The Incidence of Tax Credits for Hybrid Vehicles*

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Abstract

A variety of state and federal tax incentives have been used to subsidize gas-electric hybrid vehicles. In this paper, I estimate the incidence of these tax incentives using microdata on sales of the Toyota Prius, in order to determine who benefits from these policies. I focus on three sharp changes in federal subsidies stemming from the Energy Policy Act of 2005 and assemble several pieces of evidence which indicate that consumers captured nearly all of the benefit. First, subsidy exclusive transaction prices do not jump in the anticipated direction in response to large changes in federal tax incentives. Second, estimates that account for consumer heterogeneity indicate that consumers captured the majority of the gains. Third, a state panel regression on state tax incentives shows that state tax incentives have little or no effect on transaction prices, which is consistent with the federal result.

The conclusion that consumers captured the subsidy poses a challenge to standard models of tax incidence. Toyota faced a binding capacity constraint when the credit was introduced. Given a fixed supply, standard models predict that Toyota would capture the subsidy. I argue that consumers gained instead because Toyota believed that raising prices to clear the market would lower future demand for hybrids. I outline a stylized model in which current prices influence future demand and show that a capacity constraint can generate the tax incidence observed in the data. I then discuss factors that could give rise to such a demand system, drawing on the theory of search among alternatives and the behavioral literature on fairness. Finally, I draw lessons for the study of tax incidence in other markets.

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1 Introduction

Federal and state governments in the United States have responded to rising concerns about the consequences of oil consumption in part by introducing tax subsidies for new vehicles that feature fuel-efficient technologies, including gas-electric hybrids. These policies aim to reduce oil consumption in the personal transportation sector, which accounts for 40% of gasoline consumption and 20% of greenhouse gas emissions (Environmental Protection Agency, 2007). At the federal level, the Energy Policy Act of 2005 introduced a substantial personal income tax credit for hybrids. At the state level, thirteen states have passed tax incentives for hybrids, and many others have considered similar actions. In this paper, I determine who benefits from tax incentives for hybrids using transaction level microdata to estimate the incidence of existing subsidies for the Toyota Prius.

I find that consumers capture nearly all of the benefits of tax subsidies. Transaction prices for the Prius did not change surrounding changes of up to $2,650 in the value of the subsidy. Since consumers receive the subsidy directly from the government after their purchase, constant transaction prices imply that consumers capture the benefits of government intervention. This finding has implications for the evaluation of existing and future policies. It also has broader implications for the study of tax incidence because the result, when combined with additional facts about the market for the Prius, is difficult to explain in standard models and may therefore point to phenomena that influence tax incidence but are typically ignored in research.

This paper makes several contributions to public economics. First, the case of the Prius poses a challenge to standard incidence models. Through much of the sample period, the Prius was in excess demand, and consumers had to wait in a queue for several weeks to make a purchase. Given these wait lists, it is difficult to construct a conventional model that allows for a situation in which consumers capture the whole benefit from a tax subsidy. I argue that the most compelling explanation is that Toyota believed that charging higher prices while the subsidy was in place would reduce demand for hybrids in the future, even though higher prices would not change the quantity sold. I construct a stylized model in which a temporary tax has no effect on price when the producer is capacity constrained and current prices influence future demand. Current prices may influence future demand if car shopping is a costly search process and consumers use past prices to form beliefs about the prices they will be offered in the future. Alternatively, current prices may influence future demand for behavioral reasons. Under either interpretation, the modeling exercise suggests that familiar features of taxation, such as the equivalence of incidence regardless of who remits a tax, may not hold in this environment. Such considerations are most likely to influence tax incidence in markets for new products or "green" products and in markets in which final prices are negotiated.

Second, the paper proposes a method for establishing bounds on the incidence of a tax when tax changes

are anticipated. The federal tax credit introduced sharp changes in the value of the subsidy, and the date of these changes was known in advance. This induced a timing response among consumers, who moved their purchases into the more favorable tax windows. If consumers who adjust their timing in response to a tax change differ systematically from those who do not, then a comparison of prices before and after the tax change will give a biased estimate of tax incidence. To account for this, I employ a novel procedure to estimate an upper bound on price changes. The estimator developed here is similar to the bounding estimator off Lee (2005) in that it provides worst-case bounds to account for missing information, but Lee (2005) addresses a situation with a randomly assigned treatment and missing outcome data, whereas the estimator developed here applies to situations with complete outcome data and selection into the treated category. Anticipated tax changes are a common feature of policy; examples include changes to the capital gains tax rates in the Tax Reform Act of 1986, the tax holiday on repatriated corporate earnings included in the American Jobs Creation Act of 2004, and subsidies for energy saving home improvements in the Energy Policy Act of 2005. Economists have noted the importance of timing responses and the challenge they pose to estimation of permanent responses (Slemrod, 1992); the bounding method used in this paper may be useful to future research that analyzes tax policies, or other policies, with this structure.

Third, this paper is one of the first to analyze hybrid vehicles from an economic perspective. While hybrid vehicles remain a small part of the new car market (about 1.5% of all new cars sold in 2006 were hybrids), their market share has grown nearly 100% per year since 2001. Despite their growing importance to environmental policy, almost no economic research exists on hybrids. The exceptions are a pair of papers that document the correlation between Prius ownership and Green Party registration and other signals of environmental preferences (Kahn, 2007a,b) and a paper that correlates state tax incentives with sales volumes (Gallagher and Muehlegger, 2007).

Finally, this research fills a gap in policy evaluation. Through the third quarter of 2007, the hybrid vehicle tax credit cost the federal government about $785 million, with $394 million going to Priuses.[1] Knowing who benefited from these subsidies is necessary not only to evaluate the current policy, but also to inform future legislative action.[2] Many politicians have called for an increase in the federal credit or for a removal of its phase-out provision.[3] Hybrid tax incentives also remain an active policy consideration at the state

[1] Author's calculations, based on sales data from *Automotive News*, assuming an 85% take-up rate. Hybrids produced by General Motors are not included because they report only aggregated numbers that include both hybrids and conventional models. This should have little impact on the estimate, however, because General Motors has sold very few hybrids.

[2] A full policy evaluation should consider not only incidence, but also the effect on total units sold. I return briefly to this issue in the conclusion.

[3] President Bush publicly supports the removal of the cap (Associated Press, 2006). In 2005, Rahm Emmanuel (D-IL) introduced a bill in the House of Representatives to increase the credit for domestic hybrids; Evan Bayh (D-IN), Joe Lieberman (D-CT) and Sam Brownback (R-KS) introduced a senate bill in 2006 to remove the phase-out provision from the existing credit; and a 2007 bill introduced in the House would give a $4,000 tax credit to plug-in hybrids (Union of Concerned Scientists, 2007).

level.[4] Moreover, future subsidies for other advanced technologies are likely to take a similar form.

The balance of the paper is organized as follows. Section 2 describes important features of the automobile market, with specific attention to the case of the Prius. Section 3 details the federal tax incentives, and section 4 describes the data used. Section 5 includes the principle analysis. Estimates provided in this section demonstrate that there was a clear timing response, indicating that agents were aware of the tax laws, but there was little or no price response, indicating that consumers captured the subsidy. Section 6 considers the possibility that there was heterogeneity among those responding on the timing margin and provides tax estimates that account for this. Overall, these results confirm that the subsidy primarily benefitted consumers. In section 7 a different empirical methodology is used to estimate the incidence of state tax incentives. This yields a very similar estimate of incidence. In section 8 I describe why these results pose a challenge to standard models of tax incidence and outline an alternative model, in which current prices are assumed to influence future demand, that could explain the result. Section 9 concludes.

2 Some Facts About the New Vehicle Market and the Prius

The objective of this paper is to estimate how prices respond to changes in a tax subsidy. This requires accurate measurement of the relevant prices. In the new vehicle market, there are several different prices — the suggested retail price, the dealer invoice price and the final transaction price. In this section, I define these prices and describe how they vary across vehicles and over time. Knowing how these prices typically change is important for constructing counterfactual prices that would be expected in the absence of tax change. I also describe the history of the Prius, which is unusual in that it was in excess demand for several years. This excess demand is key to the final interpretation of the empirical estimates.

The price posted on the sticker of a vehicle is known as the Manufacturer's Suggested Retail Price (MSRP). The manufacturer sets the MSRP and rarely changes this during the model year. The MSRP also does not typically vary across localities, except through differences in destination charges (shipping fees). The MSRP must, by federal law, be posted on all vehicles.[5] Furthermore, a car may not be sold for more than the MSRP unless the dealer attaches a new sticker that includes an additional cost, called an "additional dealer markup" or "additional dealer profit." Dealers can and occasionally do post additional markups on vehicles in high demand. The posting requirement, however, makes it difficult for an individual salesperson to negotiate a price above MSRP if management prefers not to add a markup. The posting requirement also

[4] The list of states that have introduced a hybrid tax incentive bill in 2007 alone includes, but is not limited to, California, Florida, Hawaii, Iowa, Illinois, Indiana, Kansas, Kentucky, Massachusetts, Missouri, New Jersey, Ohio, Rhode Island, Tennessee, Vermont and Wisconsin (Union of Concerned Scientists, 2007).

[5] As part of the Dealer's Day in Court Act of 1956, sticker prices were made mandatory in order to curb a practice called "price-packing," in which customers were offered a high price on their trade-in. The trade-in premium was packaged into the price of the new car, for which the consumer had no reference price (Time Magazine, 1958).

makes it transparent to consumers that the markup is a price increase that is not a reflection of dealer cost.

The manufacturer charges dealers what is known as the dealer invoice price for each vehicle. Franchise law dictates that dealers be charged the same price for identical goods, with concession to cost differences, including local advertising fees or delivery fees.[6] As a result, the dealer invoice price for a specific vehicle varies little across dealerships. The dealer invoice price is also constant over the model year cycle, in most cases. Dealerships pay the invoice price for a vehicle when it is shipped to them. This means that dealers have already paid for all of the vehicles in inventory. Instead of changing the invoice price, manufacturers offer cash incentives to dealerships when they want to lower the effective price. This allows them to change the price of all vehicles in inventory, which have already been sold.

The true, economic transaction price of a vehicle depends on not just the final price that appears on the contract, but also on manufacturer incentives and the trade-in allowance. Manufacturers do not change the MSRP within a model year, but they directly influence the transaction price by offering cash rebates and low interest financing to consumers. Furthermore, two identical cars sold at the same contract price can represent two different real outcomes, if the consumers receive different trade-in allowances. The trade-in over or under allowance is the difference between the amount listed for the trade-in on the contract and the dealer's actual estimated cash value, which is used for entering the vehicle into their own inventory. To accurately measure the price of a new vehicle, one must account for cash rebates, the value of low-interest financing and the trade-in allowance. Fortunately, the data described in the next section allow me to account for all of these things at the level of the individual transaction.

At any point in time, final transactions prices vary across vehicles because idiosyncratic bargaining outcomes cause the dealer's margin to vary from vehicle to vehicle and from customer to customer. Over time, some movements in the average transaction price are regular and predictable. When a new vintage of a model is introduced, typically in the early fall, it begins selling at a relatively high price. In most cases, the price declines steadily over the model year, with prices falling at a 9.2% annual rate, on average (Copeland, Dunn and Hall, 2005).[7] Automobile sales also follow a pronounced weekly and monthly cycle. Friday and Saturday see the most sales; Monday and Thursday sales are higher than sales on Tuesday and Wednesday; and very few cars are sold on Sundays. There are also more cars sold at the end of the month, as manufacturers seek to hit sales volume targets. These selling cycles translate to less dramatic price cycles, with small price discounts measured on weekends and at the end of the month.[8] The data used in this paper include the exact date of each transaction, which enables me to control for these regular price movements.

[6] Manufacturers do create some price dispersion through the use of bonuses and rewards for meeting certain benchmarks and through variation in advertising fees across localities.

[7] The run of a vintage is known as the model year. It typically begins in the fall and ends after about 18 months.

[8] Busse, Silva-Risso and Zettelmeyer (2006) report a weekend price discount of $28 and an end of month discount of $56 in their main regressions.

Macroeconomic shocks also influence vehicle prices, and they may influence different vehicles in different ways. For example, the price of gasoline has different effects on vehicle demand according to fuel economy. Previous research has shown that vehicles with different fuel economy have different responses to gasoline price changes in both sales volume (Linn and Klier, 2007; West, 2007) and price (McManus, 2007). Research has also shown that gasoline prices affect used vehicle prices differently by fuel economy class (Kahn, 1986). It is therefore important to account for time period effects and the price of gasoline in estimation.

2.1 The Toyota Prius

The Toyota Prius is a parallel gas-electric hybrid car. A gas-electric hybrid vehicle has both a gasoline engine and an on-board electric power supply. In a parallel hybrid, both the electric motor and the gas engine are capable of supplying power directly to the wheels. Hybrid technology increases fuel economy by using the electric motor to power the vehicle at low speeds and by recharging the battery with energy generated in the braking process (Alson, Ellies and Ganss, 2005). The Prius is not plugged into an electrical outlet, and it is fueled by conventional gasoline.

The Prius was introduced on a small scale in the United States in model year 2001. The second generation Prius, which introduced the current, distinctive body style, debuted in model year 2004. Shortly after its introduction, the second generation Prius was in excess demand. This lasted until the 2007 model year became available, which was produced on a greater scale. Toyota originally planned to sell 20,000 Priuses per year in the United States. Through the first three quarters of 2007, they were on pace to sell 170,000.

Excess demand led to wait lists, which will turn out to be an important part of the story of how taxes influenced Prius prices. The microdata used in the remainder of this paper do not have a measure of wait times, but they do include a measure of the "days to turn" — the number of days that a vehicle was in the dealer's possession before being sold. Average days to turn should be inversely related to wait lists: the more common are wait lists the faster vehicles will turnover.

The median days to turn for all vehicles in the market is close to 60 days. Figure 1 shows the mean and median days to turn of the Prius for the 2003 to 2007 model years. The break between the first and second generation Priuses is apparent in the data. At the end of its run, the first generation Prius sold very slowly. The second generation Prius sold at a remarkable rate for several years. Between the end of 2003 and the fourth quarter of 2006, the Prius turned over around every 4 or 5 days. The 2007 model year began at this same low rate, and rose, starting in November 2006. This may indicate the end of wait lists in many locations. Average days to turn rose further through the new year, and then fell, stabilizing at a new rate of 10 days. The rate of turnover for the second generation Prius at its highest point was only one-third the

market average.

This suggests that wait lists appeared at the end of 2003 and faded in late 2006. Two other sources of evidence corroborate the notion that the wait lists began to recede in November 2006. First, media reports declaring the end of wait lists began appearing in November 2006 (e.g., Woodyard (2006)). According to these reports, industry data indicated a rise in the days to turn of Priuses, and analysts inferred from this a reduction in wait lists; and, Toyota executives reported that, with the 2007 model year line, they had enough vehicles to meet demand.

Second, a small sample of data is available from HybridCars.com, which invited hybrid buyers to report their date of purchase, wait times and transaction prices in a public forum. Between April 2005 and August 2007, 253 Prius buyers reported their wait times. Figure 2 shows the weekly average reported wait times for this sample. The average wait time in this sample fell to about 2 weeks in September and October 2006, and then went to zero starting in November. Thus, this small sample of wait time data supports the conclusions from the more comprehensive turnover data.

There are several reasons to analyze the Prius in order to understand the hybrid market and the effect of tax incentives. First, the Prius, by itself, represents more than half of the entire hybrid market. Second, the Prius is the most distinct and well-known hybrid vehicle. Third, the market for the Prius is more mature than other hybrids, since it has been through several model year cycles. Finally, unlike most other hybrids, the Prius experienced three policy shifts in the sample period. I move now to a discussion of these policy changes.

3 Tax Incentives for Hybrid Vehicles

The federal government has subsidized hybrids through the individual income tax system for several years. Before 2006, the clean fuel vehicle deduction allowed consumers to deduct the "incremental cost" of a clean technology, including hybrids, from their income. This was a regular deduction that could be claimed even if the taxpayer was not using itemized deductions. The incremental cost was capped at $2,000, and all available hybrids qualified for this maximum amount.[9] The Energy Policy Act of 2005, passed in August 2005, eliminated the deduction completely for tax year 2006, and replaced it with the more generous hybrid vehicle tax credit. The new law allowed a tax *credit* of up to $3,400, based not on incremental costs, but on estimated fuel savings. The value of the credit is based on two components: a fuel economy credit and a conservation credit. The fuel economy credit is worth up to $2,400 and is determined by the percentage

[9]The IRS received many questions about how to calculate incremental cost. In October 2002, the IRS decided to allow filers to use incremental cost estimates provided by the auto manufacturers (Internal Revenue Service, 2002). The result was that all hybrid vehicles qualified for the full $2,000 maximum.

gain of the hybrid in city rated fuel economy over a model year 2002 benchmark. The conservation credit is worth up to $1,000 and is based on the total number of gallons of gasoline saved over a 120,000 mile vehicle lifetime, as compared to the same benchmark. To qualify for the credit, hybrids also must meet stricter emissions standards. Manufacturers are required to send applications for each model year to the IRS, and the IRS then sets the exact benefit.[10]

Not every person who purchases a hybrid is eligible to receive the benefit. The credit does not offset tax obligations for those paying the Alternative Minimum Tax. Furthermore, the credit is non-refundable. (Note that these same restrictions applied to the clean fuel vehicle deduction in earlier years.) If a vehicle is leased, the lessor may claim the credit, not the lessee. The seller may claim the credit if the buyer is a tax exempt entity. The credit is available to business purchasers.

The Energy Policy Act of 2005 also included a phase-out provision. The provision is triggered when a manufacturer sells 60,000 eligible vehicles. The credit is unchanged in the quarter in which the 60,000th vehicle is sold and in the next quarter. After that, the credit falls to 50% of its original value for the next 2 quarters, then 25% for another half year, and then expires completely.

The phase-out was allegedly designed to prevent foreign automakers from benefiting more than domestic automakers over the life of the program (Lazzari, 2006; Leonhardt, 2006). Toyota hit the 60,000 mark in the second quarter of 2006, triggering a cut in credit amounts that began on October 1, 2006. The benefit fell again on April 1, 2007, and it will expire completely on October 1, 2007. Honda's phase-out will begin on January 1, 2008. No domestic automaker has reached the cap.

The sharp date changes provide a natural experiment for the analysis of the influence of the tax policy on the hybrid market. A Prius purchased on or before December 31, 2005 was eligible for a $2,000 deduction (worth at least $500 for households in a middle income bracket and up to $720 for the highest income individuals in 2000). A Prius purchased between January 1, 2006 and September 30, 2006 was eligible for a $3,150 credit. A new Prius purchased between October 1, 2006 and March 31, 2007 was eligible for $1,575. A Prius sold between April 1, 2007 and October 1, 2007 garnered a credit of only $787.50. Table 1 summarizes the variation in the federal policy. I use this variation in subsidy size over time to identify the incidence of the federal income tax credit. A number of states have also legislated a state income tax credit or a sales tax exemption for hybrids. These policies are described in more detail in section 7.

[10]The certification process has created information lags, which are described in greater detail in section 8.

4 A Description of the Data

This paper uses data from J.D. Power & Associates' Power Information Network (henceforth PIN).[11] J.D. Power collects transaction details directly from a large sample of dealers in all major markets in the United States. The sample includes about 15% of all new car sales to final consumers. PIN data include the price of each vehicle sold, the exact date of the sale, financing details, cash rebates and the truncated Vehicle Identification Number (VIN). The data also include age, sex and state of residence of purchasers.[12] The version of the PIN data released to me suppresses the personal identifying information of consumers and the dealer information that would allow identification of specific dealerships, to preserve confidentiality. I restrict the sample to purchased (not leased) vehicles with complete price information.[13] The sample excludes fleet sales. The final sample begins in the fall of 2002 and ends in May 2007.

The VIN of the new vehicle identifies the make, model, model year, and a variety of other characteristics. The VIN includes information on engine displacement, cylinders, transmission, doors, body type and trim level, but it does not detail all available options (e.g., sun roofs or stereo systems). All factory and dealer installed options, advertising fees and delivery fees, are reflected in a measure called the dealer cost, which is essential for allowing price comparisons of similarly equipped vehicles. Note that dealer cost is not identical to dealer invoice (see the appendix for details).

The data include a number of additional variables. These include the trade-in vintage and odometer. Also important is the "days to turn" — the number of days that a vehicle was on the dealer's lot before being sold. Transaction details also include information on service contracts, interest rates and other loan details.

Two additional pieces of information come from other sources. I merge official fuel economy ratings from the Environmental Protection Agency's fuel economy guide according to make, model, model year, cylinders, displacement, transmission and trim level. I also use weekly tax inclusive national retail gasoline prices provided by the Energy Information Administration.

