Regulated and Unregulated Substitutes: Aversion Effects of an Ethanol Mandate

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Abstract

One approach for handling more aggressive goals under an ethanol mandate is to use a "dual blend" mandate in which both the preferred new ethanol blend and the old (possibly ethanol-free) blend of gasoline coexist. Highlighting the case of New South Wales, Australia, we show the dual nature of such a mandate can potentially lead to significant costs when consumers are averse. We show consumers en masse rejected the new blend and paid 43 cents per gallon more to avoid it. Not even the second of the mandate's four targets could be reached, and the consumer cost was substantial.

JEL Classification: L51, Q41, Q42, Q51

1 Introduction

Regulation is a tool policymakers can use to steer markets away from private outcomes deemed to be socially suboptimal or inefficient. Regulations work either by altering market incentives or changing consumers' choice sets. As they attempt to reshape or restrict private market equilibria, they can sometimes lead to unexpected consumer reactions and unanticipated consequences, such as higher consumer costs or reduced effectiveness in meeting goals.

The extent to which a regulation can have adverse and unanticipated consequences depends on the nature and design of the regulation. In this article, we highlight a case where the design of an unpopular and hurried regulation led to especially adverse consequences. The case is that of the recent ethanol mandate in the state of New South Wales, Australia.

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Ethanol mandates have become popular with legislators over the past decade and currently sixty-two countries have some form of one (GRFA (2014)). A typical mandate requires producers to blend a certain percentage or certain volume of ethanol into the overall supply of gasoline. The U.S. mandate, for example, requires 18.2 billion gallons of renewable fuels, primarily ethanol, be blended into the gasoline supply in 2014, up from 16.6 billion in 2013 (EPA (2013)). The European Union mandate requires 5.75% renewable fuels in gasoline by 2010 and 10% by 2020 (EU (2003, 2007)).

Ethanol mandates have been controversial, however (Griffin (2013), Rodriguez et al. (2011), Grafton et al. (2012), Serra & Zilberman (2013), Westbrook et al. (2014), and others). Proponents argue they help slow greenhouse gas accumulation, promote renewable energy, and reduce dependence on foreign oil. They also point out benefits to the domestic farming and ethanol production industries which is sometimes a goal in itself. Critics, on the other hand, question their environmental value, the need for fossil fuel replacement, the lower energy yield, and potential for food price inflation when crops grown for food are converted to ethanol use (Carter et al. (2013)).[1] They also point out that ethanol blends tend to be more expensive for consumers, on an energy adjusted basis, than unblended gasoline. Mandates tend to be, on net, unpopular with consumers.[2]

An important consideration when transitioning to a new ethanol mandate or a higher ethanol blend under an existing mandate is ensuring compatibility with the vehicle fleet. Ethanol is an alcohol and, in higher concentrations, can be corrosive to engine valves, seals, and gaskets in older vehicles not designed with ethanol's properties in mind.

An option many jurisdictions have used in implementing ethanol mandates is to limit the ethanol blend to a level tested and widely believed to be compatible with the vast majority of vehicles on the road. In the United States and Canada, for example, a 10% blend has been implemented almost universally, while a 5% has been used universally in many European countries. If regulators instead deem that higher blends are desirable, another option is to mandate that newly built vehicles be

[1] When corn futures tripled in price following the introduction of the U.S. mandate, many pointed at the mandate. The President of the National Corn Growers' Association testified before Congress in 2013 that there was no discernable effect of the mandate on the corn prices (NCGA (2013)).

[2] Consumers tend to range anywhere from indifferent to disapproving of ethanol mandates, with relatively fewer strongly in favor. Drivers in Germany largely rejected efforts to introduce E10 there, and even in the U.S. and Canada during the transition to E10, there were websites devoted to the cause against ethanol blending and helping drivers locate stations with still ethanol-free gasoline. Optional E85 adoption in the U.S. has been especially poor.

compatible with the new higher blend and then implement the fuel mandate once the vehicle fleet has largely turned over. However, vehicle turnover can take decades and this approach has not been as popular with regulators.

A third option that has found some favor is to introduce a higher ethanol blend that a majority of vehicles can use while still making the previous (possibly ethanol-free) blend available as long as there are those who still need it. In principle, this "dual blend" approach promises to accommodate more aggressive ethanol mandates and lead to more ethanol in the fuel supply more quickly. However, we show that this kind of dual blend or "selective" mandate, in its efforts to hurry ethanol blending beyond the capabilities of the vehicle fleet as a whole, or beyond the confidence of consumers in its safety, can have severe negative consequences.

A selective mandate requires more than just having multiple blends available – it must incentivize drivers who can safely use the new higher blend to actually use it. This can be done through favorable tax treatment of the new blend, quotas on production of the old to drive up price, or other means. One simple approach that has been used is to increase the ethanol content only in regular grade gasoline while leaving the more expensive premium grade gasoline alone, thus making the old blend available but discouraging it through the higher premium price.[3]

This leads to an interesting situation. Unlike universal mandates where only a single blend, one believed to be safe for the vast majority of the vehicle fleet, is available and consumers cannot avoid it, selective mandates must by construction maintain both blends as an option. This leads to the potential for consumers averse to ethanol to avoid the new blend, for concerns real or perceived, at a higher cost to themselves. The greater the overall consumer aversion to ethanol, the greater is the potential aversion cost. The greater the inflated price of the old blend, the greater again is the potential cost.

