up)*MPG Quart 3	-34 (37)	146** (56)
GasolinePrice(3 mo mixed)*MPG Quart 3	-50 (41)	161** (59)
GasolinePrice(3 mo down)*MPG Quart 3	-77+ (46)	168** (60)
GasolinePrice(3 mo up)*MPG Quart 4	98+ (52)	1768** (52)
GasolinePrice(3 mo mixed)*MPG Quart 4	86 (60)	1945** (60)
GasolinePrice(3 mo down)*MPG Quart 4	82 (64)	2081** (64)

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.
This table only reports the coefficients on gasoline prices.

Table A-16: New and Used Cars: Inventory results†

	New Cars			Used Cars		
Variable	Coefficient (SE)	DTT sample mean	% Change in DTT	Coefficient (SE)	DTT sample mean	% Change in DTT
GasolinePrice * Quart. 1 (least fuel-efficient)	12** (2.3)	68.3	17.57%	.71 (.63)	47.8	1.49%
GasolinePrice * Quart. 2	2.3** (.89)	61.4	3.75%	1.5** (.57)	47.3	3.17%
GasolinePrice * Quart. 3	.56 (.9)	57.2	0.98%	.12 (.63)	49.1	0.24%
GasolinePrice * Quart. 4 (most fuel-efficient)	-5.4** (.88)	50.2	-10.76%	-.9 (.6)	45.4	-1.98%

† This table only reports the coefficients on gasoline prices. The full specification for both new and used cars is:

$$DTT_{irdjt} = \omega_0 + \omega_1(\text{GasolinePrice}_{it} \cdot \text{MPG Quartile}_j) + \omega_2\text{Demog}_{it} + \omega_3\text{PurchaseTiming}_{jt} + \delta_{dj} + \tau_{rt} + \mu_{rt} + \nu_{ijt}$$

where DTT_{irdjt} measures days to turn for transaction i in region r at dealer d on date t for car j. We use the same extensive set of controls we have used in the market share specification (see page 14) with one addition. To control for the fact that different dealerships may have different inventory policies we include car type × dealer fixed effects (δ_{dj}).

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.

Table A-17: New and Used Cars: Trade-in results†

	New Cars MPG	**Used Cars** MPG
GasolinePrice	.94** (.052)	.48** (.051)

† This table only reports the coefficients on gasoline prices. The full specification for both new and used cars is:

$$\text{MPG}_{irjt} = \beta_0 + \beta_1 \text{GasolinePrice}_{it} + \beta_2 \text{Demog}_{it} + \beta_3 \text{PurchaseTiming}_{jt} + \delta_l + \tau_{rt} + \mu_{rt} + \xi_{ijkt}$$

where MPG_{irjt} is the MPG of the car of car type j sold in transaction i in region r on date t for which car l was traded in during that transaction. δ_l is a "car type" fixed effect for the *trade-in*. In addition to conditioning on the MPG of a previously purchased car, including trade-in fixed effects controls for unobservable characteristics of the buyer that are not accounted for by demographics, but which might be correlated not just with a car the buyer has purchased in the past, but with the car purchased in the current transaction.

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.

Table A-18: New and Used Cars: Actual cash value of trade-in†

	New Car Trade-in Actual Cash Value	Used Car Trade-in Actual Cash Value	Used Car Transaction Prices
GasolinePrice*MPG Quart 1	-1177** (56)	-995** (27)	-1073** (40)
GasolinePrice*MPG Quart 2	-887** (39)	-588** (45)	-900** (58)
GasolinePrice*MPG Quart 3	174** (46)	205** (43)	118* (53)
GasolinePrice*MPG Quart 4	1275** (37)	778** (39)	1766** (51)

† This table only report the coefficients on gasoline prices. The full specification for both new and used cars in columns 1 and 2 is:

$$\text{ACV}_{ilrt} = \beta_0 + \beta_1 \text{GasolinePrice}_{it} \cdot \text{MPG Quartile}_l + \beta_2 \text{Odometer}_{ilt} + \beta_3 \text{Demog}_{it} + \beta_4 \text{PurchaseTiming}_{jt} + \delta_l + \tau_{rt} + \mu_{rt} + \xi_{ilrt}$$

where ACV_{ilrt} is the actual cash value booked in transaction i for trade-in car l in region r on date t. We add a new control variable to this specification, which is the odometer reading of the trade-in car; cars with higher odometer readings have experienced greater depreciation and should be booked at lower actual cash values, all else equal. In the specification, we include the demographic characteristics of the buyer; these should not have a direct effect on the average cash value, but may be correlated with unobservable quality characteristics ("wear and tear") of the trade-in car. We also include the purchase timing of the transaction, in case cars are assigned different actual cash values on, for example, weekend days, when there is typically higher transaction volume. Finally, we include detailed "car type" fixed effects for the trade-in, as well as our region-specific year and region-specific month-of-year fixed effects.

* significant at 5%; ** significant at 1%; + significant at 10% level. SEs (robust and clustered at the DMA level) in parentheses.