As described in section 2, the final transaction price of a new car must account for several things. To construct the necessary measure, I begin with the transaction price inclusive of factory installed options but exclusive of taxes, fees, service contracts and after-market options. The excluded items do not generally influence the resale value of the vehicle, and service contracts and after-market options are often negotiated

[11] Standard data sources that include vehicle purchases and demographic detail will generally have too few hybrids for analysis. There are roughly 100 million households in the United States, and about 16 million new vehicles are sold annually. The Consumer Expenditure Survey (CEX) has about 100,000 consumer units per year. Since the Prius comprises about 1% of the market, one expects roughly 160 Priuses per year in the CEX. In addition, standard data sets have a substantial lag. The most recent CEX is from 2005, and the most recent National Household Travel Survey is from 2001.

[12] Sex is imputed from first names, and ambiguous first names are thus missing.

[13] Less than 3.5% of Priuses in the sample were leased.

after the final price of the vehicle is determined. I adjust the transaction price inclusive of factory installed options to account for the trade-in allowance, manufacturer's direct to customer cash rebates, and financing incentives. To construct the value of the financing incentive, I assume a 4% annual discount rate and estimate the difference in the present discounted value of the loan actually observed in the data (given the loan amount, interest rate and term) to that same value using the Federal Reserve's 48-month car loan interest rate series.[14] I call this the "incentive adjusted price," or just "price".

This measure of price will vary with the set of options installed on a vehicle, creating significant price variation. For example, the 2007 Prius has a base MSRP of $22,175, but the premium options package adds $6,350 to the retail sticker price. If the number of Priues that have this options package changes from week to week, average prices will change, even if the prices of identical vehicles do not.

To construct a measure that accounts for the value of options, I also use a measure which subtracts dealer cost from the incentive adjusted price. I call this the "incentive adjusted markup," or just "markup". Note that this is a level amount, not a percentage. Note also that this markup does not distinguish between revenue collected by the dealer and the manufacturer. For example, a dealer's gross profit could rise when the markup falls, if the manufacturer offered a direct to consumer incentive that lowered the final price by less than the full incentive amount.

Table 2 shows the sample size, price and markup for the final sample of 64,706 Priuses by model year. The 2007 model year features a premium trim level "Touring" package, which is listed separately in table 2. The last column in each panel shows totals for the entire model year. For example, the sample contains 2,381 model year 2003 Priuses. They sold for an average price of $21,068, which was $611 above the average dealer cost.

The main estimates in this paper focus on transactions that occurred within two weeks on either side of each federal tax change. Table 2 breaks down the number of observations, average prices and average markups in each of these windows by model year and trim level. The first two tax changes are close to changes in model years. The 2006 model year Prius began selling in November 2005, and the 2007 vintage began selling in September 2006. The latter is evidenced in table 2 by the sharp drop in 2006 model year Priuses between the end of September and beginning of October.

Since it is critical to compare identical vehicles before and after each tax change, I estimate the effect of the first tax change using only 2006 model year Priuses, and I estimate the effect of the other two changes using only 2007 Priuses with the base trim level. These samples are indicated by shading in table 2. Thus, for example, there are 513 Priuses in the sample in the last two weeks of December 2005 and 1,007 in the first two weeks of January 2006, but I use only 433 from December and 925 from January in the principal

[14] This price adjustment methodology follows Corrado, Dunn and Otoo (2006).

analysis, to restrict comparisons to a single model year. Except where noted, analysis of all the model years and trim levels together does not change any result significantly. Having described the market, the policy variation and the data, I now proceed to a description of how consumers responded to tax incentives.

5 Responses to Changes in the Federal Tax Credit

Transactions surrounding each of the three changes in the federal tax credit reveal two key facts. First, there was a clear shifting of transactions into the tax preferred time period in each case. Second, Priuses purchased in the higher subsidy period, near a tax change, were sold for about as much as Priuses purchased in the lower subsidy window near that change. Since consumers later receive a tax break from the government, constant transaction prices imply that net of tax consumer prices move by the full amount of the subsidy. Together, these two facts suggest that agents were aware of the tax policy and that consumers capture most of the benefit.

5.1 Agents Shifted Transactions Into High Subsidy Time Periods

The sales distributions surrounding the policy changes reveal strategic shifting. Shifting is limited, however, to the two weeks before and after each tax change. Figure 3 shows the distribution of sales over the 62 days in December 2005 and January 2006 for both the Prius and for non-hybrid Toyota sedans.[15] Priuses purchased in December were eligible for the deduction (worth up to $720), and January purchases were eligible for the credit (worth up to $3150). Relative to Toyota sedans, the Prius was sold more heavily at the beginning of January than at the end of December, suggesting that transactions were shifted into January, where the subsidy was greater.[16]

To ensure that the extra January Prius sales are a result of the tax and not a regular time pattern specific to the Prius, we can examine the sales distribution over the same dates in a year with no tax change. Figure 4 shows the distribution of sales of the Prius versus non-hybrid Toyotas for December 2004 and January 2005, where there was no change in tax incentives. These data do not show a similar spike in January sales.

Figures 5 and 6 show the corresponding distributions for September and October. As expected, Prius sales were abnormally high in September 2006, just before the tax credit phased out. In this instance, Prius transactions were moved to an earlier date, whereas the December and January picture shows that Prius transactions were moved to a later date. This symmetry of response bolsters the conclusion that differences between sales patterns of the Prius and non-hybrid Toyota sedans were driven by tax changes. Figures 7

[15] Results are very similar if the entire sedan market is used instead of Toyota sedans.

[16] January 1, 2006 was a Sunday, accounting for the low sales. The selling cycle described in section 2 is evident in these figures.

and 8 provide the same information for March and April 2007, and lead to the same conclusion.

Table 3 quantifies the shift in purchase timing. Relative to the monthly sales volume, the shift is large — about 15% of monthly sales are shifted on average over the three events. In addition, the relative shift is larger for the largest tax change and smallest for the smallest tax change. Furthermore, the sales distribution occurred entirely with the two-week window around each change. The distributions are very similar at the beginning and end of the two-month windows. Given the significant amount of money at stake, it is perhaps surprising that more shifting did not occur.

5.2 Average Prices Were Non-Responsive: Descriptive Evidence

Figures 9 through 11 show seven-day moving averages of prices and markups in the two months surrounding each tax change.[17] The samples in these figures are restricted to a single model year and trim level to avoid introducing price changes that are due to model year seams. Overall, these pictures provide no evidence that prices moved in the anticipated direction in response to tax changes, but there are important differences between prices and markups. Before discussing the graphical evidence, I discuss the interpretation of a discrepancy between price and markup.

Price versus Markup

If average prices and markups fail to move together, it must be because (a) the average value of installed options changed or (b) Toyota changed the dealer invoice (the price it charged dealers) for identically equipped vehicles. Around the first two tax changes, dealer invoice did not change, which means that differences between prices and markups are driven by options packages and that the preferred measure for incidence analysis is the markup. Ultimately, the same is true of the third tax event, but price changes in that case are more complicated, as explained below.

Recall from section 2 that dealer invoice prices rarely change during the model year, except through dealer cash incentives. Industry sources that report weekly on these incentives indicate that no dealer incentives were in place for the Prius during any of the tax windows.[18] The Toyota dealers that I spoke with indicated that they have never received dealer cash incentives on the Prius. In addition, the distributions of costs in the sample show evidence of changes in the proportion of different options packages, but generally support

[17] The moving average is symmetric, using three days on either side of the date. To avoid smoothing a discontinuity, the moving average does not include values from both tax regimes at any point.

[18] Specifically, I examined the "Dealer Incentives" table in relevant issues of *Automotive News*, which indicate no dealer incentives for the Prius in December 2005, January 2006, September 2006, October 2006 or March 2007 (Automotive News, 2005 - 2007). *Automotive News* does report an incentive in April 2007, but this may have indicated either the "economic savings bonus" or a reimbursement for the costs of using a Prius as a loaner vehicle if the customer later bought a Prius (Rechtin, 2007), in which case the incentive would have influenced a tiny fraction of vehicles. In a personal correspondence, an *Automotive News* employee has indicated to me that they believe no dealer cash incentive existed in April 2007, though they were unable to explain what was reported in the magazine at that time.

the notion that Priuses with the same options package cost the same around each of the first two tax windows (see Appendix for details).

Dealer cost did, however, change around the third tax date. In February and March of 2007, Toyota introduced low-interest financing for the Prius. These incentives were eliminated on April 2, 2007, just as the tax credit dropped from $1575 to $787.50.[19] Toyota simultaneously announced an "economic savings bonus" for the Toyota Prius which took effect on April 2. This "economic savings bonus" lowered the price of each options package by as little as $600 or as much as $2000. The dealer invoice for each options package was also changed as part of this program.

To determine whether consumers paid more or less for similarly equipped vehicles in April 2007, as compared to March, we need to know how much each April Prius would have cost dealers had it been sold in March, before the price change. To do this, I use dealer invoice prices for each options package from Edmunds.com to identify which options package each vehicle most likely had. I then adjust for the change in invoice price so that a Prius with the same options package in March 2007 and April 2007 have the same dealer cost. Details of this procedure are in the Appendix. Costs adjusted for the invoice price change are used throughout the remainder of the paper.

Graphical Results

With the distinction between prices and markups in mind, I move now to a description of the price response to tax changes. Figure 9 shows prices and profits for December 2005 (when the deduction was worth up to $720) and January 2006 (when the credit was worth up to $3150). If sellers captured part of the benefit, transaction prices should *rise* after the vertical bar in Figure 9. Instead, a small jump downward is evident in the price series, and the markup is unchanged. Since dealer cost was constant, this means that the tax subsidy was captured by consumers. The drop in the price series was due to a fall in the average value of installed options.

Figure 10 shows prices and markups for September 2006 (when the credit was worth up to $3150) and October 2006 (when the credit was worth up to $1575). There is no evidence of a price or markup jump around this tax change. Within a few weeks of the tax date, the markup is quite steady. Note that the series do not start at the beginning of September in figure 10. This is due to the model year seam. Toyota began selling the 2007 Prius in the middle of September. While there are not very many days available before the tax change, there are about 500 Priuses in the sample, as shown in table 2. Many 2006 Priuses were also sold in September, but only about 100 were sold in October, limiting the potential for analysis of the 2006 vehicles.

[19] April 1, 2007 was a Sunday.

Figure 11 shows prices and markups, using the cost adjusted for the "economic savings bonus," for March 2007 (when the credit was worth $1575) and April 2007 (when the credit was worth $787.50). In this case, there is evidence of a price *increase* when the tax credit is reduced — in contrast to our expectation that a decrease in tax credits would lead to a fall in price. This is due to the fact that the financing incentives in place in March were worth more than the "economic savings bonus."

Two explanations for this unexpected price change are possible. First, I may have miscalculated the value of financing incentives, which require an assumption about the discount rate and the use of a counterfactual interest rate. In the econometric results below, I recalculate incidence estimates using a variety of assumptions. When a 6% or 8% discount rate is used, there is no significant jump in the markup.

Alternatively, consumers may have miscalculated the value of financing incentives. Average prices that do not account for financing incentives fall through this tax change. The price increase evident in Figure 11 is entirely driven by the elimination of low-interest financing. Thus, it is possible that consumers mistakenly perceived the "economic savings bonus," which was a visible change in price posted on the sticker of the vehicle, as a price cut that offset the change in tax credit, but failed to properly take into account the price increase embedded in the financing rates.

Other research bolsters the plausibility of consumer miscalculation. Busse, Simester and Zettelmeyer (2007) find striking evidence of consumer misunderstanding surrounding the employee pricing discount promotions of domestic manufacturers in 2005. They show that, in response to announced promotions in which all consumer were eligible to purchase cars at the employee discounted price, sales surged dramatically (though temporarily) but prices *rose* on average. This was because the manufacturer's incentives in place prior to the promotion were so large that they provided a bigger discount than employee pricing in many cases. The authors point to experimental research that shows that the announcement of a sale can sometimes have an effect on demand, even if prices are not, in fact, discounted (Inman, McAlister and Hoyer, 1990).

In sum, there is considerable graphical evidence that consumers captured the full tax subsidy because markups did not jump in response to tax changes. There are also interesting differences between prices and markups, which indicate the importance of accounting for options packages. The only evidence of a change in markups is around the third tax event, at which point prices moved in the "wrong" direction. This may be the result of imperfect calculation of the value of financing incentives by consumers, which were changed on the same day that the tax changed.

5.3 Average Prices Were Non-Responsive: Regression Evidence

In this section, the conclusions drawn from the graphical evidence described above are confirmed via linear regression. These regressions show no evidence of a statistically significant, positive relationship between prices and the value of the federal tax subsidy. It is thus impossible to reject the hypothesis that consumers captured the entire credit.

Table 4 reports estimates from regressions of the following form:

$$Price = \frac{\alpha_1}{\Delta_1} H_1 + \gamma_1 W_1 + \frac{\alpha_2}{\Delta_2} H_2 + \gamma_2 W_2 + \frac{\alpha_3}{\Delta_3} H_3 + \gamma_3 W_3 + \mathbf{X}\beta + \mu_{\mathbf{j}} + \varepsilon,$$

where subscripts denote the three tax changes (1=December 2005 and January 2006; 2=September 2006 and October 2006; 3=March 2007 and April 2007), Δ is the dollar amount of the tax change in each case, H is a dummy equal to 1 if the transaction is for the analyzed model year (see table 2) and occurs in the *high* tax side within two weeks of a change, W is a dummy equal to 1 if the transaction occurs on either side within two weeks of the change, $\mathbf{X}$ is a vector of controls, μ is a vector of dummies for each model year and trim level, and ε is an error term. Thus, for example, H_1 is coded as 1 if and only if the transaction is for a model year 2006 Prius sold in the first two weeks of January 2006. W_1 is coded as 1 if and only if the transaction is for a model year 2006 Prius sold in either the last two weeks of December 2005 or the first two weeks of January 2006. The dependent variable is the incentive adjusted price paid by consumers.

The sample includes all model year 2003 to 2007 Priuses (N=64,706). The Priuses not in the treatment windows add precision to the estimation of the control variables. The vector of controls includes vehicle cost, day of the week dummies, a dummy for the last five days in a month, state dummies, the retail price of gasoline and a quadratic trend in the length of time that type of Prius was available on the market.

The α/Δ's are the coefficients of interest. Since the α/Δ's are coefficients on the high subsidy time period dummies, if there is a price change in the expected direction, the α/Δ coefficients will all be *positive*. Furthermore, since the high subsidy period dummies are divided by the dollar amount of the tax change, the estimates may be interpreted as the *change in price per dollar of tax change*. The standard tax incidence model thus predicts that $0 \leq \alpha/\Delta \leq 1$. In calculating the size of each tax change, I use the maximum credit amount ($3150, $1575 and $787.50) and I assume a 25% marginal tax rate for the deduction, meaning it is assumed to have been worth $500.[20]

Table 4 reports the α/Δ coefficients for several specifications. The first column contains only the model

[20]The 25% tax rate fits the most appropriate income range. For example, married couples filing jointly with adjusted gross income between $59,400 and $119,950 have a marginal tax rate of 25%. This range includes the mean self-reported income of Prius buyers in 2005 ($87,500) from marketing research data (CNW Research, 2007). In 2005, 21% of all tax filers had a marginal tax rate of 25%, and only 6.4% had a marginal rate above this (see Table 3.4, Internal Revenue Service (2007a)). The top marginal rate in 2005 was 35%, which would raise the value of the subsidy to $700.

year and trim level dummies as controls. It is, therefore, simply the difference in means of vehicle prices in the 2-weeks with a higher subsidy value and the 2-weeks with a lower subsidy value, adjacent to each tax change, scaled by the change in subsidy value. The second column adjusts for options package composition by including the dealer's cost of the vehicle as a regressor. The third column includes vehicle cost, and adds all of the other controls.

As an example of how to interpret the coefficients, consider the estimate in the first row and second column: controlling for dealer cost, prices fell by 3.7 cents for every increased dollar of subsidy when the tax credit was introduced in January 2006. Given the standard error of 2.4 cents, this is not statistically distinguishable from zero. Since dealer cost was constant in the tax windows (argued above), the specifications that control for dealer cost (columns 2 and 3) are preferred. In these specifications, the price effects for the first two changes are statistically indistinguishable from zero, and are tightly estimated. The third tax change has a statistically significant sign in the unexpected direction. As noted below, the statistical significance of this coefficient's difference from zero is sensitive to alternative definitions of financing subsidies.

In sum, regression evidence indicates that the subsidies did not generate any statistically significant upward price movement in the price that consumers paid, so that one cannot reject the hypothesis that consumers captured the entire subsidy. The possibility that these estimates are biased downwards because "savvier" car buyers were more likely to move their transaction into the higher subsidy tax window is explored in the next section.

6 Accounting for Heterogeneity in Strategic Timing

The incidence estimates analyzed in the previous section are based on a comparison of transactions before and after each tax change. Such a procedure could lead to biased estimates if consumers who reacted to tax changes by moving their date of purchase differ systematically from those who did not. In this section, I provide evidence that there was a difference between consumers who purchased in the high and low tax windows, discuss a procedure for establishing an upper bound on the price effect of taxes when this type of heterogeneity is present, and generate estimates of this upper bound in the case of the Prius. For the first two tax changes, these upper bounds are fairly tight, which confirms that consumers captured a significant majority of the tax benefits.

6.1 Evidence of Heterogeneity in Strategic Timing

Even though the data contain relatively few demographic variables, the transaction details are sufficiently rich to reveal differences between consumers who purchased in the high subsidy window and the low subsidy

window. Table 5 shows mean characteristics of transactions that occurred within two weeks on either side of each tax change. The table also reports an estimate of the difference in mean characteristics of high subsidy and low subsidy transactions taken from a regression of the following form:

$$Characteristic = \beta H + \gamma_1 W_1 + \gamma_2 W_2 + \gamma_3 W_3 + \varepsilon,$$

where H is a dummy equal to one if the Prius is the model year analyzed and the transaction is within two weeks of a tax change on the high subsidy side, and W are dummies equal to one if the vehicle is the model year analyzed and the transaction is within two weeks on either side of each of the three tax events.[21]

Table 5 shows that high subsidy consumers were less likely to trade-in a vehicle, required a smaller down payment, were less likely to buy a service contract, generated less service contract income for dealers, paid lower total expenses on after-market options, taxes and fees, and were less likely to accept an interest rate that exceeded the buy rate – as compared to low subsidy consumers.[22] High and low subsidy transactions are statistically indistinguishable from each other in age, sex, trade-in vintage, trade-in value, amount financed and whether or not the transaction included life insurance.[23]

Thus, high subsidy car buyers differ from their counterparts in ways that suggest they are better negotiators. Intuitively, consumers with excellent knowledge of the car market are probably less likely to agree to a transaction that allows dealerships to generate income through service contracts, interest rate markups and after-market options. In addition, previous research has found that consumers who trade-in a vehicle pay more for their new car (Scott Morton, Zettelmeyer and Silva-Risso, 2001). Thus, table 5 demonstrates not only that a difference exists between high and low subsidy buyers, but also that consumers who purchase in the high tax window are likely to be better negotiators, which means that they will pay less for an identical car than their counterparts. If true, then the estimates in table 4 underestimate the true tax effect, since high subsidy buyers (a) likely pay less on average than low subsidy buyers within any given tax regime and (b) are more likely to buy a car in the high tax benefit period.

6.2 Bounding Estimates of the Price Effect of the Tax Credit

To understand the implications of heterogeneous shifting for the estimation of tax incidence, consider the following model. Suppose that there are two types of Prius buyers, "movers" and "stayers". Each individual

[21] All results are very similar if (a) the high and low transactions are all grouped together without separate dummies, (b) Prius transactions from a previous year with no tax change are used to construct a difference-in-differences estimate, or (c) non-hybrid Toyota sedans are used as a comparison group to construct a difference-in-differences estimate.

[22] The buy rate is the rate that the financing agency quotes to the dealership. Dealers sometimes sign a contract for a higher rate than the buy rate, allowing them to make income on the difference.

[23] Dealerships offer life insurance that offsets debt on a car loan.

has an exogenously assigned ideal date of purchase drawn from a distribution common to both movers and stayers. If a mover has an ideal date of purchase near a tax change, that individual will move their transaction into the high subsidy time period. In contrast, a stayer makes their purchase on the ideal date, regardless of pending tax changes. Suppose also that, consistent with the evidence in table 5, movers are better negotiators, on average. Under this assumption, a comparison of transactions on either side of a tax change would result in a biased estimate of the tax effect because it compares buyers with different average bargaining abilities.