Without loss of generality, imagine the case where regular grade gasoline is replaced with an ethanol blend and premium grade remains ethanol-free. The vast majority of consumers now have an individual choice between two almost-perfect substitutes – the regulated ethanol blend and the

[3] This approach has been widely considered. Several countries (e.g. Canada, Australia) have used it, while several states (e.g. Montana and Missouri) with their own mandatory ethanol requirements exempt blending ethanol into premium gasoline. Another state (Mississippi) debated a bill that would have kept premium ethanol-free. The cited benefits of this selective-by-grade approach is that it does not force small retailers to choose between selling the old or new blends or installing costly new tanks and pumps to accommodate both.

unregulated, but more expensive, ethanol-free premium "blend". While regulators might assume consumers will choose the cheapest option, the fact is they do not have to and, if they have enough aversion to ethanol, they will not. The greater consumers' aversion to ethanol, the more they reject the new blend, the greater the diversion to premium, and the greater is the cost to those consumers in terms of higher expenditures on fuel. Also, the more it is rejected, the greater the potential for the mandate to stumble or fail in spite of these costs.

For a second group of averse consumers who are universally advised, even by regulators, to avoid the new ethanol blend, the more expensive premium is the only feasible option. They necessarily bear a cost. The more aggressive the mandate, the greater the number of consumers in this group, and the higher is the cost in terms of higher expenditures on fuel. Only for the remaining consumers whose vehicles require premium anyway will there be no added cost, assuming away any price effects from the mandate.

In this article, we examine the experience of the selective mandate in New South Wales, Australia. In 2007, New South Wales introduced legislation to replace ethanol-free regular gasoline with a 10% blend, E10, while leaving the more expensive premium grade gasoline as the ethanol-free substitute. The mandate took effect in October 2007 and initially required that ethanol comprise a minimum of 2% of the overall gasoline volume sold in the state. The minimum was then increased to 4% effective January 2010 and was scheduled to increase to 6% in January 2011. Beginning in July 2012, regular gasoline was to be phased out entirely and replaced with E10.[4]

We estimate the extent to which NSW consumers avoided E10, diverting to the more expensive premium grade, and the magnitude of consumer costs resulting from this diversion. The cost we measure specifically is the cost to consumers in terms of increased expenditures for fuel necessary to obtain the equivalent amount of energy as before the mandate. While there are many costs associated with ethanol mandates, measurement of this cost, accounting for the consumer avoidance of E10, is new. To our knowledge, this is the first article that addresses consumer avoidance of an ethanol blend and consumer aversion costs under a dual blend or selective ethanol mandate.

Unlike in the U.S. where E10 has been universally used for years, the suitability of E10 in

[4]See the Biofuels Act 2007; Biofuels Amendment Act 2009; NSW Government Gazette No. 133 of 10 December 2010, p. 5811; NSW Government Gazette No. 66 of 3 June 2011, p. 4667; Biofuels Amendment Act 2012.

Australian cars has been more controversial. A prominent concern of consumers, whether real or perceived, surrounds fuel-vehicle compatibility and the potential for long run damage from E10, especially in older vehicles. Since the inception of the mandate, there have been voluminous newspaper articles, press reports, internet blogs and forums, all alleging E10 damage to vehicles. In fact, from the start, regulators advised drivers of up to a fifth of Australian vehicles not to use it, citing a list of compatible vehicles compiled from automobile manufacturer recommendations. The fact that regulators did not dispute that E10 was potentially problematic in a sizeable minority of cars further legitimized consumer concerns. We do not make any claims about whether such damage reports are accurate or not, whether the list produced by manufacturers is overly broad or not, whether the cars allegedly damaged were on or off the list of compatible cars, etc., nor is it relevant for our results. We simply point out that the source of consumer aversion is clear, while the method for exercising that aversion and avoiding ethanol is built into the design of the selective mandate.

To preview results, we find that consumers in New South Wales widely rejected the mandate and diverted en masse to the ethanol-free premium grade almost-perfect substitute. Not only did consumers whose vehicles were listed as incompatible with E10 avoid E10, but also a substantial proportion of consumers whose vehicles were listed as compatible and safe for E10 rejected it as well. So pronounced was the exodus that four years into the mandate premium grade gasoline became the number one selling grade in NSW. From the inception of the mandate to the end of our sample less than six years later, the market share of premium more than doubled, from 18.4% to 38.6%. Premium is on track to reach 54.6%, triple its pre-mandate share, should ethanol-free regular be eliminated entirely.

In contrast, the market share of E10 stalled around 35% and as a result, the mandate failed to meet its goal in even the second phase of the four phase plan. The third phase of the mandate was postponed nine months to no avail, and legislation that would have required all regular gasoline to be blended with ethanol was repealed and abandoned altogether.

In spite of consumers' rejection, the mandate still came at a high cost in terms of higher fuel expenditures. We estimate expenditures increased by over $300 million dollars over the first 5 years and continues to climb. Importantly, we find that the typical method for calculating consumer costs is biased in the case of a selective mandate. The typical calculation involves comparing the higher energy-adjusted price of higher ethanol blends versus the lower blends they replace, and multiplying by the relevant quantity. However, we find the vast majority of the increased fuel cost – 96% of the total – was borne by consumers who rejected the new ethanol blend and diverted to premium instead of switching to the new blend. In other words, we show that when more aggressive ethanol goals necessitate a selective mandate situation, there is a new and potentially very significant source for increased fuel costs that does not occur with universal mandates. These costs can dwarf the costs typically estimated under ethanol mandates which assume no diversion to other substitutes. We argue that the potential for consumer aversion, and the costs that arise from it, must be considered and accounted for in the overall cost-benefit analysis of a proposed selective ethanol mandate.

There is another implication to our work as well. We find that selective mandates can yield unusually severe diminishing marginal returns. In NSW, costs rose from $1.2 million per month in 2009 to $12.3 million per month in 2013. Early suggestions of a relatively smooth consumer transition from regular to E10 proved misleading. The reason is that consumers are heterogeneous in their aversion to ethanol. Early on when the first few regular pumps were switched out for E10 pumps, consumers with little aversion to ethanol accepted the new E10 pumps and the transition began slowly but smoothly. However, as regular became increasingly more difficult to find over time, and the remaining consumers confronting the E10-premium decision were increasingly ethanol averse, consumer avoidance and aversion costs began to skyrocket. By the time of the third phase of the mandate, 60%, or *three* out of every *five* consumers who lost access to regular chose to reject E10 and instead diverted to premium, even though it cost an additional 12 cents per liter (cpl), or about 43.1 U.S. cents per gallon. We show that in NSW adding one more liter of E10 to the overall fuel supply cost *forty-five* times as much in 2013 as it did in 2009.

While aversion costs are relevant regardless of the reason for aversion, it is worth exploring to what extent consumers in NSW owned vehicles for which regulators advised against E10 and to what extent they rejected E10 even though both regulators and manufacturers assured them E10 was safe. In the former case, regulators should easily have been able to estimate the degree of aversion costs. In the latter case, regulators may or may not have expected the extent of aversion, but in principle it is predictable, could have been estimated, and steps taken to mitigate it, if the mandate itself was not reconsidered. We find roughly half of consumers who switched to premium fall into each group. We discuss the implications for policy.

2 Data

To evaluate the impacts of the mandate on gasoline volumes, prices, and the cost of fuel consumers pay overall, we use data on volumes and on retail and wholesale prices for each grade of gasoline – unblended regular, E10, and premium for each mainland state – New South Wales, Victoria, Queensland, South Australia, and Western Australia. The data period extends from January 2004 to June 2013.

Gasoline volumes, by state, grade, and month, are obtained from the Bureau of Resources and Energy Economics (BREE) of Australia and converted to millions of liters per month. Average retail prices for regular and premium grades of gasoline, by month, for each major city in each state are obtained from Fueltrac, and average retail prices for E10 for the same cities and months are obtained from the Australian Competition and Consumer Commission (ACCC) from data collected by Informed Sources. Wholesale prices, known as terminal gate prices in Australia, are obtained for each major city and by month from Orima Research. All retail and terminal gate prices are in Australian cents per liter. Data on vehicle registrations, by month and state, are obtained from BREE and are reported in thousands of vehicles, and unemployment data are obtained from the Australian Bureau of Statistics. Finally, information on fuel-vehicle compatibility are obtained from the Federal Chamber of Automobile Industries (FCAI), the Independent Pricing and Regulatory Tribunal (IPART), and Wilson et al. (2011).

Summary statistics for key variables are shown in Table 1.

3 Methodology

We use a difference-in-differences framework to estimate the impact of the ethanol mandate on the volumes and composition of grades sold and on the prices within each grade. The treatment state is New South Wales and the other mainland states act as mandate-free control states. The differencing method essentially compares the change in volumes and prices in New South Wales after the introduction of the mandate to the change in volumes and prices in other control states that never had mandates. This enables us to “difference away” any effects from global or national factors (e.g. commodity price changes) and isolate the effect of just the mandate itself on volumes and prices in New South Wales.

That is not to say that effects from global or national factors on the relative prices of E10 and other grades are not important. To the contrary, we account for changing relative prices overall. Once we have estimated the mandate-caused changes in volumes and prices, in the second stage of our analysis, we estimate the overall burden of the mandate, in terms of increased fuel costs, by calculating the difference between what consumers actually paid in the presence of the mandate and what they would have paid for the same amount of energy in a world absent the mandate. If the composition of volumes across grades change due to the mandate (and we will find they do), and the prices of those grades are different for any reason (as they are), then relative prices affect costs. As actual relative prices change over time (due to commodity price changes or other reasons), so does our measure of the actual cost.