The estimate obtained by comparing transactions on either side of a tax change can be written and decomposed as follows. Let m denote movers and s stayers, and let τ^H denote the high tax subsidy time period and τ^L the low subsidy time period. Denoting the price as p, the standard estimate is:

$$\begin{aligned} E[p|\tau^H] - E[p|\tau^L] &= \rho E[p|\tau^H, m] + (1-\rho)E[p|\tau^H, s] - E[p|\tau^L, s] \\ &= \rho(E[p|\tau^H, s] - \zeta) + (1-\rho)E[p|\tau^H, s] - E[p|\tau^L, s] \\ &= \theta - \rho\zeta, \end{aligned}$$

where E is the expectations operator, ρ is the percentage of those in the high subsidy period that are movers, $\theta \equiv E[p|\tau^H, m] - E[p|\tau^L, m]$ is the treatment effect of the tax on movers and $\zeta \equiv E[p|\tau^H, s] - E[p|\tau^H, m]$ is the difference in mean price paid between stayers and movers in the high subsidy period. If movers are, on average, better negotiators than stayers, then $\zeta > 0$ and the observed effect is a downwards biased estimate of θ.

This simple model demonstrates three important things. First, the parameter that could potentially be uncovered is the treatment effect on stayers (θ). Since movers are, by definition, observed in only one period, one cannot hope to directly recover the tax effect on movers, without auxiliary assumptions. Second, if $\zeta > 0$, then the standard before/after comparison (as in table 4) is an underestimate of the tax effect on stayers. Third, two pieces of information are required to recover θ: the percentage of movers in the high subsidy period (ρ) and the premium paid by stayers (ζ).

Even if a defensible estimate of ζ is not available, however, one can still bound θ under the following assumptions. First, suppose that the lowest price obtained by a stayer is higher than the highest price paid by a mover. This is stated in assumption 1:

Assumption 1. $\min[p|\tau^H, s] \geq \max[p|\tau^H, m]$.

Under this assumption, one can identify all the stayers in the high subsidy period, given information about how many stayers and movers are present in the period, because they will be those with the highest prices.

This is an extreme assumption, since it supposes that all movers are better negotiators than all stayers.

Also required is an estimate of the proportion of stayers present in the high subsidy period (ρ). A plausible estimate of the number of stayers in the high tax period is the number of stayers in the low tax period. This would be true if stayers purchase vehicles at a constant rate within four weeks of each tax change. This is stated in assumption 2 as:

Assumption 2. $n_s^H = n_s^L$,

where n is used to denote the size of the sample in each period.

Combining assumptions 1 and 2, we can identify the prices paid by stayers in each high tax period — they are simply the n_s^L highest prices. Given the extremity of assumption 1, the mean of the n_s^L highest prices in the high subsidy period should *overestimate* the mean price of stayers in the high subsidy period. Combining this overestimate with the underestimate from the standard before/after comparison provides a set of bounds on the true tax effect on stayers.

This methodology is an example of partial identification in the presence of corrupted data, which is analyzed by Horowitz and Manski (1995) and extended by Horowitz and Manski (1997). The corrupted data model supposes that the observed data are a mixture of true data and noise. Given information about the probability of noise, Horowitz and Manski (1995) show how to construct bounds on various parameters. In the present case, prices observed in a tax favored window are a mixture of true data (prices paid by stayers) and noise (prices paid by movers). Assumption 2 is necessary to provide an estimate of the probability of noise. This methodology has not been previously applied to the literature on tax incidence, and, more generally, has rarely been applied (an important exception is Hotz, Mullin and Sanders (1997)).

The estimator employed here is also related to the bounding technique developed in Lee (2005), which can also be cast as a corrupted data problem. Lee (2005) addresses a situation where the effect of a randomly assigned treatment is only partially identified because some outcome data are missing. In contrast, the approach developed here addresses a situation where selection into the treatment group may occur on unobservable characteristics, but all outcomes are observed.

Next, if the tax effect on stayers is the same as the tax effect on movers, then we have identified the full parameter of interest. This is stated in assumption 3:

Assumption 3. $E[p|\tau^H, m] - E[p|\tau^L, m] = E[p|\tau^H, s] - E[p|\tau^L, s]$.

An individual consumer need not be aware of or responsive to the tax credit in order for it to influence their final price. This is the essence of an incidence model — any individual's price depends not only on their own reaction to the tax, but also on the reactions of others. One way to think about assumption 3 is the

following. Overall supply and demand (which is influenced by the tax regime) determine some reference price in each period. Those with high bargaining ability pay some amount less than this reference price, and those with low bargaining ability pay some amount more. In such a case assumption 3 is natural; people at all bargaining abilities experience a shift in the reference price, due to the shift in demand.

Table 6 shows results from this exercise, with varying controls. The first three columns match the control specifications in table 4. Thus, the lower bound reported in these columns is the corresponding point estimate in table 4. The fourth column contains a variety of additional controls that may indicate individual bargaining ability: sex, age, total after-market options, a dummy for an APR above the buy rate, a dummy for life insurance, a dummy for the presence of a trade-in, trade-in actual value, trade-in vintage, and a dummy for a service contract. The reported standard error on the lower bound is a standard estimate from a regression. The standard error on the upper bound is obtained via nonparametric bootstrap, with 5,000 repetitions.

The upper bound is constructed by collecting the n highest residuals from the high subsidy period from the regression that generates the lower bound, where n is the number of observations in the corresponding low subsidy window. The mean of these residuals is scaled by the size of the tax change and added to the lower bound to generate the upper bound. Given the scaling, both the lower and upper bound may be interpreted as dollar price changes per dollar of tax change.

Table 6 demonstrates that, even under the extreme assumption regarding heterogeneous shifting, large price responses to the tax change can be ruled out in the first two tax changes, whenever options are controlled (columns 2, 3 and 4). According to column 3, the upper bound estimates for the first two tax changes indicate that consumers got *at least* 73% of the gains around the first tax change and 92% of the gains around the second.

The estimated bounds for the third tax event, however, have little bite. Mechanically, this is due to the larger price variation observed in April 2007. This larger variation is partly due to the financing incentives: as long as some consumers pay cash, the presence of low-interest financing will increase price variation. Economic explanations, which revolve around waiting lists, of the varying results across tax changes are explored in detail below. To preview, a likely explanation is that there were wait lists for the Prius during the first and second tax change, which meant that prices were inflexible. Wait lists had disappeared by the third tax change, making price movements possible, which induced greater variation and potentially a larger tax effect.

In sum, analysis of the response to the federal tax credit suggests that subsidies had very little effect on prices paid by consumers to dealers. Thus the subsidy, during the first two tax changes, almost exclusively benefitted consumers. Before moving to an analysis of state tax incentives, I provide some robustness checks

on these results.

6.3 Robustness

The bounding estimates in table 6 use only one model year and trim level to analyze each tax change, employ a particular definition of financing incentives and do not account for aggregate shocks to the market directly, other than controlling for the price of gasoline. In this subsection, I briefly address each of these issues and discuss how they influence the range of possible estimates of tax incidence.

Accounting for Other Model Years

The first two tax changes occur near seams in the model year. In the estimation above, I use only one model year and trim level in the estimation in order to avoid conflating tax effects with price changes due to the model year seam. This will influence an upper bound estimate if it influences the relative number of observations in the high and low tax period.

To understand how the upper bound estimator is sensitive to relative sample sizes, consider the following extremes. Suppose that there was only one Prius purchased in the low subsidy window around a tax change. In that case, the upper bound estimate would be the highest priced Prius in the high subsidy window minus the price of the lone Prius from the low subsidy period. Alternatively, suppose that there were exactly as many Priuses in the low subsidy window as the high subsidy window. In this case, the upper bound estimate would be identical to the lower bound estimate, since the relative sample sizes indicate that no shifting took place. The choice to use only a single model year, therefore, has consequences for upper bound estimates to the extent that using only a single model year changes the relative sample sizes in the tax windows.

Rather than just lumping all of the Priuses together to address this concern, which might conflate compositional changes with tax effects, I adjust the upper bound estimate to account for the proportion of Priuses sold in each window. For example, in the second tax change, the upper bound estimate in table 2 uses the 383 highest prices from late September (high subsidy) to form an estimate of the September price for stayers, because there were 383 Priuses in the October (low subsidy) window. Instead of using that number, I use the proportion of Priuses of all model years that were sold in September to determine how many September sales represent stayers. Since 495 Priuses of all vintages were sold in October and 1,203 were sold in September, the October sales were 41% as many as the September sales. Using that proportion, the number of stayers estimated to be in the September sample is 189. This will mechanically raise the estimated September price of stayers.

Table 7 replicates the bounding results with this alternative methodology. As expected, the upper bound

on the second tax event rises noticeably. Even so, however, it is an informative upper bound, which says that, even under the most conservative assumptions, consumers captured *at least* half of the tax subsidy. As is evident from a comparison of 6 and 7, this procedure actually tightens the bound on the first tax change, and it has a minimal influence on the third tax change.

Calculation of Financing Incentives

The measurement of financing incentives necessarily involves assumptions about the discount rate and the counterfactual interest rate. In the case of the first two tax changes, these assumptions are unlikely to exert much influence on estimation, since there was no significant change in financing incentives near the tax date. In the third instance, however, financing incentives changed, making the estimates more sensitive to the assumptions used.

Recall that financing incentives are estimated by comparing the APR that a person receives on their vehicle loan from the lending agency with a prevailing market APR, based on the Federal Reserve's survey of commercial lenders. I calculate the monthly payments, given the amount of the loan and the term, using both interest rates, and then compute the present discounted value of the difference in these monthly payment streams using a discount rate of 4%. In the robustness checks, I vary this discount rate, and recompute the bounding estimates using a discount rate of 2%, 4%, 6% and 8%.

The Federal Reserve's benchmark interest rate is a market wide average. It may not be an excellent counterfactual for any given individual, but it should be accurate for the average car buyer. If Prius buyers, however, are different *on average* than other car buyers in terms of credit, then this market average will be a biased estimate for the average Prius buyer. To account for this possibility, I calculate the difference between the average APR of all Prius buyers and the market rate, during the wait list time period, at which time one expects that Toyota was not subsidizing loans. For the 2004, 2005 and 2006 model years, Prius buyers received an average APR that was one-half point below the market rate, suggesting that they have better credit than the average new car buyer. I construct a modified counterfactual market interest rate by subtracting this premium from the Federal Reserve's survey rate.

One other approach is suggested by Corrado et al. (2006). They use data from the Survey of Consumer Finances to estimate the determinants of the interest rate obtained on new car loans. They report that each year of age is associated with a .05 point reduction in the interest rate, and use this to adjust the counterfactual interest rate so that a person at the mean age receives the unadjusted rate, and those above or below receive a modified rate. I construct a modified counterfactual market interest rate by following their procedure.[24]

[24] I assign observations with missing age the unadjusted Federal Reserve interest rate.

Table 8 reports a series of bounding estimates that vary the discount rate and use the original measure of financing incentives, the measure that adjusts for the Prius premium and the age adjusted measure. The table reports bounding estimates from a specification with control variables, which matches the third column in table 6. The estimates in bold face are identical to the estimates from that table.

As expected, the bounds on the first and second tax change are affected very little by the discount rate or the interest rate measure used. The upper bound does rise somewhat when the age adjusted measure is used. This is not surprising, since the upper bound will rise whenever variance increases, and the adjustment procedure will increase variation by modifying significantly the counterfactual interest rate at very high or low ages. The statistically significant negative sign of the lower bound on the third tax change is eliminated at higher discount rates, but it is affected relatively little by the choice of interest rate measure. Thus, it is possible that the significant, negative sign is the result of the choice of discount rate. The high upper bound, however, is qualitatively unaffected.

Time Period Effects

The estimates above are based on prices observed in different time periods. By using a narrow window around each tax change, the estimates mitigate the probability that macroeconomic shocks caused Prius price movements. The tax changes, however, are each on the first day of a new quarter. Automobile manufacturers are sometimes willing to cut prices at the end of a quarter in order to meet sales targets, so it is worth investigating whether or not other models showed significant prices changes around these dates.

Table 9 replicates the before / after comparison of column 3 from table 4 using several samples of non-hybrid vehicles, in order to estimate whether or not there were unusual price movements in the car market as a whole. The samples include non-hybrid Toyota sedans (6 models), the set of best-selling sedans in the same vehicle class from each nameplate (28 models, including all 6 Toyotas), and a subset who have an EPA rated combined fuel economy above 29 miles per gallon (8 models). The coefficients are *not* scaled by tax changes, so they are interpreted as dollar changes around the tax date. For example, the first column says that, on average, among all non-hybrid Toyota sedans, prices fell by $50 from late December 2005 to early January 2006.

Overall, table 9 gives little reason to believe that time effects significantly influence the tax estimates for the Prius. Only three of nine coefficients are statistically significantly different from zero, and all are small in magnitude. Adjusting the tax estimates for the Prius according to even the largest of these estimates would have no impact on the main conclusions of this paper.

Another way to look for time period effects is to look at each model individually. Table 10 shows the estimated time period effects from the same specification for every vehicle manufactured by Toyota, including

vehicles sold under the Lexus and Scion brands. Several of the Lexus models sell for more than twice the amount of the Prius. Given this variance across models, table 10 uses estimates on log price to make coefficients more comparable. Statistically significant time effect estimates are labeled with an asterisk. There is no overall pattern in table 9 that would suggest a caution for the Prius estimates. While there are some statistically significant, small price movements, there is little action among sedans, and many of the price movements in any given window are of opposing sign.

In sum, the principal conclusions of the bounding estimates in table 6 are robust to concerns regarding the use of a single model year, assumptions made in the construction of financing incentives, and time period effects in the broader new vehicle market. The only potentially important deviation from the baseline estimates is that the alternative methodology for estimating the number of stayers present in the high tax window does raise the upper bound on the estimate for the second tax change.

Having established that consumers captured the majority of the gains of federal subsidies, at least around the first two tax changes, I move now to analysis of the incidence of state tax incentives. The analysis of state tax incentives necessarily involves a different research design, but it leads to the same conclusion. Consumers captured the vast majority of state tax incentives as well.

7 Estimation of the Effect of State Incentives

In several states, federal tax subsidies for hybrid vehicles were supplemented by state policies. In this section, I use a state panel research design to estimate the incidence of state tax incentives for the Prius. I find that, as in the case of the federal tax credit, consumers captured nearly all of the benefits from state tax incentives.[25]

State policies do not lend themselves to narrow analysis of transactions around tax changes because sample sizes for all but the largest states are too small. Since state laws change at different times, however, a state panel research design is possible. This design has two significant advantages that complement the federal analysis. First, the estimating equation can include general time period effects, which alleviates any potential concern about macroeconomic shocks. Second, given credible time period controls, it becomes more palatable to use observations further away from the tax change. Thus, in the state panel regressions below, I use data from the entire life of each tax program, not just transactions immediately around a policy change.

Table 11 lists the states with tax incentives, along with the type of incentive, the amount and the

[25]Note that, if the law of one price prevails across states, then the effect of a state tax incentive might be different than a federal tax incentive. States demonstrate significant differences in prices, however, suggesting that prices are not smoothed completely across borders.

effective dates. Twelve states have passed tax incentives that subsidize the Prius. Connecticut, the District of Columbia, Maryland, Maine, New Mexico, and New York had or have a full or partial sales tax exemption. Colorado, Louisiana, New York, Oregon, Pennsylvania, South Carolina, and West Virginia had or have a state income tax credit.[26] Colorado and West Virginia had the largest incentives, which were worth more than the maximum federal credit for some model years. Sales tax exemptions in Connecticut and the District of Columbia, as well as the credits in Oregon and New York were also worth more than a thousand dollars for most Priuses.[27]

Table 12 reports regressions of the form:

$$Price = \lambda\tau_{st} + \mathbf{X_{st}}\beta + \gamma_t + \delta_s + \mu_j + \varepsilon_{ist}$$

where s indexes state and t time period, $Price$ is the incentive adjusted price, τ is the state tax incentive, $\mathbf{X}$ is a vector of controls, γ are week dummies, δ are state dummies, μ are model year cross trim level dummies, and ε is the error term. The parameter of interest is λ. The controls include dealer's cost, day of the week dummies, a dummy for the five days at the end of a month and a quadratic trend in time on the market.[28] The regressions are run on the same sample of Priuses used above.

In these regressions, the coefficient on the tax variable is identified by states that experience a policy change in the sample period. Of the twelve states with tax incentives for the Prius, only eight experienced a change in the sample period: Connecticut, the District of Columbia, Maine, Maryland, New York, Pennsylvania, South Carolina and West Virginia. The final two columns of table 11 show how many Priuses are in the sample when the state policy was in effect and when it was not.[29]

Table 12 reports the results. The point estimate in column one says that, for a one dollar increase in a state tax incentive, the price of a Prius rises by five cents. Whether or not the cost of the Prius is included as a regressor, the point estimate is indistinguishable from zero. The upper bound on the 95% confidence interval is .21. These results are robust to the exclusion of any of the states with tax incentives, ensuring that the result is not driven by a single state with a large sample or a big tax change.

[26] Utah had a credit for which the Prius did not qualify because it does not have a non-hybrid version.

[27] Some states also passed laws that allow hybrids to use car pool (High Occupancy Vehicle) lanes, regardless of the number of passengers. Estimating the effect of these incentives on Prius prices directly is challenging, because such a policy should affect prices as soon as it is expected to be effective and the effective dates for most states is imprecise. In most cases, a bill was in process for some time in the legislature. In several cases, after the bill became law, uncertainty remained about the policy because states required a waiver from the federal government to allow vehicle access on federal interstate highways. The states with HOV policies were not the same as the states with tax incentives, so HOV policies pose a problem only to the extent that they introduce bias into the estimation of time effects. The most concerning case is California, which is large enough to impact regression estimates. Results reported below are robust to including separate dummies for California for when the HOV policy was active and when it was not.

[28] Note that a variable indicating the value of the federal tax credit would be perfectly collinear with time period dummies, since the federal credit only varies over time.

[29] New Mexico's policy changed in the time window, but there are no New Mexico Priuses in the sample before the change.

These estimates do not explicitly control for the heterogeneous shifting behavior addressed in the bounding exercise in section 6. Any concerns about this heterogeneity, however, are greatly mitigated by the fact that the state panel estimates do not just use transactions very close to tax changes. If heterogeneous shifting takes place only close to changes, then shifting will be too small to play a significant role in these estimates. In the case of the federal policy, table 3 showed that extra Priuses were sold only within two weeks of each tax change. It is quite likely, therefore, that only a small number of transactions were shifted by state incentives, where less money was at stake, relative to the total number of Priuses sold in those states.

The point estimates in table 12 are small enough that a zero effect cannot be ruled out, but precise enough to rule out large price movements. Thus, these results corroborate the conclusions drawn from the federal policy: consumers capture the vast majority of tax credits for the Prius. Having established that consumers captured all, or nearly all, of both state and federal tax incentives for the Prius, I move now to an interpretation of this empirical result.

8 Why Did Prius Prices Not Respond to Tax Changes?

The empirical estimates in this paper show that the price paid to dealers for the Prius was not responsive to changes in tax subsidies. In this section, I offer an interpretation of this result. In the standard static, competitive tax incidence model, this result indicates that supply is quite elastic, relative to demand. I argue that this interpretation is inconsistent with other facts about the market, particularly the existence of wait lists. Moreover, in any standard model, if Toyota was capacity constrained, they should be expected to appropriate the gains from a subsidy. The empirical result, which indicates precisely the opposite, is therefore puzzling.

One possible explanation is that Toyota believed that future demand for hybrids would be diminished if they charged market clearing prices for the Prius during the period of capacity constraints. If so, then an increase in demand due to a temporary tax credit may have no effect on price, even if the seller is capacity constrained. I outline a two period model that assumes that first period prices shift the second period demand curve. I show how a tax subsidy in the first period can be captured by consumers, even if the seller faces a binding production constraint. I then discuss market characteristics that could give rise to such a demand system, including directed search and a concern for fairness. The section concludes by drawing lessons for the analysis of tax incidence in other markets.

8.1 Standard Models are Inconsistent with the Case of the Prius

In incidence analysis, the default procedure is to translate a price change into a statement about relative elasticities of supply and demand. The most basic, textbook model of incidence is a static, partial equilibrium model of a competitive market. Analyzing this case is important because it underlies the default interpretation of empirical estimates. The derivation of incidence begins with definitions of the elasticity of supply and demand and the market clearing condition. Log-linearized, this leads to the familiar system

$$\hat{Q^D} = \eta^D(\hat{p} + \hat{\tau})$$
$$\hat{Q^S} = \eta^S \hat{p}$$
$$\hat{Q^S} = \hat{Q^D},$$

where I have assumed that the consumer remits the tax and used the notation of Fullerton and Metcalf (2002): $\hat{x} = \frac{\partial x}{x}$, η is the own price elasticity, Q is quantity, p is price, τ is tax and S denotes supply and D demand. Substitution leads to the expression:

$$\frac{\hat{p}}{\hat{\tau}} = \frac{\eta^D}{\eta^S - \eta^D}.$$

In this simple model, a zero price effect ($\hat{p} = 0$ for $\hat{\tau} \neq 0$) can result from two extreme cases: (a) perfectly inelastic demand ($\eta^D = 0$), or (b) perfectly elastic supply ($\eta^S = \infty$).