In the third stage of our analysis, we decompose the total cost of the mandate into two components 1) the increase in costs to consumers who switched from unblended regular to E10, and 2) the increase in costs to consumers who avoided E10 and switched to ethanol-free premium instead. The first group is the group usually considered when thinking about the increased cost of fuel due to an ethanol mandate. The second group has largely been ignored in the literature and was largely ignored by policymakers. We will show that, in this case, the cost to the second group was so significant and so large as to dwarf the costs paid by the first - accounting for 96% of the total cost from consumer grade switching. The potential for the existence of the second group remains anytime multiple blends at different prices are simultaneously available.

There are three “treatment" periods, commencing in October 2007, January 2010, and October 2011 respectively, and corresponding to the introduction of the three implemented phases of the mandate, the, 2%, 4%, and 6% phases respectively.

The basic estimating equation is given by

$$\begin{aligned} Y_{gst} &= \alpha_{g0} + \alpha_{g1} D_s + \alpha_{g2} D_{2,t} + \alpha_{g3} D_{4,t} + \alpha_{g4} D_{6,t} \\ &\quad + \alpha_{g5} D_{2,t} D_s + \alpha_{g6} D_{4,t} D_s + \alpha_{g7} D_{6,t} D_s + X_{gst} B_g + \varepsilon_{gst} \end{aligned} \tag{1}$$

where Y_{gst} is the variable of interest, either $VOLUME_{gst}$ or $PRICE_{gst}$, of gasoline grade g in state s at time t.[5] Dichotomous variable D_s takes on a value of one for New South Wales, and dichotomous variables $D_{2,t}$, $D_{4,t}$ and $D_{6,t}$ take on values of one after October 2007, January 2010, and October 2011, respectively.[6] Therefore, the cumulative effects of the mandate in the 4% and 6% periods, relative to the pre-mandate period, are the sums of the relevant coefficients. The ε_{gst} are normally distributed error terms. Each grade is estimated separately and robust standard errors are clustered at the city level to account for serial correlation.

As a reduced form estimation of the effects of the mandate on equilibrium volumes and prices, the matrix X_{gst} contains additional control variables affecting equilibrium volumes and equilibrium prices from both demand and supply side sources. We control for contemporaneous and lagged values for new vehicle registrations, contemporaneous and lagged unemployment rates, and dichotomous indicator variables for each calendar month on the demand side, and wholesale prices (terminal gate prices) on the supply side.

We also estimate an alternate price equation that allows for the possibility that retail prices respond to changes in wholesale prices asymmetrically and with a lag. Lagged and asymmetric responses have been studied by Borenstein, Cameron & Gilbert (1997), Noel (2009), Lewis (2009), Tappata (2009), Lewis & Noel (2011), and many others. Recognizing the cointegrated nature of retail and rack prices, we estimate a vector autoregressive error correction model (VAR) in the

[5] We first estimated pre-treatment trends in volumes and prices and found the trends among treatment and controls groups to be very similar. We do not include prices other than own price since prices are almost perfectly collinear in the sample, with pairwise correlations of 0.98, 0.98 and 0.997 for the three combinations. Our approach is consistent with the literature which, in its focus on regular grade of gasoline, typically includes a single price.

[6] We also estimate a version where individual dummies are included for each of the control states. The results are mathematically identical in Specifications (1), (3), and (5), and very similar in Specifications (2), (4), and (6).

spirit of Engle and Granger (1987):

$$\begin{aligned} \Delta PRICE_{gst} \quad = \quad & \delta_{g,0} + \sum_{i=0}^{I} \delta^{+}_{g,1+i} \Delta TGP^{+}_{gs,t-i} + \sum_{i=0}^{I} \delta^{-}_{g,1+i} \Delta TGP^{-}_{gs,t-i} \\ & + \sum_{j=1}^{J} \delta^{+}_{g,1+I+i} \Delta PRICE^{+}_{gs,t-j} + \sum_{j=1}^{J} \delta^{-}_{g,1+I+i} \Delta PRICE^{-}_{gs,t-j} \\ & + \phi_{g,2}(PRICE_{gs,t-1} - \varphi_g TGP_{gs,t-1} - \Gamma_g) + X_{gst} B_g + \upsilon_{gst} \end{aligned} \tag{2}$$

where $\Delta TGP^{+}_{gs,t-i} = \max(0, \Delta TGP_{gs,t-i})$, $\Delta TGP^{-}_{gs,t-i} = \min(0, \Delta TGP_{gs,t-i})$, and $\Delta PRICE^{+}_{gs,t-j}$ and $\Delta PRICE^{-}_{gs,t-j}$ are similarly defined. The error correction term, in parentheses on the last line, represents the long run relationship between retail price and terminal gate prices, to which it can be expected to return. The Γ_g are grade specific constants and the υ_{gst} are normally distributed errors. We decompose the left hand side $\Delta PRICE_{gst} = PRICE_{gst} - PRICE_{gs,t-1}$ and add $PRICE_{gs,t-1}$ to both sides, to obtain the final form used in the estimation. Standard errors are again robust and clustered by city.