Neither of these cases is a plausible explanation for the Prius, given additional facts about the market. First, it is unlikely that demand is extremely inelastic in such a narrow market. The subsidy in question applies only to hybrid vehicles, for which conventional vehicles are generally a close substitute. Furthermore, since Toyota is a monopoly seller of the Prius, if $\eta^D = 0$ at the chosen quantity, Toyota could raise the price of all Priuses without reducing quantity sold.

Second, the existence of wait lists makes elastic supply implausible. If supply were perfectly elastic, then a tax subsidy would cause a sharp increase in the quantity sold. Since Toyota in fact had a capacity constraint, supply must have been inelastic.[30] The existence of wait lists indicates that Toyota did not simply increase production to satisfy increased demand at a constant price. Moreover, in such a simple static model, a capacity constraint would imply a perfectly *inelastic* supply curve. This would imply that *suppliers* would capture the entire subsidy, which is precisely the opposite of the empirical facts.

[30] Toyota never issued a general press release citing a supply shortage, but there was a known shortage of hybrid batteries reported in early 2005 (Truett, 2005), and media reports have quoted Toyota spokespeople claiming that the shortage of Priuses was due to production and supply constraints (e.g., Benton (2005); Bailey (2007)).

Relaxing Competitive and Dynamic Assumptions Does Not Explain the Result

The incidence expression discussed above is based on a static, competitive market and a permanent tax change. This is a useful benchmark, but the assumptions involved are poor approximations of the vehicle market. Relaxing restrictive assumptions, however, will not explain all of the facts of the Prius case unless the model can explain wait lists. In general, adding market power and dynamic considerations can create additional conditions under which consumers will capture the entire benefit of a tax credit. These results, however, will not hold if there is a wait list, so that sellers can raise prices without lowering quantity sold.

The non-response of Prius transaction prices to tax changes is therefore a puzzle. If Toyota faced a capacity constraint, why were they unable to appropriate all of the gains from an increase in demand? I argue below that prices did not respond to the introduction of the tax credit because Toyota had a vested interest in keeping prices low, in order to increase demand for hybrids in future periods. Before analyzing this possibility, I provide evidence that the pricing puzzle is not due to widespread ignorance or ineligibility.

8.2 Awareness and Eligibility Do Not Explain the Result

One would not expect to observe price changes in response to an income tax credit if consumers were unaware of the credit or if they were ineligible to receive the benefits. In this section, I argue that awareness and eligibility may have had some effect on the magnitude of tax responses, but that the effect was likely to have been small.

Tax provisions are often complicated and obscure. As a result, individuals may not respond to a tax incentive because they are ignorant of it or are confused by its implications.[31] If consumers did not know about the hybrid vehicle tax credit, or misunderstood the phase-out schedule, one might expect constant transaction prices. Moreover, slow information dissemination by the Internal Revenue Service may have contributed to confusion regarding the hybrid vehicle tax credit. The tax credit took effect on January 1, 2006, but the IRS did not officially certify the Toyota Prius or announce the size of the credit until April 7, 2006 (Internal Revenue Service, 2006a). The first phase-out of the credit began on October 1, 2006, but the official IRS statement that the phase-out would begin was not issued until September 20 (Internal Revenue Service, 2006b).

In spite of the slow dissemination of official information, accurate details about the credit were available on the Internet and in other media. The American Council for an Energy-Efficient Economy released a

[31] Confusion may prevail even when the stakes are large. For example, Romich and Weisner (2000) and Smeeding, Ross and O'Connor (2000) find that a large percentage of Earned Income Tax Credit (EITC) recipients cannot distinguish between refunds due to over withholding and EITC payments. And, Jappelli and Pistaferri (2007) argue that tax reforms in Italy had no discernible effect on the mortgage market because people did not understand how the changes influenced the implicit subsidy of mortgages.

report estimating eligibility and credit amounts in the fall of 2005 (American Council for an Energy-Efficient Economy, 2005). Other media cited this report, which provided very accurate predictions regarding credit amounts. In terms of the phase-out, Toyota sold over 42,000 hybrids in the first quarter of 2006. Thus, they were certain to reach 60,000 hybrids in the second quarter. The phase-out implications were well understood by the media and correctly reported long before the IRS pronouncement. This information was further disseminated by individuals in Internet chat rooms, which frequently included discussions of the tax credit.[32] In addition, evidence from the Internet shows that consumers sought this information. Figure 12 shows the relative density of searches on Google for the term "hybrid tax credit," which reveals search spikes prior to the credit's introduction and phase-out, and at other logical times.

All of this suggests that many consumers were informed about the credit, but it does not imply that all consumers were informed. One reason to believe that nearly all consumers were informed is that dealers had an incentive to inform them. All automakers have a system for transmitting information to dealerships about incentives and policies. Dealerships then inform salespeople during regular meetings. The Toyota dealers I spoke with confirmed that Toyota distributed information about the tax credit several weeks prior to each change, which ensures that dealers were informed. In order for dealers to potentially capture part of the tax subsidy, they would have to make sure that customers knew they would later receive a benefit on their tax returns.

Even if consumers were well informed, the tax credit may not have influenced prices if very few were eligible to receive the benefit. Recall that taxpayers subject to the Alternative Minimum Tax (AMT) and those with no tax obligation will not benefit from the credit. To determine what percentage of consumers were eligible for benefits, one would ideally like to compare take-up rates in tax return data to the total sales of hybrids. Unfortunately, the Statistics of Income (the division of the IRS that reports this type of data) has no available data on vehicle credits from 2006 tax returns at this time. Furthermore, they have no data on the tax deduction from earlier years, because the deduction was added as a miscellaneous item in a line on the 1040, and the coding of the data did not disaggregate hybrid deductions from several other items.[33]

In the absence of data from the IRS, one might attempt to estimate the proportion of Prius buyers who were not eligible by estimating the tax situation from detailed income information, but the data to do this with precision are not available.[34] CNW Research, a marketing research firm in the auto industry, does report the mean self-reported income and home ownership rates of Prius owners. In 2006, they report the

[32]Two relevant examples are PriusChat.com and the town hall section of Edmunds.com, http://townhall-talk.edmunds.com/direct/view/.f0a4a16.

[33]I have been told by people at the Treasury Department that no one has calculated the revenue expenditures from the clean-fuel tax deduction using actual tax return data.

[34]As mentioned above, publicly available data like the Consumer Expenditure Survey and the National Household Travel Survey are not recent enough and contain too small a sample to be useful.

mean income of Prius buyers to be $88,750, compared to $60,750 for new car buyers across the whole vehicle market. In 2006, 77.1% of Prius buyers reported owning a home, compared to 57.9% for the whole market (CNW Research, 2007). Given these numbers and the fact that the Prius costs around $25,000, it seems unlikely that very many Prius buyers have too little tax obligation to gain from the non-refundable credit.

Despite the fact that Prius owners are relatively wealthy and relatively likely to own a home, the limitations imposed by the AMT probably did not affect many Prius buyers because the AMT applied to a low percentage of tax returns. In 2005, the most recent year for which official AMT data is available, in only five states were more than 5% of returns affected by the AMT (Internal Revenue Service, 2007b). The highest rate was New Jersey, where 6.8% of all filers were affected by the AMT. Thus, even if Prius buyers were twice as likely to be influenced by the AMT as the rate in the highest state, 86% would be unaffected.

Furthermore, many AMT payers are uncertain of their AMT status before filing. In addition, it appears that many consumers affected by the AMT were surprised to find that they could not benefit from the credit. The discussions at PriusChat.com and Edmunds.com on the Prius include a number of references to the AMT. Most posters who were affected by the AMT seemed surprised that they did not receive the full benefit. Thus, the most likely form of misinformation actually works in favor of creating a price and sales response, because many ineligible consumers apparently expected to receive the credit.

In sum, there are several reasons to believe that awareness and eligibility could only have played a small role in creating a zero price response for the Prius. The data indicated that many consumers understood the policy, and it is reasonable to believe that nearly all consumers would have been informed by dealers. The vast majority of Prius buyers were likely eligible for the credit, and the most likely type of confusion, regarding eligibility and the AMT, probably made many ineligible consumers believe that they were eligible, which would have amplified the price response. Since awareness and eligibility do not explain the price result, the puzzle remains. I move now to a stylized model that describes conditions that could give rise to a zero price response.

8.3 An Explanation; and a Stylized Model that Encapsulates It

Standard models cannot explain all of the facts of the Prius market unless they can explain the presence of wait lists. The conventional explanation among industry watchers for wait lists is the following. Toyota was surprised by the strength of demand for the second generation Prius, which led to shortages beginning in 2003. They did not want prices to rise sufficiently to clear the market because they had a long term interest in establishing hybrids as an affordable, cost efficient technology in the eyes of consumers. As the symbol of hybrid technology, they did not want the Prius to be perceived as a vehicle available only to the

wealthy. In addition, they wanted the Prius to be perceived as a car comparable in cost to midsize sedans like the Camry and Accord, because they believed that, over time, that is where they would price the Prius. In other words, Toyota believed that if prices rose to clear the market during the period of excess demand, then demand for hybrids in the future would be lower.

Toyota could not meet the higher than expected demand by increasing production because they faced capacity constraints. In the automobile industry, there are very large fixed costs to production, and there are potential bottlenecks in parts suppliers, especially if a vehicle needs an uncommon part like a hybrid battery which is produced by only one supplier. Prior to the 2007 model year, all Priuses were assembled at one plant, the Tsutsumi Plant in Toyota City, Japan. When Toyota ramped up production significantly for 2007, it required the opening of a new assembly line in a different plant. This suggests that there were indeed large capital investments that could not be quickly changed to accommodate greater than forecasted demand.

Toyota is heavily invested in hybrid technologies. Toyota sold its one millionth hybrid in June 2007, and it announced that it expects to sell one million a year by 2010, making hybrids 10% of Toyota's global sales (Healey, 2007). Hybrids already represent 10% of Toyota sales in the United States, as of 2007. In 2003, Toyota pledged to introduce a hybrid version of all of their vehicles. They have backed away from this recently, but still plan to double the number of models available and make a hybrid version available in every market segment within a few years (Healey, 2007). Toyota currently holds over 1,000 patents on hybrid related technologies, and Nissan, Ford and Fuji Heavy Industries have agreements to use Toyota's techniques (Rowley, 2006). This suggests that, if Toyota did believe that higher Prius prices in 2005 would jeopardize hybrid demand in later years, then they had a lot at stake.

Model

To understand how such a concern could influence tax incidence, I develop a simple two period example in which a monopolistic seller faces a first period capacity constraint and first period price is assumed to influence second period demand. I show that a first period tax credit may have no influence on the price. This example highlights several key issues, including the distinction between tax exclusive and inclusive prices, which I return to in the discussion.

For ease of exposition, I assume a linear functional form for demand. I posit a multiplicative relationship between first period prices and second period demand. The benefit of analyzing this case is that closed form optimal values take very simple functional forms, and comparative statics are then immediately transparent.

Let D denote demand, p price, τ the tax subsidy, and denote second period variables with a x' symbol.

$$D = \alpha(A - (p - \tau))$$
$$D' = (\alpha' - .5\beta p^2)(A - (p' - \tau')),$$

where A, A', α, and α' are positive scalars. We can interpret A, A', α, and α' as shifters of the size of the market in each period. β is a scalar that describes how first period price influences second period demand. If β is zero, then the model collapses to a standard case. If β is positive, then high first period prices shrink future demand. The setup assumes that consumers remit the tax and that second period demand is influenced by the subsidy exclusive price. The latter assumption is substantive, as will be noted below. As a regularity condition, assume that $\alpha' - .5\beta p^2 > 0$ for the optimal p.

The firm produces at constant marginal cost c in both periods, but it faces a capacity constraint in the first period, at which time it can produce only up to N units.[35] Thus, it maximizes profits (π) by solving the following problem:[36]

$$\max_{p,p'} \quad \pi = (p - c)Q + (p' - c)(\alpha' - .5\beta p^2)(A - (p' - \tau'))$$
$$\text{where} \quad Q = \begin{cases} \alpha(A - (p - \tau)) & \text{if} \quad \alpha(A - (p - \tau)) \leq N \\ N & \text{if} \quad \alpha(A - (p - \tau)) > N. \end{cases}$$

Consider first the case where the capacity constraint is not binding, so that $Q = D = \alpha(A - (p - \tau))$. The first-order conditions produce a system of two equations. Substitution yields the optimal values — labeled $*$ for optimality and u for unconstrained:

$$p_u^* = \frac{A + \tau + c}{2 + \frac{\beta}{\alpha}\left(\frac{A' + \tau' - c}{2}\right)^2}$$
$$p_u'^* = \frac{A' + \tau' + c}{2}.$$

If $\beta = 0$, which means that first period price has no effect on second period demand, as would be true in a standard model, then $p_u^* = \frac{A+\tau+c}{2}$, which is the monopolist's price in a static one period model and is symmetric to the second period price. If β is positive, then the second term in the denominator is also positive. As one would expect, the larger is the second period effect on demand (β), the lower is the optimal first period price. Note that, because the scale effect on the market is multiplicative, the optimal second

[35] The capacity constraint is exogenous in this example. It can be thought of as arising from a choice made in a prior period, in which the producer must pay fixed costs to build capacity but is uncertain of demand.

[36] A discount factor could be added, or, equivalently, α' and β can be interpreted as including the discount factor.

period price is unchanged by first period prices.

In the constrained case, the monopolist's optimal price is below the price that creates N units of demand. Because the monopolist is capacity constrained, it will sell N units at the optimal price, but the market will not clear. There will be excess demand. In this case, the optimal prices may be written as follows, with N denoting the capacity constrained case:

$$p_N^* = \frac{N}{\beta\left(\frac{A'+\tau'-c}{2}\right)^2}$$
$$p_N'^* = \frac{A'+\tau'+c}{2}.$$

As expected, given the independence of second period price from scale effects, the capacity constraint has no effect on second period prices, so that $p_N'^* = p_u'^*$. The first period price changes, however, so that all first period terms no longer influence first period price. The parameters of the first period demand curve are no longer relevant because the seller has chosen a price / quantity bundle that is not on the demand curve.

The main point of this exercise is that, in the capacity constrained case, a shift in the first period demand curve caused by a tax credit does not have an effect on the price charged by a monopolist, unless it causes the monopolist to shift from the constrained quantity to an unconstrained one. The relevant comparative statics from this simple example, assuming that $\beta > 0$, are:

$$\frac{1}{2} \geq \frac{\partial p_u^*}{\partial \tau} > 0 \qquad \frac{\partial p_N^*}{\partial \tau} = 0$$
$$\frac{\partial p_u'^*}{\partial \tau'} = \frac{1}{2} \qquad \frac{\partial p_N'^*}{\partial \tau'} = \frac{1}{2}$$
$$\frac{\partial p_u^*}{\partial \tau'} < 0 \qquad \frac{\partial p_N^*}{\partial \tau'} < 0$$
$$\frac{\partial^2 p_u^*}{\partial \tau \partial \beta} < 0 \qquad \frac{\partial^2 p_u^*}{\partial \tau \partial A'} < 0.$$

The first period tax subsidy has a positive effect on first period price whenever the producer is unconstrained, but it has no effect on price in the constrained case. Second period prices rise 50 cents on the the dollar in response to second period tax subsidy changes. Note that this is identical to the comparative static that would arise in the first period if $\beta = 0$, so that there was no price effect on second period demand. Thus, the effect of first period price on second period demand mutes the tax response in the first period. We see also that an increase in the second period subsidy will *decrease* first period price. The reason is that an increase in the second period subsidy represents a shift in the second period demand curve that makes that market more profitable, and the value of expanding that market through low first period prices expands. Finally, note that the first period tax effect in the unconstrained case gets smaller as β and A' rise, because a larger

β indicates a bigger effect on second period market size and A' indicates a more profitable second period market. Moreover, as $A' \to \infty$, $\frac{\partial p_u^*}{\partial \tau} \to 0$; i.e., as the second period market gets sufficiently large, the first period tax effect will shrink to zero.

This modeling exercise suggests a set of conditions under which a temporary tax credit for the Toyota Prius might not influence the current price charged by Toyota. This would be true if (a) Toyota was capacity constrained when the subsidy was available and (b) by raising price while the tax credit was available, Toyota would hurt the market for their product in the future. Even if they were not capacity constrained, if the size of the future market is sufficiently large, the tax effect in the first period may approach zero.

The key assumption made here is that first period, *subsidy exclusive* prices have an influence on demand in the second period. If second period demand is influenced by the tax inclusive price, then the tax pass through would be different. In the constrained case, the pass through would be 1, not 0. The intuition is simple; in the constrained case, the firm has chosen the optimal scaling factor for the second period market, and it wants to keep this same optimal factor after a change in the subsidy. To do so, it must completely offset the subsidy increase. Thus, which price influences future demand is an important distinction to keep in mind for the discussion of what behavior might give rise to such a stylized model. I move now to a discussion of factors that could give rise to the demand system analyzed in this example.

8.4 Directed Search May Generate Such a Result

In this and the next subsection, I describe two different approaches to explaining why current prices might influence future demand. In this section, I describe how costly search can create this link. In the next section, I discuss the economic literature on fairness. The description in this section can be thought of as rational in the neoclassical sense, whereas the next section relies on what might be called behavioral considerations.

Consider the following description of the car buying process. Consumers do not know the final transaction price of a vehicle or how much they like a particular model until they invest time researching, test driving, obtaining a price quote from a dealer, or even bargaining over price. Consumers do not know the exact price or how much they will like a particular model before incurring these time costs, but they have beliefs about how these outcomes are distributed. Given these beliefs, they choose a model to research, test drive and price and thus receive a draw from the distribution. They can either accept this draw and buy the vehicle or obtain another draw by searching again — over the same model or a different model. At some point, the consumer will choose to end the search process, and will purchase the vehicle that represents the best option from the set of draws.

The model of Weitzman (1979) describes a search problem with all of these features.[37] In his model, an

[37] I am not the first to suggest that the Weitzman model is a good model of the car buying process, see Moorthy, Ratchford

agent faces a set of alternatives, which each have a unique search cost and a distribution of possible outcomes. After searching among several alternatives, the agent chooses the best option. The optimal search algorithm describes the order in which the options are searched and the optimal stopping rule. Weitzman (1979) shows that all of the alternatives can be described by their "reservation value", which is a relatively simple function of the payoff distribution and costs. Agents search the option with the highest reservation value, and they stop when a realized value of one of the searched options exceeds the reservation value of all remaining options.[38]

Consumer *beliefs* about the price distribution of a model, therefore, may influence final demand for that model because it influences the model's reservation value. Higher expected prices will lower the reservation value of a vehicle, which will move it further down the search queue. Since consumers who achieve a good realization from an early search will stop searching and purchase a vehicle, fewer consumers will search over a vehicle when it is moved down the queue. As a result, demand will fall. Note that, even if the actual distribution of prices is constant, a change in consumer beliefs will shift the demand curve inward.

Such a characterization of the car buying process only makes sense if final transaction prices are not costlessly observable. Final transaction prices are not immediately observable in the new vehicle market. List prices are obtainable at minimal cost, but final transaction prices vary significantly across geography, over time and according to idiosyncratic factors, like trade-ins and credit ratings.

Surveys indicate that consumers, on average, consider only about three models before making a new vehicle purchase (Ratchford and Srinivasan, 1993; Moorthy et al., 1997; Ratchford, Lee and Talukdar, 2003). As a result, search order will have a very large impact on demand, which in turn implies that automobile manufacturers should be very concerned with factors that determine consumer's "shopping lists," including past transaction prices.

Past transaction prices will influence future demand for a particular model if past transaction prices are known to consumers and used to form their beliefs about the distribution of prices. Past transaction prices are collected by consumer services agencies, like Edmunds.com and Consumer Reports, and reported to consumers. Past transaction prices are also posted on Internet websites, and they are transmitted via word of mouth within social networks. Thus, it is likely that past prices are used in forming beliefs about future prices.

In terms of the stylized model, this implies that $\beta > 0$, so that higher current prices reduce the number of consumers who search a particular model, and thus reduces future demand. When a new product, like

and Talukdar (1997).

[38] Weitzman uses the term "reservation price," which I have modified to "reservation value" to avoid confusing it with transaction prices. One of the key points of this model is that reservation values are not the same as expected values, even with risk neutral agents. An option that has a higher expected value than another may nevertheless have a lower reservation value.

a hybrid vehicle, is introduced on the market, consumers will be uncertain of its price. If early transaction prices are very high, consumers may expect future prices to be high, and this will shift inward the future demand curve.[39] Thus, an automaker who makes a capital investment that limits the production of a model and then finds that demand is higher than expected faces a choice. If they plan to make a bigger capital investment in the future, so that future sales will rise and the market clearing price will fall, should they let prices rise to clear the market in the short run? If so, demand for the vehicle in the future may fall, if consumers interpret high prices as indicative of future prices.

Might consumers be able to infer that high early prices are an overestimate of future prices? If consumers knew that high early prices were the result of a capacity constraint, or if they understood the true cost of hybrid components, then they might not interpret high early prices as a signal of high future prices in equilibrium. Consumers are unlikely to be informed about production constraints and technology costs in the automobile industry, because much of this information is considered proprietary and is held secret. None of the industry analysts I spoke with claimed to know with any precision how much hybrid components cost Toyota. It seems unlikely, therefore, that consumers are able to estimate future hybrid costs based on fundamentals. Instead, they probably use current and past prices to form beliefs about future hybrid prices.

Tax Equivalence: Which Price Influences Future Demand?

Directed search explains the tax incidence of the Prius only if consumer beliefs are influenced by *subsidy exclusive* past prices. In the stylized model, this means that second period demand was shifted by p, not $p - \tau$. Evidence presented above suggests that hybrid buyers knew of the tax credit and understood its implications. This does not, however, imply that potential future buyers know anything about it. Even if those who purchased while the credit was in effect were perfectly well informed, the price transmitted to future buyers may be the subsidy exclusive price. Prices posted on internet chat rooms, Edmunds.com, Consumer Reports and other such sites are almost always tax exclusive prices. Individuals sometimes report "out the door" prices which include taxes and fees, but, since sales taxes vary across localities, reporting agencies typically report tax exclusive prices. In the case of the hybrid tax credit, these agencies did not subtract out the credit when reporting transaction prices.

Note also that, if Toyota is concerned with how the subsidy exclusive price influences future demand, then a subsidy paid directly to Toyota might have had a different incidence. This is in contrast to standard models, but it is a natural consequence of the stylized example, given the assumption that the relevant signal is tax exclusive.

[39] Note that high prices could also be interpreted in some cases as a signal of quality. I abstract from such concerns in the present discussion, but this could be built into a more formal model.

If consumers do know about the tax credit and attempt to adjust their forecast of future prices accordingly, they will have to have a method for distinguishing between a higher price due to taxes and a change to Toyota's long term projected costs. The costs of a new technology are uncertain, even to the manufacturer. Automakers are continually updating their beliefs about long run costs and viability of varying hybrid systems. If Toyota adjusted upward their long run cost projections, this may look just like an increase due to a temporary tax credit to consumers. Given this ambiguity, it may be profit-maximizing to ration quantities in early periods. A temporary increase in demand due to a tax credit may therefore have no effect on price because the manufacturer wishes to signal a particular future price to the market.

The Role of Dealerships

Once Toyota sells a vehicle to a dealer, the dealer owns it, and Toyota is prohibited from dictating the retail price. Even if Toyota wanted to keep prices below market clearing levels, why would dealers not raise prices? The most obvious answer is that, while Toyota is legally prohibited from setting retail prices, they nevertheless have enormous leverage over dealerships and can punish dealerships who do not comply with their sales strategy. According to Toyota dealers that I spoke with, Priuses were allocated based on how fast they were sold by dealerships. Thus, if a dealership raised the price of a Prius, so that it cleared the local market, eliminated the wait list, and Priuses took longer to sell, then that dealership would see the arrival rate of future Priuses decline. This would have been quite costly, since the Prius, even if it sold at sticker price with no markup, was grossing far more than any similarly priced vehicle. Thus, even if dealers had no independent reason to hold prices below market clearing levels, Toyota was probably able to incentive them to comply with their pricing scheme.

8.5 Concerns for Fairness May Generate Such a Result

A starkly different interpretation of the stylized model is based on behavioral considerations, including a concern for fairness. If consumers are willing to punish firms that are perceived as unfair, then prices may not respond to a tax subsidy if such a price change is deemed unfair. While this is unnatural in a neoclassical model, there is a substantial body of research that documents concerns for fairness and a willingness to punish. In terms of the example above, a firm violating fairness in the first period will shift the demand curve downward in the second period (i.e., $\beta > 0$).

Behavioral considerations may also explain the case of the Prius if consumers are subject to framing biases, in the spirit of Kahneman and Tversky (1979). In the car market, vehicles are commonly classified into segments (sedans, compact cars, midsize SUVs, etc.) and price levels (economy, luxury, etc.). Vehicles

are frequently compared to other vehicles in their "class" in terms of their reliability and performance. If framing matters, consumers may rate a car differently depending on the quality of other vehicles in its class.

The Prius is typically classified as a compact sedan, but it is the most expensive compact sedan, and is more expensive than many midsize sedans. If prices had risen during the wait list period, the Prius would have approached the price of some *luxury* sedans, which tend to have significantly better performance and features. Consumers may have deemed the Prius to be of inferior quality if they compared it to these luxury sedans, and this reputation may have influenced future demand. If so, then Toyota may have wished to hold prices below market clearing levels to maintain a comparison with compact sedans. An increase in demand due to the tax credit might therefore not have influenced price.

Behavioral concerns may also explain why *dealers* did not raise prices to clear the market. Kahneman, Knetsch and Thaler (1986) asked consumers whether or not it was fair for an automobile retailer to raise prices by $200 in response to a shortage for a popular model. In one version, respondents were told that the dealer had been selling the car at the list price; the increase would therefore require charging more than the sticker price. In a second version, respondents were told that the dealer had been selling the car at $200 below list price; the increase would therefore lead to a new price equal to the list price. In the first case, 71% of respondents said the price increase was unfair, but only 42% thought the price increase was unfair in the second case. (The difference is statistically significant.)

This is direct evidence that the sticker price is a salient reference point. Dealers may have felt that charging above the sticker price would be perceived as unfair. Car dealers may be especially concerned about such reputations because many consumers distrust them. If dealerships experience a discrete reputation cost when charging above the sticker price, a marginal increase in demand due to a temporary tax credit may induce no transaction price response. Note also that this means that the sticker price is a way for Toyota to influence retail prices, if the sticker price acts as a ceiling on the retail price.

More generally, consumers appear to rate the fairness of a price change differently, depending on the perceived cause of the change. Kahneman et al. (1986) ask several questions that demonstrate the difference in perceived fairness between price increases due to temporary shortages versus changes in cost. In one example, they ask respondents whether or not it is fair for a hardware store to increase the price of snow shovels the day after a snowstorm; 82% say that this is unfair. Frey and Pommerehne (1993) follow a similar method and find that 80% of respondents believe that price increases made to clear markets with short-run excess demand are unfair.

Toyota may be especially concerned about fairness perceptions in regards to the Prius because the Prius has generated public goodwill for Toyota. For many, the Prius is a metonym for Toyota, while the Hummer is a metonym for General Motors. For those concerned with the automobile industry's role in carbon emissions,

this reflects positively on Toyota and negatively on GM. It may be partly because of this gap in perception that there was no outcry when Toyota passed GM in global sales in the first quarter of 2007. This marked the first time in 80 years that GM was surpassed, but there appeared to be more celebration of Toyota's leadership in fuel economy than nostalgia for the American company's age of dominance in the public discourse. In other circumstances, it is easy to imagine Toyota's ascension as a spark for policy intervention to aid the domestic industry. This is not directly a reason why Toyota would not charge more for a Prius, but it is a reason why Toyota has a significant investment in the goodwill afforded by the Prius. If sharp price changes in response to taxes jeopardized that goodwill, Toyota might be better served to forgo the revenue from a higher price.

Tax Equivalence and Fairness

A concern for fairness may also break tax equivalence, if consumers view a subsidy rebated to them differently than a subsidy rebated to a seller. This line of reasoning suggests an interpretation of the results in Busse et al. (2006), who find that consumers capture roughly all of a customer cash rebate, but less than half of a dealer cash incentive. They attribute this result to information asymmetry, but it is also consistent with consumers feeling some "ownership" over a rebate given directly to them. If consumers feel entitled to a cash rebate or tax credit "given to them," then incidence may depend on which side of the market remits the tax.

Willingness to Punish is Key

We should expect firms to respond to fairness criteria only if future demand responds to violations of fairness norms. Some evidence regarding consumer willingness to punish firms that offend fairness norms comes from similar survey questions (Kahneman et al., 1986; Campbell, 1999). A willingness to punish has also been shown in experiments (see Fehr and Gächter (2000) for a discussion of the evidence).

Another piece of evidence regarding the value of fairness perceptions to a firm comes from a recent episode in the mobile phone market. In July 2007, Apple introduced the iPhone, a high priced mobile phone. The 8-gigabyte iPhone debuted at a price of $599, and people queued for days to buy one on the release date. Only two months later, in September, Apple dropped the retail price by a third to $399. Consumers who had purchased the identical phone in the first two months were outraged. The public relations pressure was sufficient to move Apple CEO Steve Jobs to post an open letter apologizing to customers and to provide all early purchasers with a $100 store credit. This rebate was essentially a $75 million check written to consumers to recover goodwill.[40]

[40]In early September, Apple claimed to have sold its millionth iPhone. As a conservative estimate, if Apple had to rebate

In sum, a link between current prices and future demand can explain the tax incidence observed in the data. This link could be forged by imperfect information, which forces consumers to use past prices as a signal of future prices. Or, it could be created by behavioral considerations, including fairness perceptions. I next present additional evidence from the data that links the incidence result to the wait lists, and then conclude with lessons for future research on tax incidence.

8.6 Evidence in Support of the Importance of Wait Lists

The modeling exercise suggests that incidence may depend on whether or not a product is in excess demand. Several pieces of evidence from the hybrid market are consistent with this. First, in the case of the Prius, the difference between the first two and the final tax change is consistent with incidence differing in the presence of wait lists. Second, Prius prices were more sensitive to other price determinants when there was not a wait list, which supports the notion that prices were inflexible during the 2004 to 2006 model years. Third, evidence from other hybrid models confirms the case of the Prius — those vehicles that had wait lists look similar to the Prius in their response to taxation.

The bounding exercise produced a much tighter bound on the first two tax events than the second (see table 6). Thus, it may be the case that the pass through effect of the final tax change, at which time there was no wait list, was larger than the first two events. Toyota's introduction of the economic savings bonus program is also suggestive of a response to taxation, even though the price influence of this program was offset by the change in low interest financing. Recall again the argument that consumers may have perceived a price cut that offset the tax change, even if this was true, as suggested by (Busse et al., 2007).[41]

In addition, the price of the Prius was more sensitive to other factors during the wait list period. Table 13 shows regression results from a model of Prius prices in which the end of the month dummy, the price of gasoline and weeks that the model has been available are interacted with a wait list dummy. For this specification, I assume that all 2004, 2005 and 2006 model year Priuses were on a wait list, and 2002 and 2007 models were not. All three interactions are statistically significant, demonstrating that the Prius was more sensitive to these factors when there was no wait list in place. This corroborates the notion that the price of the Prius was inflexible during wait list periods, which explains why tax changes would not influence prices.

Finally, bounds estimated for the price effect of tax changes on other hybrids are broadly consistent with zero effects for vehicles on wait lists, and not for other models. Only two non-Toyota models were present in

$100 on only 750,000 units, that would work out to be $75 million.

[41] Note that the estimates from the state tax changes are almost entirely based on the wait list period. Thus, the state variation is not helpful in directly comparing the wait list period to the non-wait list period, but it does confirm that the low pass through result is due to variation in the wait list period.

reasonable numbers before the tax policy was initially introduced. These are the Ford Escape and the Honda Civic. The Ford Escape did not sell at an especially fast turnover at any point in its history. The Honda Civic, however, looks much like the Prius at the end of 2005 and beginning of 2006, when the tax credit was introduced. The 2006 Honda Civic debuted a fully redesigned body style, and both the conventional and hybrid versions of the Civic sold at a very rapid rate, making them look much like the Prius during the tax change.

There are two other Toyota vehicles with sufficient available data, the Highlander and the Camry. The Highlander Hybrid has sold like a normal vehicle for its entire history. The Camry was introduced shortly before the first tax phase-out, and was in excess demand at that time. It was still selling at a very fast rate, and was unavailable on lots in many locations, at the second phase-out.

Table 14 reports the incidence bounds for these other vehicles using the same specification as column three in table 6, which is reported again for comparison. The Escape and Highlander, which did not experience excess demand, show higher upper bounds. In two out of three cases for the Highlander and in the case of the Escape the lower bound estimate is also positive, unlike the Prius. These estimates are, however, far less precise than the Prius estimates. The Civic and Camry, which were in excess demand at the tax changes, both have negative lower bounds, with varying tightness on the upper bound, just like the Prius.

Overall, this evidence indicates that Prius prices were inflexible during the wait list period, and that this inflexibility led to no change in transaction prices in the face of tax changes. Thus, as an empirical matter, the incidence of a tax may be quite different when a product is in excess demand. This is consistent with the stylized example described above. Several other lessons for the economics of tax incidence are suggested in the next section.

8.7 Lessons for the Economics of Tax Incidence

The model above demonstrates that, when current prices influence future demand, a model of tax incidence may generate predictions that deviate significantly from standard models. In general, if future demand is inversely related to current tax exclusive prices, then consumers will bear more of the burden of a temporary tax (or gain more of the benefit of a subsidy) than would otherwise be the case.

In addition, the incidence of a tax introduced when a product is experiencing a shortage may be different than the same tax placed on the same product at a different point in time. Temporary and permanent taxes may also be expected to have different effects in the presence of a binding capacity constraint.

Furthermore, if the current *tax exclusive* price is the price that determines future demand, then the model suggests that a subsidy to consumers may have a different incidence than a subsidy to producers.

The economics of taxation has recently shown renewed interest in cases under which various tax equivalence theorems fail to hold. Slemrod (2007) analyzes a partial equilibrium model that characterizes conditions under which tax incidence varies, according to who remits a tax. This is closely related to the labor supply model of Slemrod (2001). The driving force behind incidence asymmetry in these models is tax avoidance, compliance and enforcement, which depend on the system of remittances. This line of reasoning is pursued in both Slemrod (2007) and Kopczuk and Slemrod (2006) as an explanation for the real world discrepancies between theoretically equivalent retail sales taxes and value-added taxes. A recent paper by Chetty, Looney and Kroft (2007) explores a different failure of tax equivalence. In a field experiment, they find that demand falls for groceries that are posted with tax inclusive prices. They interpret this result in a bounded rationality framework, in which consumers incur cognitive costs when calculating tax-inclusive prices. In the car market, Busse et al. (2006) argue that information asymmetry generates differences in the incidence of manufacturer incentives — which act like a subsidy — depending on whether incentives are rebated to consumers or dealers. The case of the Prius highlights conditions under which remittance matters, not because of avoidance, bounded rationality or information asymmetry, but instead because tax exclusive prices influence future demand.

The case of the Prius highlights several conditions that increase the likelihood that current prices will influence future demand. First, the Prius was a new product and the manufacturer was uncertain about consumer demand. This led to a conservative capital investment, which led to a binding capacity constraint. It also meant that consumers were unsure of the price. Second, the Prius generated goodwill among consumers towards Toyota. Toyota may have been especially reluctant to raise prices temporarily, if it might jeopardize goodwill. Third, it is costly to learn about prices in the car market. As a result, past prices, which are reported on the Internet and in consumer buying guides, hold considerable value in informing car buyers on how to direct their search for a new vehicle. Future research that determines which of these conditions is pivotal, and that distinguishes between "rational" and "behavioral" explanations, could shed considerable light on how taxes effect behavior in a variety of markets.

Many "green" products are likely to feature these conditions. Many firms now feature products that are environmentally friendly for marketing and public relations reasons. And, many "green" products are new products, for which the overall market demand is uncertain. As government agencies seek to encourage environmentally friendly practices through the tax system, the potential for incidence asymmetry and the incidence results for the Prius should be kept in mind.

Immediate examples of similar products are other advanced technology vehicles, such as plug-in hybrids, hydrogen fuel cell vehicles, clean diesels and solar or electric powered cars. Many of these advanced technology vehicles are already subsidized by state and federal policies, and they are likely to receive further subsidies in

the future. A reasonable expectation for any of these products, if they become popular, is that early adopters would get a windfall gain from government subsidies. For example, a new line of electric sports cars, made by a firm called Tesla Motors, will go on sale during the 2008 model year. The first year's entire production line has already been sold ahead of time. The vehicles will likely qualify for preexisting tax incentives, but this will not affect the price paid by consumers to Tesla.

9 Conclusions and Directions for Future Research

This paper uses transaction level data on new vehicle purchases to assemble several pieces of evidence which indicate that consumers captured the significant majority of the benefits from tax subsidies for the Toyota Prius. The federal tax credit for hybrids, which was introduced by the Energy Policy Act of 2005, created three sharp changes in the value of federal tax subsidies. Incidence estimates based on comparing transaction prices just before and just after each tax change show that subsidy exclusive transaction prices moved very little, if at all, which implies that consumers captured the bulk of the subsidy.

Many transactions were shifted across time in order to maximize tax benefits. This implies that consumers were aware of the tax policy, and it raises the possibility that consumers who purchase just before or just after a tax change differ systematically from each other, because some choose to move their transaction to gain the higher tax subsidy but others do not. The paper develops a method of bounding the effect of the tax in the presence of this type of heterogeneity, which may be useful to incidence analysis whenever tax changes are anticipated. This methodology yields informative upper bounds on the first two tax changes and verifies the conclusion that consumers captured the majority of the subsidy.

An analysis of the incidence of state tax incentives corroborates this result. The paper uses a state panel research design and finds that consumers capture all, or nearly all, of state tax benefits. The empirical finding that consumers capture the bulk of state and federal tax benefits has important implications for policy and for future research on tax incidence.

The federal government spent approximately $400 million on the tax credit for the Prius. The incidence estimate in this paper implies that this money went directly to Prius owners, not to Toyota or to dealers. A full evaluation of the policy would include not only an incidence estimate, but also an estimate of the effect of the credit on the total number of Priuses sold. A full analysis of the latter question requires a structural approach, but institutional facts give reason to doubt that the production response was significant. Given that there were wait lists prior to the 2006 model year, Toyota probably did not produce any "extra" Priuses as a result of the policy, since they appear to have been capacity constrained before the law was passed. Toyota made a major capital investment prior to the 2007 model year, but this investment was made with

the knowledge that the tax credit was already scheduled to phase-out. Thus, the credit probably had little impact on the capacity expansion.

As mentioned in the introduction, Gallagher and Muehlegger (2007) find that state sales volumes rose in response to tax credits and other incentives. One cannot readily interpret their estimates as a *production* response, however, since their reduced form methodology does not distinguish total sales effects from timing effects or geographic diversion. Toyota's response to a state tax policy may be to divert Priuses that would have been sent to a different state into the state with the incentive. Future research that estimates a production response to the federal credit or untangles geographic shifts in sales from the overall production response would be an important complement to the price analysis performed in this paper.

The finding that consumers captured a significant majority of tax incentives is important beyond the scope of immediate policy analysis because the result is difficult to explain in standard models of tax incidence. The paper argues that Prius buyers captured the benefits of tax incentives because Toyota believe that raising prices would jeopardize future demand for hybrids. The paper provides a theoretical example in which future demand depends on current prices, which might make a seller with a capacity constraint willing to hold prices below the market clearing level, in order to increase future demand.

In such a model, the standard result that who remits a tax does not influence incidence may not hold. There is growing interest in public economics regarding such deviations from traditional tax theory, which may be guided by the case of the Prius. The characteristics of the Prius market that likely contributed to this situation were that it was a new product, that learning new vehicle prices involves costly search, and that consumer good-will toward the company was tied to the product. Many "green" products are new and are used by firms to generate goodwill for a brand, and many such products are likely to be subsidized by governments aiming to combat rising environmental and security concerns raised by the consumption of oil. Such policies should be designed with potential incidence asymmetry in mind. In addition, future research should consider such policies a fruitful area for finding deviations from traditional tax theory which may deepen our understanding of how non-standard considerations determine how taxes affect real world behavior.

Appendix

This appendix provides details about the measure of dealer cost used throughout the paper, analyzes the stability of this measure and documents the adjustment made to account for the price change instituted by Toyota in April 2007. The results presented in the paper above are sensitive to whether or not dealer cost is controlled. Thus, it is important to determine whether or not dealer cost varies over time because Toyota charges dealers a different amount for identical cars, or because the percentage of cars with more expensive options fluctuates. Toyota also made a change to invoice and sticker prices in April 2007, which it called an

"economic savings bonus." The base price of the vehicle did not change, but the invoice and sticker price of each options package did. Thus, to compare identical vehicles before and after the tax change, it is necessary to adjust dealer cost for cars sold in April, which requires knowing which options package each vehicle had. Since their is no indicator for options packages in the data, I develop a method for assigning options packages to each car by examining the dealer cost data.

In the case of the Prius, the vast majority of the variation in dealer cost comes from the factory-installed options package. The 2006 Prius had eight options packages, and the 2007 Prius had six. Each vehicle is shipped from the factory with one of these options packages installed, adding up to $6,000 to dealer cost. If the data included an indicator for each options package, one could simply see if Priuses with any particular options package cost the same amount before and after each tax change. Even without this, if the dealer cost variable in the data was influenced only by the options package, then the dealer cost measure could easily be matched to outside information on the invoice price of each package. There are other factors that influence the dealer cost, however, which introduce noise into this procedure.