Throughout our analysis, we wish to compare prices per unit of energy, rather than per liter, and thus adjust the price of E10 for its energy content. Straight ethanol has about 33% less energy content than non-blended regular gasoline, so E10 has about 3.3% less.[7] The energy-adjusted price of E10 is defined as the amount of money necessary to buy the same amount of energy contained in one liter of unblended regular gasoline.

We denote D_s as NSW, and $D_{N,t}$ as $N\%\text{-}PERIOD$ in the accompanying tables, for readability.

4 Results

4.1 Volume and Price Effects Due to the Mandate

We begin by examining the mandate's impact on the volume of premium grade gasoline. Ethanol was not blended into premium in New South Wales and premium did not physically change as a result of the mandate. Its availability was also unchanged. One would expect the mandate to affect premium volumes little absent consumer avoidance of E10.

[7] Ethanol-free gasoline contains approximately 114,000 BTUs (British Thermal Units) of energy per gallon, whereas E10 contains 110,300 BTUs.

Table 2 reports the difference-in-differences estimates of the impact of the mandate on premium grade volumes from the reduced form specification. Specification (1) reports our estimates without additional controls, Specification (2) includes the additional controls.

We find that premium volume increases are insignificantly different than zero in the 2% period but significantly higher, and dramatically so, in the 4% and 6% periods. The fact that premium volumes did not increase as much in the early 2% period can be expected, as regular was still widely available. The actual overall percentage of ethanol blended into the gasoline supply lagged well behind the mandated minimum, increasing just 1% after one year and reaching the 2% level only at the very end of the 2% period, 26 months later.

In the 4% and 6% periods when unblended regular became scarcer, premium volumes surged. Using Specification (1), we find that premium volumes in the 4% period increased by 46.96 million liters per month relative to control states (by adding up the relevant coefficients in the table), statistically significant at the 1% level. In the 6% period, premium volumes increased 84.87 million liters per month relative to control states, also significant at 1%. These correspond to 53.2% and 94.3% percent increases relative to changes in other states.

In fact, the market share of premium grade gasoline eventually more than doubled by the end of the sample, rising from 18.4% in October 2007 to 38.6% in July 2013. While premium market shares in other states remained stable (increasing only half a percent during the period), significant numbers of consumers in New South Wales rejected the mandated E10 and sought out the ethanol-free substitute. Specification (2), which includes additional controls, yields the same conclusion, with the controls having the expected signs.

So large was the exodus away from E10 and into premium in New South Wales that as of 2011, premium grade gasoline became the number one selling grade of gasoline. Moreover, since premium gasoline was substantially more expensive than E10 (about 12 cents per liter or about 43.1 US cents per gallon), but has no ethanol in it, the added cost borne by these consumers as unblended regular disappeared did not come with the purported benefits associated with the mandate.

Specifications (3) and (4) in Table 2 report difference-in-differences estimates of the mandate's impact on regular grade gasoline volumes and Specifications (5) and (6) do the same for E10. Using Specification (3), regular grade volumes in New South Wales decreased by 49.37 million liters per month (11.9%) in the 2% period, 178.28 million liters per month (42.9%) month in the 4% period, and 241.21 million liters per month (58.2%) in the 6% period, relative to control states. Using Specification (5), E10 volumes increased by 50.24 million liters per month in the 2% period, 139.94 million liters per month in the 4% period, and 166.17 million liters per month in the 6% period, relative to increases in control states. Specifications (4) and (6), including additional controls for regular and E10 respectively, yield the same conclusion. All estimates are statistically significant. While it is not surprising that regular volumes decreased and E10 volumes increased due to the mandate, the precise point estimates will be important for the cost calculations that are to follow.

Figures 1, 2, and 3 show the actual volumes and the predicted (in the absence of the mandate) volumes for premium, regular, and E10, respectively, for the pre-mandate period and for the 2%, 4%, and 6% mandate periods.

The mandate can affect not only volumes, but also prices. We report the mandate's impact on the prices of the three grades in New South Wales relative to other control states in Table 3. Specifications (7), (9), and (11) include the terminal gate price as a control. Specifications (8), (10), and (12) use the more flexible vector autoregressive error correction model allowing for asymmetric and lagged responses to terminal gate prices.

In short, we universally find no statistically significant effect of the mandate on the prices for any grade.[8]

We do see, as expected, that terminal gate prices drive retail prices. Coefficients of the terminal gate price in the simple supply models are all very close to one, showing near perfect pass-through of wholesale prices into retail. Their t-statistics range from 38 to 164 across grades. The error correction model tells a similar story. We report the full set of coefficients on lagged prices and terminal gate prices in Appendix Table A1.

Although we find a lack of price effects, it does not mean prices do not matter. It only means that price changes for each grade were not caused by the mandate. Since there are significant changes in volumes across grades, and grades have different prices, the cost of the mandate still

[8] The only statistically significant coefficient among the interaction terms in any of the six price specifications is the 6%-PERIOD coefficient in Specification (8). However, recall that the relevant effect for the 6% period (relative to the pre-mandate period) is given by the sum of the 2%, 4% and 6% interaction terms, and this sum is not statistically significant.

depends on the price differences between grades as the mandate induces changes in composition.