Dealer invoice of the base model and each options package is readily available from online sources, which acquire this information and provide it to consumers for purposes of price negotiation. The challenge is to match this precisely to the measure of dealer cost in the data. The measure of dealer cost available in the data includes factory installed options, dealer installed "hard add" options, advertising fees and the delivery charge. It does not include what is known as the holdback.

Factory-installed options include not only the options package, but also small additional features, like floor mats, a cargo net or a satellite radio. Thus, two Priuses with the same options package may differ in price because one includes a cargo net, and the other does not. Dealer cost will also reflect "hard adds," features that add to the resale value of the car, such as a roof rack or upgraded tires. It is impossible to determine from cost data alone which of these features is present in a vehicle, and these factors therefore introduce noise into the process.

Recall from section 2 that dealer invoice prices for identical items do not vary across localities, in accordance with franchise law, but geographic variation does arise in small measure through fees. Toyota adds $55 to the delivery fee for Alabama, Georgia, Florida, North Carolina and South Carolina. Since the delivery charge is a known function of state, I can easily account for this in the calculations. There may also be some geographic variation in document preparation fees, however, which will introduce a small amount of noise. More substantial variation may come through advertising fees, which are typically between 1% and 3% of the base MSRP for a vehicle, depending on the cost of advertising in the local market. There is no reliable source of information that indicates the variation across geography in advertising fees. My accumulation of anecdotal evidence, however, suggests that most Priuses were charged very close to 2% of base MSRP.

The final important discrepancy between dealer invoice and dealer cost is what is known as the holdback. The holdback is a rebate that the dealer receives from the manufacturer after a car is sold. In the case of Toyota, the dealer holdback is known to be 2% of the base MSRP. Thus, dealer invoice prices quoted in consumer resource guides are 2% higher than the actual final cost to the dealer. Since the measure of cost in the data nets out holdback, it is necessary to subtract holdback from the invoice price to make them comparable. Since the cost measure includes advertising fees, however, which are estimated to also be roughly 2% of base MSRP, I let these two omissions cancel each other out. This will be correct on average, but it will induce variation, to the extent that advertising fees are above or below 2% in a particular location.

Thus, several considerations create small amounts of variation in the dealer cost measure. This variation makes it impossible to match exactly each vehicle to an appropriate invoice price and thereby infer the options package. Fortunately, the noise appears to be small enough that the imputation is meaningful. In figure 13, I show a kernel smoothed density of the dealer cost of all 2007 Priuses in the sample between September 2006 and March 2007. The dealer cost variable is adjusted for the $55 surcharge on deliveries in the relevant states. The vertical bars are at invoice prices, estimated from Edmunds.com data as follows: I sum the base price, options package price and delivery fee for each vehicle. Based on my reading of numerous consumer accounts, I add the dealer invoice price of floor mats to all but the least expensive options package, since all consumers report floor mats being included on all Priuses with options package 2 or greater in these years. Overall, figure 13 shows remarkable consistency between high points in the density, and the invoice prices. If advertising fees are on average 2% (and thereby offsetting the holdback on average), we would expect modal prices to be somewhat to the right of each line, since small additional options would add weight to the distribution asymmetrically.

Now, I move specifically to a discussion of how cost may vary around each tax change. Recall from section 2 that the dealer's invoice price of a vehicle rarely changes during the model year cycle. When these prices do change, this is usually a part of a public campaign, as in the case of the "economic savings bonus" for the Prius in April 2007. Instead, the manufacturer typically manipulates price by offering cash incentives to dealers. *Automotive News* reports on these types of incentives for all models weekly, and it reports no such dealer cash incentives for the Prius at any point, with the exception of a cash incentive that appears to have affected a very small proportion of vehicles (see section 2 for details and citations). Thus, we are looking for confirmation that there were no other cost changes.

Figures 14 to 16 show kernel density plots of vehicle cost for the two months surrounding each tax change. Looking at the first two tax changes, it is apparent that there was a composition shift. There were clearly more richly equipped Priuses sold in December 2005 than January 2006; and there were clearly fewer sparsely equipped Priuses sold in September 2006 than October 2006. In addition, there appear to be spikes in prices that line up at nearly identical values in each case. This suggests that, for these two experiments, there was a noticeable composition change, but that identically optioned cars cost dealers the same amount before and after the tax changes.

As expected, figure 16 tells a different story. In this case, there appears to be both a shift in composition and a dramatic shift downward in cost from March to April 2007. This coincides with the introduction of Toyota's sale. Since the composition does not appear stable, it is important to compare cost adjusted consumer prices to estimate a tax effect. To do so, I assign an options package value to each vehicle from April 2007 and then use the cost measure that would have been in effect for that vehicle, had it been sold in March. Note that this procedure will blur dealer's gross profit and confuse the allocation of benefits between Toyota and dealers, but, if the assignment is correct, it will accurately reflect consumer prices.

Table 15 shows the MSRP and dealer invoice prices for each options package before and after the price change, according to Edmunds.com. I assign each Prius an options package as follows. I add the base price, the delivery charge ($660), and the cost of floor mats ($141) to each options package according to April prices. Because locations with lower than average advertising fees will have costs below this number, I assign cut-off values at $100 below this number. Any Prius with a price greater than this number, but less than the next highest cut-off is assigned to that options package. Having assigned options packages, I then add the cost difference back into dealer cost. If the vehicles were correctly assigned, then the dealer cost will now be identical to the dealer cost in March for the same vehicle.

Figure 17 shows the adjusted April cost distribution against the March distribution. These now look remarkably similar in the location of peaks. This highlights again that there was a composition change, with more expensive options packages being sold in April. Overall, this similarity of the March and April distributions suggests that the adjustment procedure did a good job assigning options values based on cost.

Figures 14 to 17 provide visual evidence to support the industry reports that suggest costs were stable through the tax windows, once one has accounted for the April price cut. A statistical test of this proposition can be performed as follows. First, I use the same procedure as described above to assign options packages to each vehicle based on cost to assign all 2006 and 2007 Priuses an options package. Then, I run a regression of the form:

$$Cost_{ij} = \alpha H + \psi_j + \varepsilon_{ij}$$

separately for each four week period surrounding a tax change, where H is a dummy for the high tax portion of that window and ψ are options package fixed effects. The regressions exclude a small number of vehicles that lie below the estimated minimum invoice price and vehicles more than $1,000 above the maximum. Table 16 reports the coefficients and standard errors on α. Sensitivity analysis showed that some results are sensitive to the size of the downward adjustment for minimum prices in a tier. I thus report a variety of values.

Overall, this table confirms the industry reports and visual evidence. Dealer cost did not change within the tax windows, except for the known sale in April. Column 1 shows that, in only 1 of 6 cases is the difference in January and December costs statistically significant. In no case is the September to October difference significant. In the March versus adjusted April comparison (column 3), 3 of 6 cases yield a significant difference. This may be due to imperfections in the cost adjustment, or it may be a statistical anomaly. As expected, if this procedure is used to compare the March and the unadjusted April numbers,

there is a vast difference in costs.

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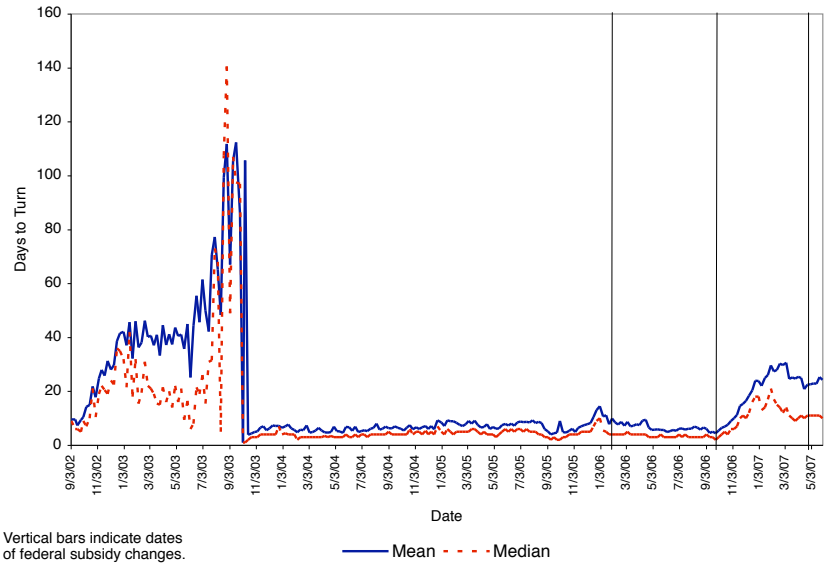
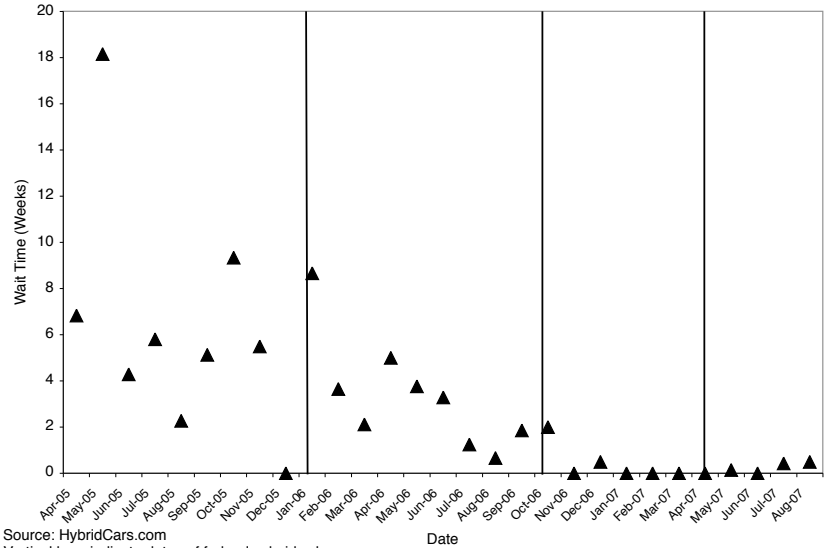
FIGURE 1: Average Days to Turn of Toyota Prius



Vertical bars indicate dates of federal subsidy changes.

FIGURE 2: Mean Reported Length of Wait List for Priuses by Month



Source: HybridCars.com
Vertical bars indicate dates of federal subsidy changes.

FIGURE 3: Distribution of Sales in December 2005 and January 2006, Prius and Non-Hybrid Toyota Sedans (First Tax Change)

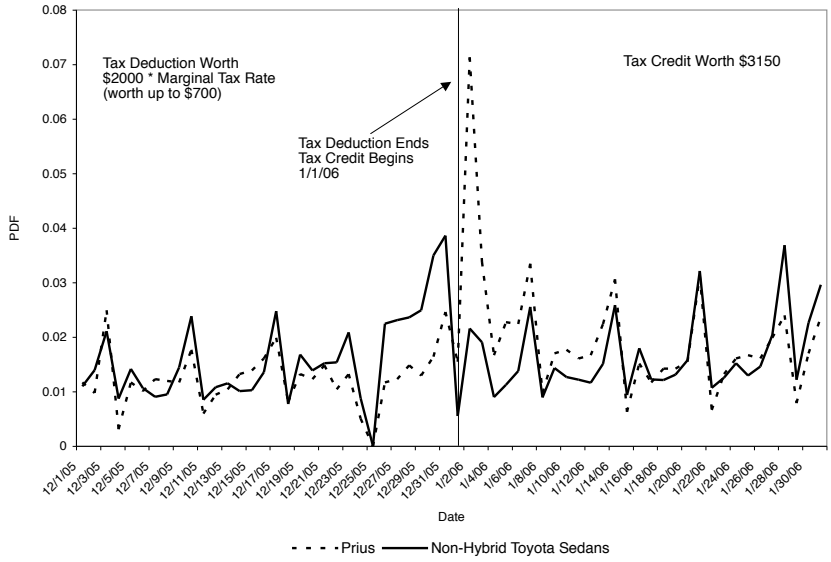


FIGURE 4: Distribution of Sales in December 2004 and January 2005, Prius and Non-Hybrid Toyota Sedans (No Tax Change)

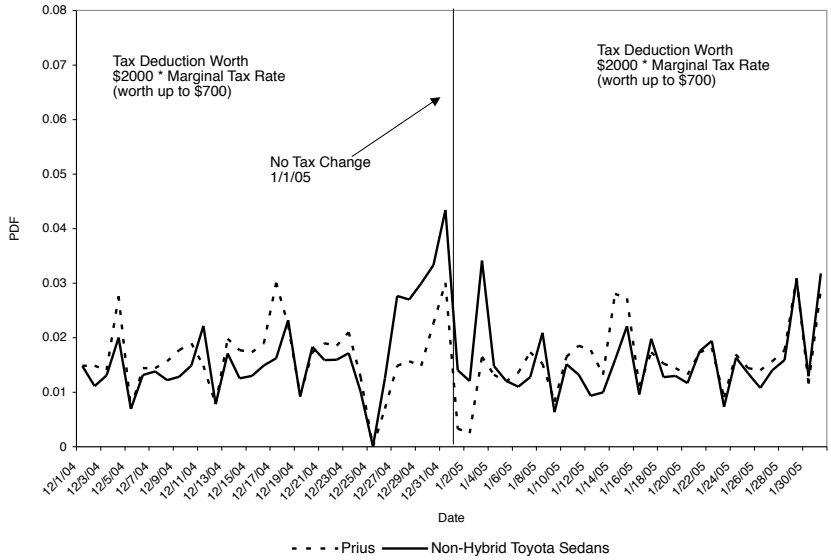


FIGURE 5: Distribution of Sales in September 2006 and October 2006, Prius and Non-Hybrid Toyota Sedans (Second Tax Change)

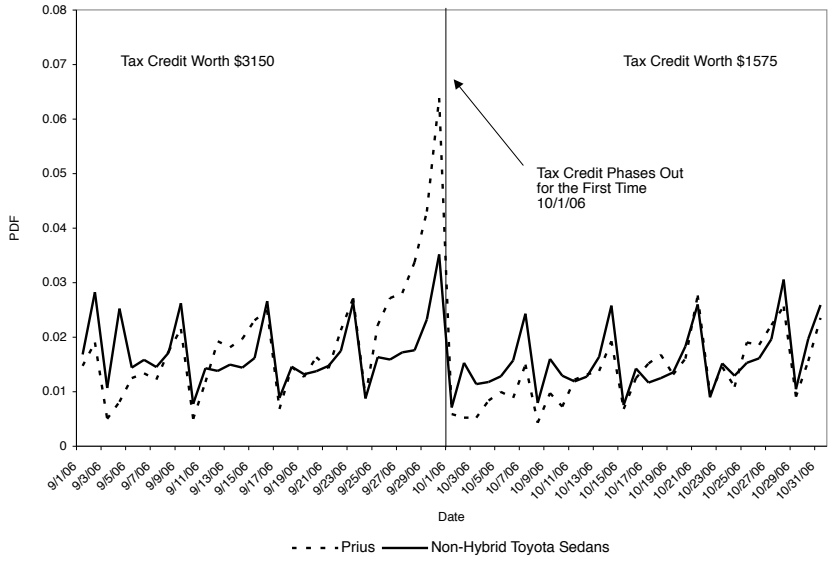


FIGURE 6: Distribution of Sales in September 2005 and October 2005, Prius and Non-Hybrid Toyota Sedans (No Tax Change)

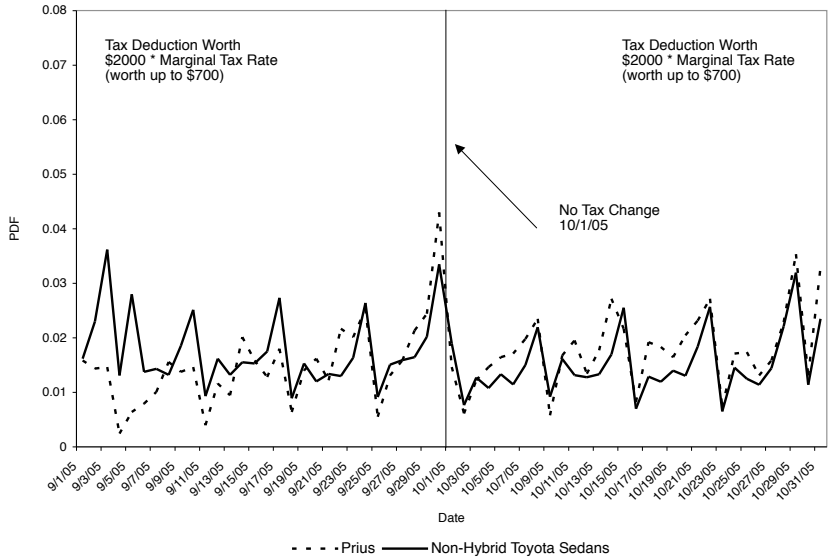


FIGURE 7: Distribution of Sales in March 2007 and April 2007, Prius and Non-Hybrid Toyota Sedans (Third Tax Change)

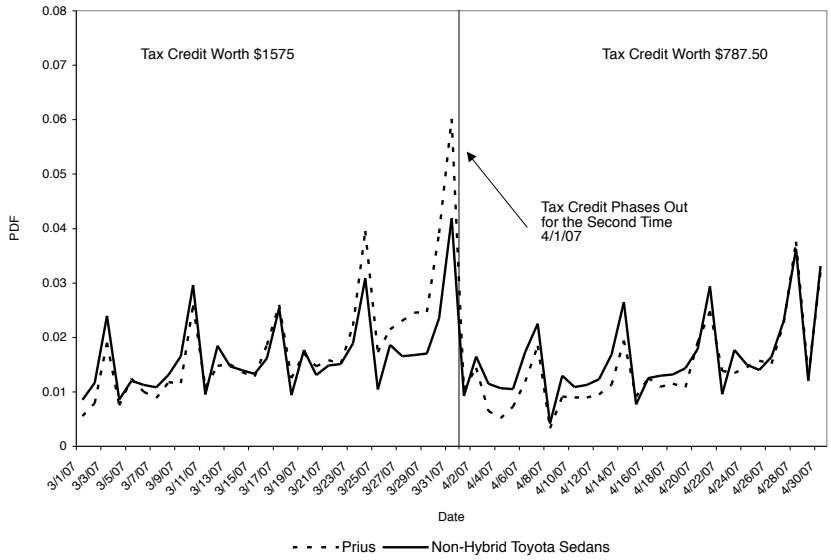


FIGURE 8: Distribution of Sales in March 2006 and April 2006, Prius and Non-Hybrid Toyota Sedans (No Tax Change)