4.2 Evidence that the Aversion Was Unanticipated

The large magnitude of switching away from E10 and toward premium grade gasoline by ethanol averse consumers was largely unexpected by policymakers. While we are not aware of direct evidence on what regulators did expect, the surprise is clearly evident by how dramatically the mandate failed to meet its ethanol targets. The actual percentage of ethanol in gasoline by volume stalled at 3.5% in 2011, less than half of the mandate's original goal.[9] The mandate failed to meet even the second (4%) phase of the complete four phase plan. Legislators responded by postponing the third (6%) phase by nine months, to no avail, and then scrapped the fourth phase altogether which would have eliminated unblended regular entirely. The percentage still stood around 3.5% at the end of the sample in 2013, a year after all four phases were to have been implemented.

Surprise is also evidenced by the fact that the overall percentage of ethanol in the fuel supply by volume is on track to reach only 4.5% if unblended regular were eliminated altogether. Absent a change in current consumer behavior, the exodus to premium means the third phase of the mandate cannot be met. Moreover, it means that the fourth and final phase of the mandate - in which all regular was to be converted to E10 - would actually be a *weaker* ethanol requirement than the third phase of the mandate (6%). E10 is on track to reach only 45.4%, which would yield an overall ethanol content of just 4.5% and would be a step backwards from the third phase. Clearly, this is not an original design. Meanwhile, premium grade gasoline is on track to rise from an 18.4% market share before the mandate to a 54.6% share, triple its pre-mandate level. The dramatic rise in premium ironically does little for the goals of the mandate, as premium remains ethanol-free.

4.3 Diversion Ratios Show Early Success Was Misleading

The New South Wales experience shows selective mandates can exhibit severe diminishing marginal returns and the apparent early success of a selective mandate can be a misleading indicator of its long run success. The reason is that consumers are heterogeneous in their aversion. The least

[9] Given an 18.4% initial premium market share, and assuming no switching to premium grade, this would be equivalent to a 8.14% ethanol requirement.

averse consumers adopt early without difficulty and only later on does the resistance of more averse consumers become apparent.

Figure 4 shows estimated volume changes, by grade, in each mandate period due to the mandate and the diversion ratios implied by them. Specifications (1), (3) and (5) are used. In the top panel, where we report changes in volumes, we report the negative of the regular grade volume changes for readability (so they appear as a positive number). In the bottom panel, diversion ratios are defined as the fraction of the reduced regular grade volumes that were diverted to either premium or E10, respectively. Standard errors are shown as "whiskers" on the figure.

In the 2% period, we see there was no diversion to premium. The decrease in regular sales (-49.37 million liters per month) was almost entirely offset by an increase in E10 sales (50.24 million liters, or 48.61 million energy-equivalent liters per month). On the basis of these aggregate data alone, it might seem that consumers were slowly but smoothly adopting E10, as regular pumps were swapped out for E10 pumps, and that the implementation of the mandate would proceed smoothly.

However, this changed by the time of the 4% period. As regular became even more and more scarce, consumers who were increasingly ethanol averse and could no longer reasonably find regular began diverting to premium in ever larger proportions. In the 4% period, the 128.9 million liter per month decrease in regular led to an increase of just 86.8 million energy-equivalent liters of E10, and now filling the gap was an additional 47.5 million liters of premium.[10] In other words, for every additional one hundred liters of regular lost, 35.4 more liters of premium were sold in the 4% period, a diversion ratio of 35.4% (up from 0%). Roughly one third of consumers losing access to regular in this period chose premium over E10.

In the 6% period, the loss of 63.4 million more liters of regular per month led to just 26.2 million more energy-adjusted liters of E10, but now an additional 37.9 million liters of premium. That is, roughly 3 out of 5 consumers losing access to regular now chose premium over E10. The diversion ratio to premium was 59.9% and premium became the number one choice for consumers

[10] The number of liters of E10 and premium gained is close, but not exactly equal, to the number of liters of regular lost. There was a small overall net loss in volumes due to the mandate. Thus we normalize the diversion ratios so that the sum of the diversion ratio is to equal 100%. The diversion ratio from regular to grade g is the number of additional liters of grade g sold divided by the number of regular liters lost that were replaced with either premium or E10.

who switched.

These diversion ratios clearly demonstrate severely diminishing marginal returns over time. In fact, adding one more liter of E10 into the overall gasoline supply in 2013 was approximately *forty-five* times more expensive than it was in 2009.[11]

Diversion ratios can be expected to continue to climb, but even if they plateaued at the current 60%, the market share of E10 would still top out at 45.4%. This in turn implies a total 4.5% ethanol content ratio by volume, well short of the mandate's goal.

The pattern of diversion ratios is consistent with consumers heterogenous in their aversion to ethanol, with the least averse consumers adopting early, and the resistance of more averse consumers becoming more apparent later on. Early apparent adoption of a selective mandate does not necessarily indicate future success.

4.4 Burden and Incidence of the Mandate

There are many potential costs and benefits to an ethanol mandate. We focus on one particular cost – the cost to consumers in terms of increased fuel expenditures for the same amount of energy. As mandates are all too often debated without a full quantitative understanding of each of its costs and benefits, our article seeks to fill in part of this gap.

In so doing, we find that the typical method for calculating consumer costs is biased in the case of a selective mandate. The typical assumption is that cost can simply be calculated as the difference between the price of the old regular grade fuel and the energy-adjusted price of the new ethanol blend which replaces it, multiplied by the relevant quantity. However, this presumes a 100% diversion ratio from the old blend (regular) to the new (E10) and no other options.

We have shown this not to be true with selective mandates in general and in New South Wales in particular. A high percentage of consumers avoided E10 and switched to the much more expensive premium grade instead. Regardless of whether consumers' aversion is based on real or perceived reasons, the costs are economically significant. We find that ignoring premium switchers ignores

[11] In 2009, when the regular-to-E10 diversion ratio was 100%, one liter of regular was replaced with one liter of E10, which cost approximately 0.4 cents per liter more. In 2013 when the diversion was 40%, one more liter of E10 required a loss of 2.5 liters of regular and a collateral gain of 1.5 liters of premium. The extra cost of the one extra liter of E10 in 2013 was close to zero but the extra cost of the extra 1.5 liters of premium was approximately 19 cents. Dividing 19 cents by 0.4 cents, the 2013 cost is about 45 times greater than the 2009 cost.

96% of the total cost of the mandate in terms of the increased cost of fuel in New South Wales.

In short, there are two groups of affected consumers. The first switched from regular to E10, as was anticipated, and paid 0.2 cents more per energy adjusted liter. The second group switched from regular to premium, largely unanticipated, and paid 12 cents more per liter (43.1 U.S. cents per gallon).[12]

Table 4 shows our estimates of the total burden of the mandate in terms of the increased cost of fuel. We calculate it two ways. For the "CV-type" calculation, we calculate the additional cost, due to the mandate, for the same amount of energy that would have been used in the absence of a mandate (compensating variation type). For the "EV-type" calculation, we calculate the additional cost, due to the mandate, for the same amount of energy that was actually used during the mandate (equivalent variation type).[13] Because the mandate resulted in a small reduction in energy-adjusted total volumes overall, the CV-type estimate is a modestly higher the EV-type estimate. The two calculations bound the loss.[14]

The table shows that, from the inception of the mandate in October 2007 to the end of our sample in June 2013, the increase in the cost of fuel paid by all consumers was \$345.2 million (about 327 million US dollars) under the CV-type calculation and \$337.2 million under the EV-type calculation.

This equates to \$5.1 million per month on average (CV-type calculation) over the full sample, a figure that has been accelerating over time. In 2009, the one-month burden was \$1.2 million; in 2010, it was \$3.5 million; in 2011, it was \$8.2 million. By 2013, it was \$12.3 million per month, and rising with the premium diversion ratio. On a per liter basis, the cost to consumers already forced off of regular averaged 3.4 cents per liter (12.2 U.S. cents per gallon) over the whole sample

[12] Consumers who did not switch could have been affected as well if the mandate affected relative prices, but price effects were insignificant across the board.

[13] Standard errors for each are calculated numerically using the Cholesky decomposition and simulating 10,000 draws of the parameter vector. See Krinsky & Robb (1986) for advantages of this method over linear approximations.

[14] The CV-type calculation assumes consumers would have purchased the same amount of energy-adjusted fuel in the presence of the mandate as they would have in the absence of it, but in reality they purchased a bit less. By revealed preference, purchasing more of something else instead of fuel during the mandate was welfare improving, so the CV-type calculation is an upper bound on the loss. The EV-type calculation assumes consumers would have purchased the same amount of fuel without the mandate as they did with it, but in reality they would have purchased a bit more. By revealed preference, purchasing more fuel instead of something else in the absence of the mandate was welfare improving, so the EV-type calculation is a lower bound on the loss. We abstract from welfare changes other than those associated with changes in the cost of fuel.

and rising.

Table 4 also decomposes the cost into that borne by each of the two groups of affected consumers. We find the cost to consumers switching to E10 was \$14.0 million, or only about 4% of the total amount (CV-type calculation). In sharp contrast, the cost to consumers who largely unexpectedly avoided E10 and switched to premium instead was \$331.1 million (about 314.6 million US dollars), or about 96% of the total. To ignore these consumers avoiding E10 and diverting to premium is to ignore 96% of the total cost of the mandate in terms of increased fuel expenditures.[15]

To the extent E10 aversion was related to safety concerns, the difference in price of E10 and premium can be thought of as an insurance premium – essentially, a "premium insurance premium". By purchasing premium gasoline instead of E10, the consumer reduces her perceived risk of ethanol damage to zero. In 2012, that insurance premium was 12.0 cents per liter. Multiplying this figure by the average fuel consumption per vehicle per year of $1,268$ liters yields an annual premium of \$152 to avoid E10. The number of premium switchers gives the number of potential insurance "policies", $982,000$ in all.