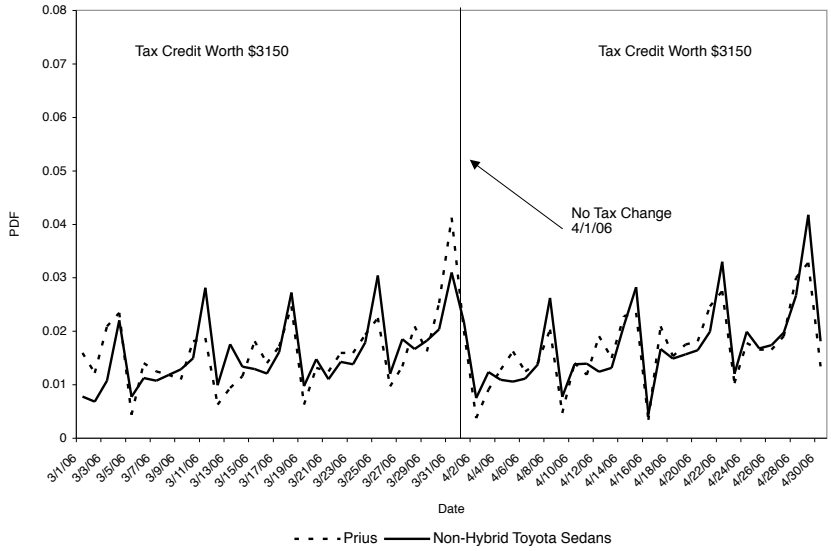


FIGURE 9: Mean Prius Prices, December 2005 and January 2006

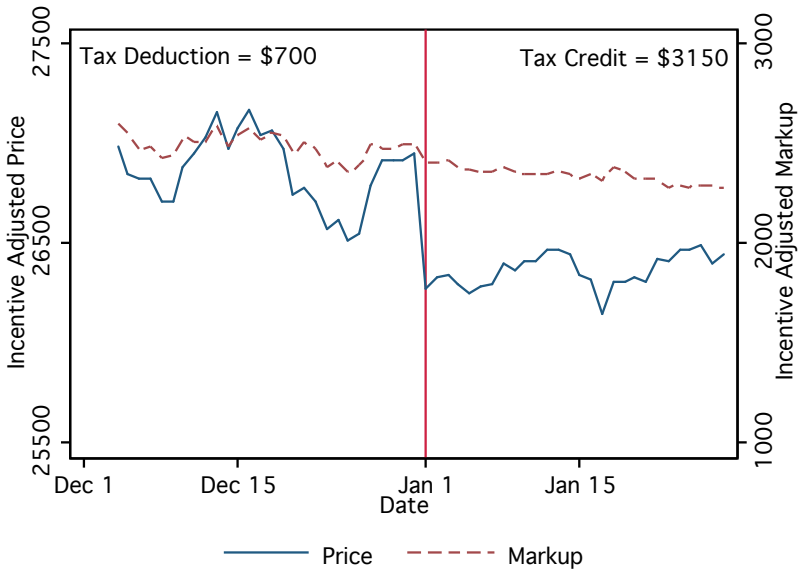


FIGURE 10: Mean Prius Prices, September and October 2006

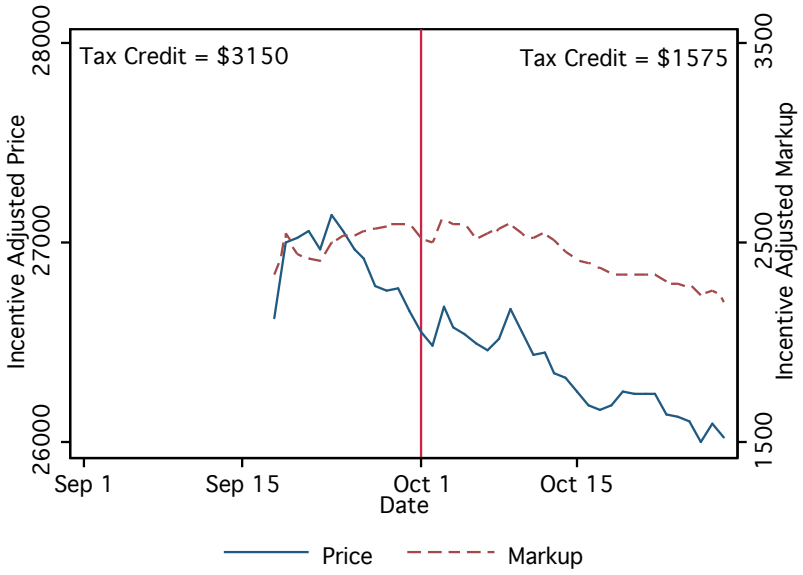


FIGURE 11: Mean Prius Prices, March and April 2007

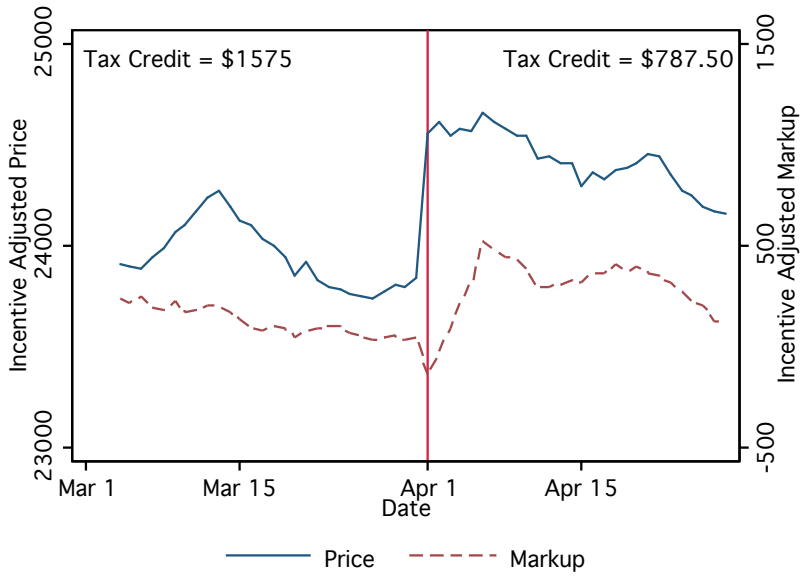


FIGURE 12: Google Trends Chart of Searches for 'Hybrid Tax Credit'

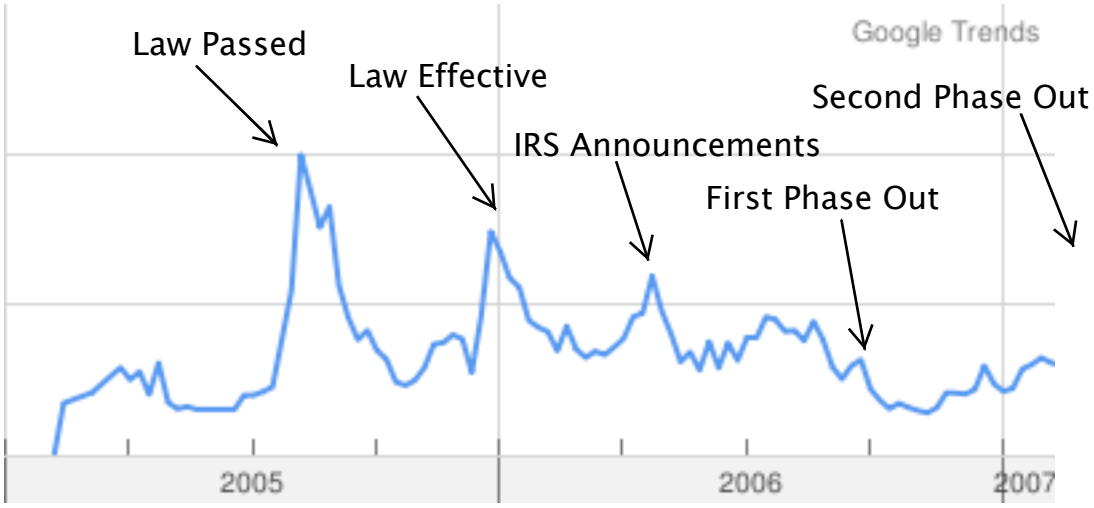


FIGURE 13: Estimated Density of Dealer Cost for Prius, September 2006 to March 2007

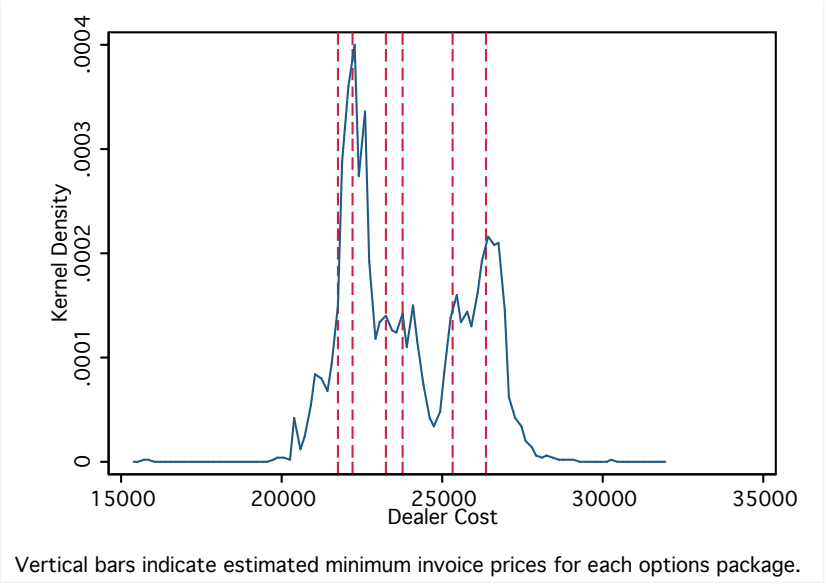


FIGURE 14: Estimated Density of Dealer Cost for Prius, December 2005 and January 2006

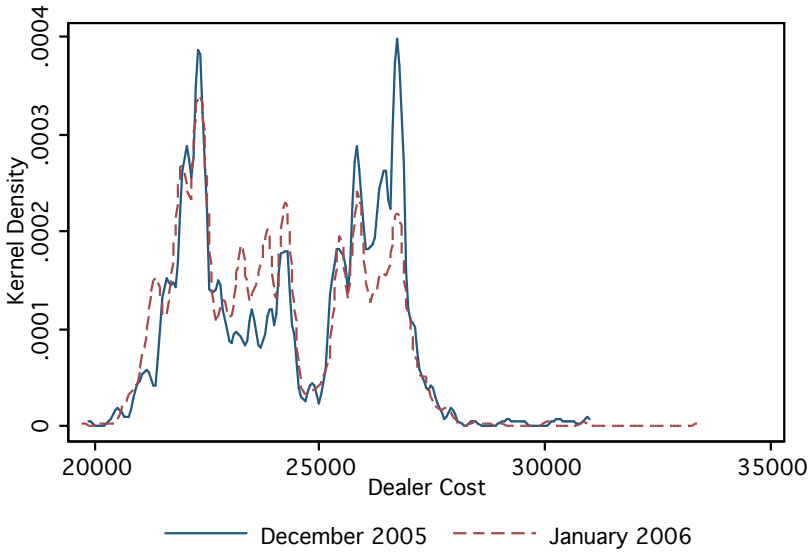


FIGURE 15: Estimated Density of Dealer Cost for Prius, September and October 2006

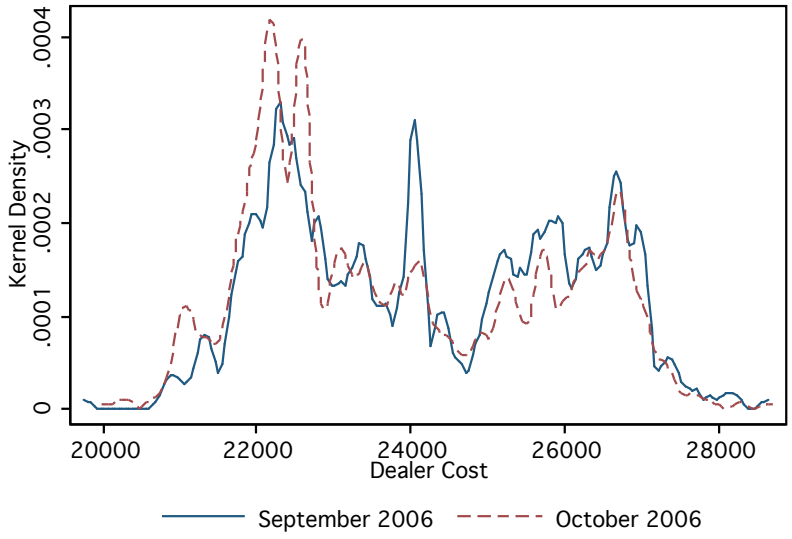


FIGURE 16: Estimated Density of Dealer Cost for Prius, March and Original April 2007

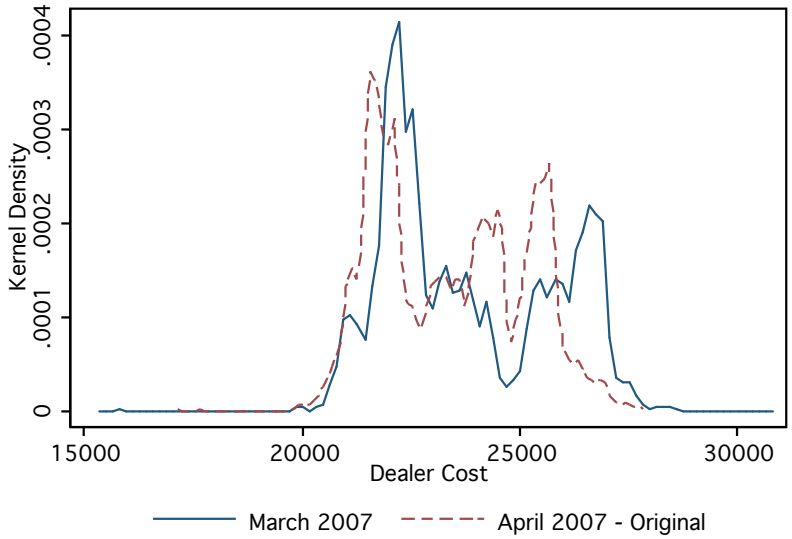


FIGURE 17: Estimated Density of Dealer Cost for Prius, March and Adjusted April 2007

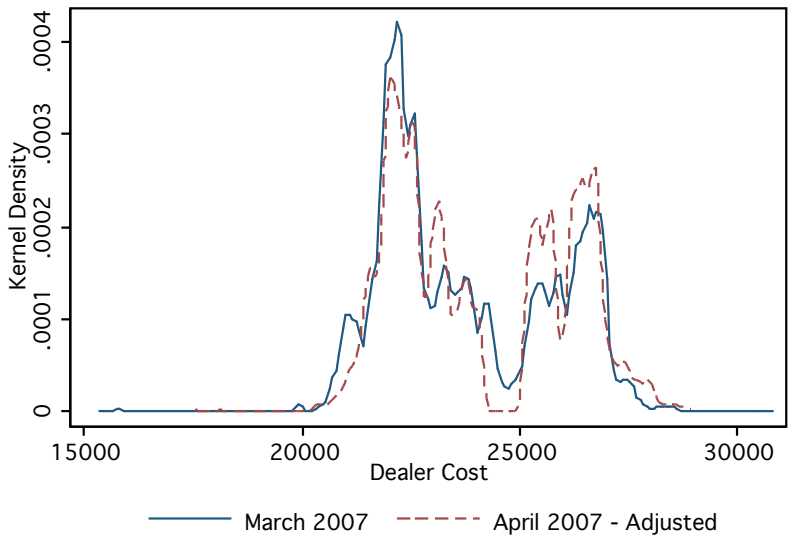


TABLE 1: Variation in Federal Tax Incentives for the Toyota Prius

Date Effective	Tax Incentive
Jan 1 2001 to Dec 31 2005	$2,000 deduction (up to $700 value in 2005)
Jan 1 2006 to Sep 30 2006	$3,150 credit
Oct 1 2006 to Mar 31 2007	$1,575 credit
Apr 1 2007 to Sep 30 2007	$787.50 credit
Oct 1 2007 forward	no credit

Source: Internal Revenue Service

The maximum value of the deduction varies slightly over time because the top marginal tax rate varies.

TABLE 2: Final Sample of Priuses by Model Year
(Sample Size, Mean Incentive Adjusted Price and Incentive Adjusted Markup)

Sample Size

	First Tax Change		Second Tax Change		Third Tax Change		Entire Sample
	Last 2 Weeks	First 2 Weeks	Last 2 Weeks	First 2 Weeks	Last 2 Weeks	First 2 Weeks	
Model Year	December 2005	January 2006	September 2006	October 2006	March 2007	April 2007	Total
2003							2,381
2004							7,776
2005	80	82					20,897
2006	433	925	723	69	2	2	15,715
2007			460	383	1,777	729	16,561
Touring 2007			20	43	125	43	1,376
Total	513	1,007	1,203	495	1,904	774	64,706

Incentive Adjusted Price, Exclusive of Subsidy (Mean)

	First Tax Change		Second Tax Change		Third Tax Change		Entire Sample
	Last 2 Weeks	First 2 Weeks	Last 2 Weeks	First 2 Weeks	Last 2 Weeks	First 2 Weeks	
Model Year	December 2005	January 2006	September 2006	October 2006	March 2007	April 2007	Total
2003							21,068
2004							24,438
2005	25,190	24,163					25,110
2006	26,855	26,340	25,914	25,683	24,854	23,300	26,397
2007			26,811	26,497	23,832	24,512	24,748
Touring 2007			27,917	28,208	26,081	26,378	26,663
Total	26,595	26,163	26,290	26,532	23,981	24,613	25,134

Incentive Adjusted Markup, Exclusive of Subsidy (Mean)

	First Tax Change		Second Tax Change		Third Tax Change		Entire Sample
	Last 2 Weeks	First 2 Weeks	Last 2 Weeks	First 2 Weeks	Last 2 Weeks	First 2 Weeks	
Model Year	December 2005	January 2006	September 2006	October 2006	March 2007	April 2007	Total
2003							611
2004							2,279
2005	1,999	1,465					2,270
2006	2,489	2,366	2,296	2,217	408	-456	2,362
2007			2,558	2,554	59	253	804
Touring 2007			2,771	2,595	199	933	1,330
Total	2,412	2,293	2,404	2,511	69	289	1,837

Shading indicates the model year and trim level used in the primary estimation for each tax change.

TABLE 3: Sales Share Differences
(Toyota Prius v. Non-Hybrid Toyota Sedans Around Tax Changes)

	Difference in Sales Share	
	Two Weeks Before Tax Change Minus Two Weeks After Change	Rest of First Month Minus Rest of Second Month
Prius		
December 2005 & January 2006	-18%	-6%
September 2006 & October 2006	20%	-3%
March 2007 & April 2007	20%	-4%
Non-Hybrid Toyota Sedans		
December 2005 & January 2006	6%	-7%
September 2006 & October 2006	4%	0%
March 2007 & April 2007	7%	-3%
	Difference-in-Differences (Prius Minus Non-Hybrid Toyota Sedans)	
December 2005 & January 2006	-24%	2%
September 2006 & October 2006	16%	-3%
March 2007 & April 2007	13%	-2%

All sales shares are based on the total sales over the two month period surrounding the tax change, using all model years and trim levels.

TABLE 4: Incentive Adjusted Price Change of Priuses Per Dollar of Tax Change
in Four Weeks Surrounding Tax Change

	No Controls	Composition Adjusted	Controls
January 2006 - December 2005	-0.194	-0.037	-0.022
	(0.054)	(0.024)	(0.024)
September 2006 - October 2006	0.199	-0.010	-0.058
	(0.106)	(0.047)	(0.047)
March 2007 - April 2007	-0.864	-0.207	-0.195
	(0.118)	(0.075)	(0.074)

Dependent variable is the incentive adjusted transaction price of a new Prius, exclusive of tax subsidies.
Heteroskedasticity robust standard errors in parentheses.
Jan-Dec estimated based on 2006 Prius, Sep-Oct and Mar-Apr coefficients based on 2007, base trim Prius.
"No Controls" includes only model year and trim level dummies.
"Composition Adjusted" adds vehicle cost as a regressor.
"Controls" adds vehicle cost, day of week dummies, state dummies, end of month dummy, price of gasoline and quadratic vehicle trend.
N=64,706 overall, with the following sample sizes in each tax window: 433 (Dec), 925 (Jan), 460 (Sep), 383 (Oct), 1,777 (Mar) and 729 (Apr).

TABLE 5: Evidence of Heterogeneous Timing Response,
Mean Consumer and Transaction Characteristics Surrounding Each Tax Change

		High Subsidy Prius Buyers within 14 Days of Change	Low Subsidy Prius Buyers within 14 Days of Change	Difference	Standard Error
Demographics					
Percent Female					
	Jan-Dec	35.1%	31.6%		
	Sept - Oct	37.2%	36.6%	1.07%	(1.62)
	Mar - Apr	36.0%	35.7%		
Age (Years)					
	Jan-Dec	44.7	44.7		
	Sept - Oct	45.3	43.1	-0.67	(0.46)
	Mar - Apr	46.0	45.2		
Trade-In Vehicles					
Percent with Trade-In					
	Jan-Dec	28.3%	30.3%		
	Sept - Oct	22.2%	30.0%	-5.41%	(1.45)
	Mar - Apr	37.5%	43.9%		
Trade-In Vintage (Year)					
	Jan-Dec	2000.2	1999.9		
	Sept - Oct	2001.2	2000.9	-0.13	(0.21)
	Mar - Apr	2000.6	2001.1		
Trade-In Actual Cash Value ($)					
	Jan-Dec	2,677	2,683		
	Sept - Oct	2,217	3,065	-609	(358)
	Mar - Apr	2,952	3,965		
Contract Details					
Total Down ($)					
	Jan-Dec	5,359	6,421		
	Sept - Oct	6,070	5,843	-482	(238)
	Mar - Apr	4,511	4,988		
Amount Financed ($)					
	Jan-Dec	24,387	24,379		
	Sept - Oct	24,400	24,565	3	(272)
	Mar - Apr	23,347	23,299		
Percent Purchased Service Contract					
	Jan-Dec	37.7%	45.0%		
	Sept - Oct	42.4%	48.6%	-4.95%	(1.53)
	Mar - Apr	45.9%	49.0%		
Service Contract Profit for Dealers ($)					
	Jan-Dec	586	738		
	Sept - Oct	771	871	-94	(27)
	Mar - Apr	779	838		
Percent Purchased Life Insurance					
	Jan-Dec	0.54%	0.23%		
	Sept - Oct	0.00%	0.26%	-0.01%	(0.24)
	Mar - Apr	0.45%	0.55%		
Total Cost of After-Market Options and Fees($)					
	Jan-Dec	2,816	3,177		
	Sept - Oct	3,592	3,455	-124	(50.83)
	Mar - Apr	3,067	3,160		
Percent with Buy Rate < APR					
	Jan-Dec	13.6%	14.5%		
	Sept - Oct	13.7%	17.5%	-8.38%	(1.13)
	Mar - Apr	3.5%	18.0%		

The difference estimate is a coefficient on a dummy equal to one if the transaction is within 2 weeks of a tax change, on the high subsidy side, from a regression with dummy variables for each 4 week window.

Sample sizes in each window are as follows: 433 (Dec), 925 (Jan), 460 (Sep), 383 (Oct), 1,777 (Mar) and 729 (Apr).

TABLE 6: Estimated Bounds on the Incentive Adjusted Price Change of Priuses Per Dollar of Tax Change in Four Week Window Surrounding Tax Change

	No Controls		Composition Adjusted		Controls		Extra Controls	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Jan06 - Dec05	-0.194	0.622	-0.037	0.249	-0.022	0.270	-0.006	0.280
	(0.054)	(0.076)	(0.024)	(0.034)	(0.024)	(0.033)	(0.023)	(0.032)
Sep06 - Oct06	0.199	0.581	-0.010	0.127	-0.058	0.082	-0.040	0.105
	(0.106)	(0.182)	(0.047)	(0.064)	(0.047)	(0.065)	(0.045)	(0.063)
Mar06 - Apr06	-0.864	2.043	-0.207	1.311	-0.195	1.264	-0.090	1.263
	(0.118)	(0.173)	(0.075)	(0.109)	(0.074)	(0.107)	(0.069)	(0.098)

Dependent variable is the incentive adjusted transaction price of a new Prius, exclusive of tax subsidies.
Heteroskedasticity robust standard errors in parentheses. Upper bound standard errors are from a nonparametric boostrap with 5,000 repetitions.
Jan-Dec estimated based on 2006 Prius, Sep-Oct and Mar-Apr coefficients based on 2007, base trim Prius.
"No Controls" includes only model year and trim level dummies.
"Composition Adjusted" adds vehicle cost as a regressor.
"Controls" adds vehicle cost, day of week dummies, state dummies, end of month dummy, price of gasoline and quadratic vehicle trend.
"Extra Controls" adds sex, age, total after-market options, a dummy for an APR above the buy rate, a dummy for life insurance, a dummy for the presence of a trade-in, trade-in actual value, trade-in vintage, and a dummy for a service contract.
N=64,706 overall, with the following sample sizes in each tax window: 433 (Dec), 925 (Jan), 460 (Sep), 383 (Oct), 1,777 (Mar) and 729 (Apr).

TABLE 7: Estimated Bounds on the Incentive Adjusted Price Change of Priuses Per Dollar of Tax Change
Using Sample Proportions to Reflect All Model Years and Trim Levels

	No Controls		Composition Adjusted		Controls		Extra Controls	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Jan06 - Dec05	-0.194	0.551	-0.037	0.224	-0.022	0.244	-0.006	0.256
	(0.054)	(0.075)	(0.024)	(0.032)	(0.024)	(0.032)	(0.023)	(0.030)
Sep06 - Oct06	0.199	1.767	-0.010	0.550	-0.058	0.518	-0.040	0.516
	(0.106)	(0.120)	(0.047)	(0.078)	(0.047)	(0.077)	(0.045)	(0.072)
Mar06 - Apr06	-0.864	2.067	-0.207	1.324	-0.195	1.277	-0.090	1.274
	(0.118)	(0.172)	(0.075)	(0.110)	(0.074)	(0.108)	(0.069)	(0.099)

Dependent variable is the incentive adjusted transaction price of a new Prius, exclusive of tax subsidies.
Heteroskedasticity robust standard errors in parentheses. Upper bound standard errors are from a nonparametric boostrap with 5,000 repetitions.
Jan-Dec estimated based on 2006 Prius, Sep-Oct and Mar-Apr coefficients based on 2007, base trim Prius.
"No Controls" includes only model year and trim level dummies.
"Composition Adjusted" adds vehicle cost as a regressor.
"Controls" adds vehicle cost, day of week dummies, state dummies, end of month dummy, price of gasoline and quadratic vehicle trend.
a trade-in, trade-in actual value, trade-in vintage, and a dummy for a service contract.
N=64,706 overall, with the following sample sizes in each tax window: 433 (Dec), 925 (Jan), 460 (Sep), 383 (Oct), 1,777 (Mar) and 729 (Apr).
The upper bound is calculated using 471 (Jan), 189 (Sep) and 722 (Mar) prices, to mimic the proportion of Priuses of all model years and trim levels in each period.

TABLE 8: Estimated Bounds on the Incentive Adjusted Price Change of Priuses Per Dollar of Tax Change
Using Various Assumptions to Calculate Financing Incentives

	Discount Rate = 2%		Discount Rate = 4%		Discount Rate = 6%		Discount Rate = 8%	
Unadjusted APR	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Jan06 - Dec05	-0.024	0.296	**-0.022**	**0.270**	-0.021	0.258	-0.021	0.251
	(0.027)	(0.038)	**(0.024)**	**(0.033)**	(0.023)	(0.031)	(0.022)	(0.030)
Sep06 - Oct06	-0.108	0.043	**-0.058**	**0.082**	-0.032	0.103	-0.017	0.117
	(0.055)	(0.075)	**(0.047)**	**(0.065)**	(0.043)	(0.062)	(0.042)	(0.061)
Mar06 - Apr06	-0.558	1.111	**-0.195**	**1.264**	0.014	1.382	0.146	1.467
	(0.085)	(0.125)	**(0.074)**	**(0.107)**	(0.070)	(0.101)	(0.068)	(0.098)
Prius Adjusted APR								
Jan06 - Dec05	-0.026	0.295	-0.024	0.270	-0.022	0.258	-0.022	0.251
	(0.027)	(0.039)	(0.024)	(0.034)	(0.023)	(0.031)	(0.022)	(0.030)
Sep06 - Oct06	-0.114	0.037	-0.062	0.079	-0.034	0.102	-0.018	0.116
	(0.057)	(0.076)	(0.048)	(0.067)	(0.044)	(0.063)	(0.042)	(0.061)
Mar06 - Apr06	-0.523	1.106	-0.167	1.276	0.037	1.397	0.165	1.481
	(0.085)	(0.128)	(0.075)	(0.110)	(0.070)	(0.103)	(0.068)	(0.100)
Age Adjusted APR								
Jan06 - Dec05	-0.015	0.457	-0.018	0.363	-0.019	0.317	-0.019	0.292
	(0.045)	(0.053)	(0.033)	(0.041)	(0.028)	(0.036)	(0.026)	(0.033)
Sep06 - Oct06	-0.042	0.324	-0.019	0.236	-0.005	0.199	0.004	0.181
	(0.089)	(0.125)	(0.064)	(0.094)	(0.053)	(0.080)	(0.048)	(0.072)
Mar06 - Apr06	-0.515	2.245	-0.170	1.941	0.032	1.813	0.160	1.765
	(0.137)	(0.166)	(0.102)	(0.132)	(0.086)	(0.116)	(0.079)	(0.108)

Dependent variable is the incentive adjusted transaction price of a new Prius, exclusive of tax subsidies.
Heteroskedasticity robust standard errors in parentheses. Upper bound standard errors are from a nonparametric boostrap with 5,000 repetitions.
The discount rate is the annual discount rate applied to the loan in order to calculate the present discounted value of interest rate subsidies.
Prius adjusted APR substracts .5 from the Federal Reserve 48-month car loan interest rate to adjust for average Prius premium when there are no subsidies.
Age adjusted APR subratcts .05 from the Federal Reserve rate per year of age above the mean to adjust for average credit differences across different ages.
Specification corresponds to column three ("Controls") from Table 6. Regression includes model year and trim level dummies, vehicle cost, day of week dummies, state dummies, end of month dummy, price of gasoline and quadratic vehicle trend.
Jan-Dec estimated based on 2006 Prius, Sep-Oct and Mar-Apr coefficients based on 2007, base trim Prius.
N=64,706 overall, with the following sample sizes in each tax window: 433 (Dec), 925 (Jan), 460 (Sep), 383 (Oct), 1,777 (Mar) and 729 (Apr).

TABLE 9: Estimated Time Period Effects on Incentive Adjusted Price of Non-Hybrid Sedans in Four Week Window Surrounding Tax Change

	Comparable Sedans	Non-Hybrid Toyota Sedans	Fuel-Efficient Sedans
January 2006 - December 2005	-49.7	79.3	-69.6
	(27.0)	(17.4)	(24.5)
September 2006 - October 2006	-24.4	25.5	-4.5
	(22.9)	(16.2)	(22.8)
March 2007 - April 2007	49.6	-23.6	-12.8
	(23.2)	(16.6)	(22.9)

Dependent variable is the incentive adjusted transaction price of a new sedan.
Heteroskedasticity robust standard errors in parentheses.
Specification corresponds to column three ("Controls") from Table 6. Regression includes model year / trim level / engine type dummies, vehicle cost, day of week dummies, state dummies, end of month dummy, price of gasoline and quadratic vehicle trend.
Comparable vehicles are the 6, Accord, Aveo, Charger, Civic, Fit, Five Hundred, G6, Grand Prix, Impala, Impreza, LaCrosse, Malibu, Maxima, Milan, Montego, Passat, Sable, Sentra, tC, xA, xB and the non-hybrid Toyota sedans.
Non-hybrid Toyota sedans include the Avalon, Camry, Camry Solara, Corolla, Matrix and Yaris.
Fuel efficient sedans include the subset of these vehicles with a combined EPA fuel economy above 29 miles per gallon: Aveo, Civic, Corolla, Fit, Matrix, Sentra, xA and xB.
Overall, N=1,536,075 for comparable sedans, 570,059 for non-hybrid Toyota sedans and 584,418 for fuel-efficient sedans.

TABLE 10: Estimated Log Price Premium For Toyota Models in High Tax Subsidy Window

		First Two Weeks Jan 06 v. Last Two Weeks Dec 05			Last Two Weeks Sep 06 v. Last Two Weeks Oct 06			First Two Weeks Jan 06 v. Last Two Weeks Dec 05		
		Log Premium	Standard Error		Log Premium	Standard Error		Log Premium	Standard Error	
Toyota Nameplate Cars										
	Avalon	0.0026	(0.0026)		-0.0065	(0.0025)	*	0.0026	(0.0030)	
	Camry	-0.0014	(0.0021)		0.0014	(0.0017)		0.0043	(0.0018)	*
	Camry Solara	-0.0056	(0.0062)		-0.0003	(0.0056)		0.0022	(0.0052)	
	Corolla	-0.0083	(0.0024)	*	-0.0011	(0.0023)		0.0019	(0.0022)	
	Matrix	0.0013	(0.0057)		-0.0036	(0.0051)		0.0031	(0.0053)	
	Yaris				0.0015	(0.0035)		-0.0040	(0.0036)	
Toyota Nameplate Light Trucks										
	4Runner	-0.0032	(0.0031)		-0.0020	(0.0033)		0.0036	(0.0033)	
	FJ Cruiser				-0.0044	(0.0037)		-0.0032	(0.0038)	
	Highlander	0.0046	(0.0031)		-0.0019	(0.0028)		0.0014	(0.0030)	
	Land Cruiser	0.0073	(0.0159)		-0.0144	(0.0143)		0.0038	(0.0175)	
	RAV4	-0.0009	(0.0032)		-0.0013	(0.0024)		-0.0049	(0.0022)	*
	Sequoia	0.0069	(0.0044)		-0.0142	(0.0045)	*	0.0056	(0.0053)	
	Sienna	-0.0098	(0.0026)	*	0.0025	(0.0023)		0.0051	(0.0026)	*
	Tacoma	0.0062	(0.0027)	*	0.0017	(0.0025)		0.0018	(0.0024)	
	Tundra	0.0093	(0.0038)	*	-0.0033	(0.0032)		-0.0342	(0.0270)	
Lexus Nameplate Vehicles										
	ES 330	-0.0035	(0.0032)		0.1902	(0.0373)	*			
	ES 350				0.0017	(0.0028)		-0.0029	(0.0028)	
	GS 300	0.0016	(0.0052)		-0.0039	(0.0133)		-0.0621	(0.0387)	
	GS 350				-0.0041	(0.0056)		-0.0054	(0.0060)	
	GX 470	0.0016	(0.0051)		0.0000	(0.0059)		0.0046	(0.0066)	
	IS 250	-0.0019	(0.0051)		0.0006	(0.0051)		-0.0024	(0.0046)	
	IS 300	0.1196	(0.0514)	*						
	IS 350	0.0026	(0.0064)		0.0065	(0.0067)		0.0061	(0.0126)	
	LS 430	-0.0031	(0.0052)		-0.0094	(0.0094)				
	LS 460							-0.0056	(0.0045)	
	LX 470	-0.0085	(0.0094)		-0.0131	(0.0097)		0.0163	(0.0141)	
	RX 330	-0.0024	(0.0029)		0.0609	(0.0216)	*	-0.0439	(0.0525)	
	RX 350				-0.0003	(0.0031)		-0.0062	(0.0111)	
	SC 430	-0.0005	(0.0082)		0.0078	(0.0114)		0.0101	(0.0120)	
Scion Nameplate Vehicles										
	tC	0.0002	(0.0029)		0.0033	(0.0026)		0.0009	(0.0028)	
	xA	0.0026	(0.0047)		-0.0045	(0.0039)		-0.0086	(0.0057)	
	xB	0.0043	(0.0041)		-0.0052	(0.0035)		0.0016	(0.0057)	

Dependent variable is the log of the incentive adjusted transaction price of a new vehicle.
Heteroskedasticity robust standard errors in parentheses. * Denotes significance at 95% level.
Specification corresponds to column three ("Controls") from Table 6. Regression includes model year / trim level / engine type dummies, vehicle cost, day of week dummies, state dummies, end of month dummy, price of gasoline and quadratic vehicle trend.

TABLE 11: State Tax Incentives for the Toyota Prius

State	Subsidy Type	Amount*	Start Date	End Date	Sample Size: Subsidy Off	Sample Size: Subsidy On
Colorado	Income Tax Credit	$3150 to $4622	7/1/00	Still Effective		
Connecticut	Full Sales Tax Exemption	6% ($1500)	10/1/04	Still Effective	47	100
District of Columbia	Full Sales Tax Exemption	7% ($1750)	4/15/05	Still Effective	32	65
Lousiana	Income Tax Credit	2% ($500)	1/1/91	Still Effective		
Maine	Partial Sales Tax Exemption	2.5% ($625)	1/1/97	12/31/05	169	193
Maryland	Partial Sales Tax Exemption	$1000 max	7/1/00	7/1/04	2,487	509
New Mexico	Full Sales Tax Exemption	3% ($750)	7/1/04	Still Effective		
New York	Income Tax Credit	$2000	1/1/01	12/31/04	1,305	214
New York	Partial Sales Tax Exemption	$240	1/1/01	2/28/05		
Oregon	Income Tax Credit	$1500	1/1/98	Still Effective		
Pennsylvania	Rebate	$500	3/25/05	Still Effective	525	1,574
South Carolina	Income Tax Credit	$630	1/1/06	Still Effective	46	182
West Virginia	Income Tax Credit	$3150 to $3750	7/1/97	6/30/06	27	11
Total					4,638	2,848

* For sales tax exemptions, the value of the exemption on a $25,000 car is included in parentheses, for ease of comparison.

TABLE 12: Incentive Adjusted Price Change of Priuses Per Dollar of State Tax Incentive Change

	Specification 1	Specification 2
State Tax Incentive	0.051	-0.022
	(0.081)	(0.088)
Dealer Cost		1.062
		(0.011)
State Fixed Effects	X	X
Week Fixed Effects	X	X
N	64,706	64,706
AdjR2	0.25	0.80

Depedent variable is the incentive adjusted transaction price of a new Prius, exclusive of tax subsidies.
Heteroskedasticity robust standard errors, clustered on state, in parentheses.
Controls include day of week dummies, dummy for end of the month, quadratic in vehicle time and model year and trim level dummies.

TABLE 13: Price Sensitivity of the Prius With and Without a Wait List

	Incentive Adjusted Price of Prius
End of Month	-8.07
	(7.51)
End of Month, No Wait List	-108
	(22)
Price of Gasoline	1.19
	(0.67)
Price of Gasoline, No Wait List	5.78
	(1.12)
Weeks on Market	-0.35
	(0.10)
Weeks on Market, No Wait List	-9.85
	(0.64)
N	64,706
R2	0.80

Dependent variable is the incentive adjusted transaction price of a new Prius, exclusive of tax subsidies.
Heteroskedasticity robust standard errors, clustered on state, in parentheses.
Controls include dealer cost, day of week dummies, quadratic in vehicle time and model year and trim level dummies.
Model year 2004, 2005 and 2006 Priuses are coded as having a wait list.

TABLE 14: Estimated Bounds on the Incentive Adjusted Price Change of Other Hybrids Per Dollar of Tax Change

	Toyota Prius		Honda Civic		Ford Escape		Toyota Highlander		Toyota Camry	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Jan06 - Dec05	-0.022	0.270	-0.034	0.348	0.164	0.359	0.023	0.443		
	(0.024)	(0.033)	(0.056)	(0.073)	(0.195)	(0.187)	(0.081)	(0.111)		
Sep06 - Oct06	-0.058	0.082					-0.034	1.061	-0.091	0.557
	(0.047)	(0.065)					(0.166)	(0.234)	(0.076)	(0.106)
Mar06 - Apr06	-0.195	1.264					0.279	2.415	-0.401	0.962
	(0.074)	(0.107)					(0.306)	(0.434)	(0.150)	(0.214)

Dependent variable is the incentive adjusted transaction price of a new vehicle, exclusive of tax subsidies.

Heteroskedasticity robust standard errors in parentheses. Upper bound standard errors are from a nonparametric boostrap with 5,000 repetitions.

Specification corresponds to column three ("Controls") from Table 6. Regression includes model year and trim level dummies, vehicle cost, day of week dummies, state dummies, end of month dummy, price of gasoline and quadratic vehicle trend.

The following model years are used: Civic (2006), Escape (2006), Highlander (2006 for first change and 2007 for second and third) and Camry (2007 for both tax changes).

Prius: N=64,706 overall, with the following sample sizes in each tax window: 433 (Dec), 925 (Jan), 460 (Sep), 383 (Oct), 1,777 (Mar) and 729 (Apr).

Civic: N=27,155 overall, with the following sample sizes in each tax window: 210 (Dec) and 364 (Jan).

Escape: N=6,804 overall, with the following sample sizes in each tax window: 67 (Dec) and 82 (Jan).

Highlander: N=9,707 overall, with the following sample sizes in each tax window: 131 (Dec), 218 (Jan), 181 (Sep), 89 (Oct), 240 (Mar) and 111 (Apr).

Camry: N=9,617 overall, with the following sample sizes in each tax window: 422 (Sep), 187 (Oct), 539 (Mar) and 288 (Apr).

TABLE 15: Price Changes Due to "Economic Savings Bonus" for 2007 Prius

Manufacturer's Suggested Retail Price				
Base		$22,175	22,175	0
Package	1	825	825	0
	2	1,175	575	600
	3	2,555	2,105	450
	4	3,180	2,580	600
	5	5,080	3,280	1,800
	6	6,350	4,550	1,800
Dealer Invoice				
Base		20,419	20,419	0
Package	1	659	659	0
	2	960	518	442
	3	2,018	1,895	123
	4	2,518	2,322	196
	5	4,133	2,952	1,181
	6	5,149	4,095	1,054

Source: Edmunds.com

TABLE 16: Dealer Cost Premium in High Tax Period, Within Assigned Options Package
2007 Prius

Options Package Threshold	Jan 06 (v. Dec 05)	Sep 06 (v. Oct 06)	Adjusted Mar 07 (v. Apr 07)	Unadjusted Mar 07 (v. Apr 07)
$25	-8.47	-13.84	-39.34	619.2
	(18.60)	(22.30)	(14.10)	(15.40)
50	-17.16	-12	-31.37	625.2
	(18.40)	(22.00)	(14.00)	(15.40)
75	-16.98	-12.31	-30.38	624.7
	(18.30)	(22.10)	(13.70)	(15.30)
100	-42.62	-13.94	-26.47	629.9
	(18.00)	(22.10)	(13.60)	(15.30)
125	-24.6	-12.45	-19.98	637.1
	(17.60)	(22.10)	(13.50)	(15.20)
150	-22.19	-13.1	-6.52	651.5
	(17.20)	(22.10)	(13.20)	(15.20)
Fixed Effect for Assigned Options Packages	X	X	X	X

Dependent variable is dealer cost. The reported coefficient is a dummy for the high tax period in each window.
Heteroskedasticity robust standard errors in parentheses.
Each coefficient is from a separate regression, which assigns each vehicle in the sample an options package if it is greater than the base price plus options price minus threshold, but less than the similarly defined cutoff for the next highest options package.
N is approximately 1,330 for column 1, 815 for column 2 and 2,370 for columns 3 and 4. The sample varies slightly because minimum and maximum thresholds for censoring vary slightly by the selected threshold.