Throughout, we have assumed the energy content of premium and unblended regular grade gasoline are the same.[16] Because consumers often perceive premium to be superior, we gauge the robustness of our results to even liberal assumptions of 1.5% and a 3% upward energy adjustments for premium. Our cost estimates still remain high – \$286.1 million and \$227.6 million respectively (CV-type calculation).

[15] It could be argued that the former group of consumers who switched to E10 (and accounted for 4% of the cost), incurred no *net* cost at all since, by revealed preference, they must have preferred E10 over unblended regular to buy it when both were available (perhaps out of desire to help the environment). However, it is important to note that unblended regular and E10 generally never coexisted at the same gasoline station – E10 pumps replaced the existing regular pumps – so that switching between blends required switching gas stations. Thus purchasing E10 is still consistent with an intrinsic preference for unblended regular or indifference in the presence of search costs and/or station differentiation. Consistent with the fact that earlier private efforts to introduce E10 in NSW and in other Australian states failed, and consistent with the universally negative press, it is unlikely many NSW consumers switched to E10 because of an intrinsic preference for E10 rather than to avoid inconvenience. Regardless, the costs estimated here are monetary costs, not net costs, and any real or perceived environmental benefits require a separate calculation. Note that the high estimated cost to the second group of consumers (\$337 million) who diverted to premium are unlikely to be offset by any pro-environmental motives.

[16] There is a popular perception that premium is a higher quality fuel than regular. However, the defining difference is that premium has a higher octane rating and is more resistant to pre-ignition and engine knock. Absent engine knock, the higher octane has no advantage (Setiawan & Sperling (1993)).

4.5 Incompatibility Aversion versus Other Aversion

Regardless of the reasons for consumer aversion which led to their avoidance of E10, the costs stemming from it are significant. However, it is interesting to explore possible reasons for their aversion, and the extent to which it could have been foreseen by regulators. We distinguish between two types - "incompatibility aversion" and "other aversion".

"Incompatibility aversion" refers to E10 avoidance by consumers whose vehicles are not certified for E10 use, according to a well cited list of manufacturer recommendations compiled by the Federal Chamber of Automotive Industries (FCAI). While the list has been criticized as being conservatively long, it is cited by parties on all sides of the mandate debate, including the New South Wales government, as the primary source for E10 compatibility information that consumers should consult before buying E10.[17] Consumers with vehicles on the list can reasonably be expected to be averse to E10 and avoid it. The list has been combined with automobile registrations by IPART (2012) and separately by Wilson et al. (2011) to estimate the percentage of registered vehicles on the road that are included in the list.

"Other aversion" refers to all other E10 avoidance by consumers whose vehicles are certified for E10 according to the list. They may have been expected to adopt it, but were averse to it for safety concerns or other reasons and avoided it.

Table 5 shows our back of the envelope calculations on the fraction of premium switchers due to each type of aversion, using the IPART estimates as the starting point in the first column and Wilson et al. ones as the starting point in the second.

Focusing on the first column, we see the IPART report estimates that in 2014, 21% of registered vehicles on the roads were on the FCAI list as incompatible with E10. However, this overstates the size of the incompatibility aversion group. Many cars on the list were using premium fuel already, including luxury cars and most European imports. We make the conservative assumption that the proportion of vehicles on the list requiring premium gasoline was the same in the entire vehicle fleet

[17] For example, see the National Roads and Motorists' Association submission to the Independent Pricing and Regulatory Tribunal in 2012, available at http://www.mynrma.com.au/media/independent_pricing_submission.pdf , last accessed March 9, 2014. Vehicles sold in Australia prior to the notion of an ethanol mandate may not have been certified absent any need. European imports, for example, were often certified for E5 only, the European standard. Manufacturers may also have little incentive to certify cars already sold since the certification process is costly, it opens the door to potential liability, and can in theory negatively impact new vehicle sales. Not certifying certifiable but already sold vehicles would be in the spirit of planned obsolesence, e.g. Bulow (1986).

(and that they consumed similar amounts of fuel). This implies the fraction of registered vehicles on the list that were running on regular before the mandate was 17.6%.

This is still too high as a measure of the current incompatibility aversion group. In 2013, unblended regular gasoline was still available in some areas, so not all consumers who would eventually have to switch already had. We conservatively assume that these consumers would not search but rather would purchase unblended regular if it were available at a station and premium if it were not. Given a market share of unblended regular gasoline out of total non-premium gasoline fuels at 44.1% in 2013, this implies that these consumers would have had to purchase premium up to 55.9% of the time. Multiplying by 17.6% yields an upper bound estimate of the expected change in the market share of premium grade gasoline due to incompatibility aversion: 9.9%.

We compare this with the total increase in the market share of premium grade gasoline over the sample of 20.2%. We therefore conclude that a little under half of the switching to premium, at most, can be accounted for by incompatibility aversion, i.e. by consumers who were advised by the FCAI list, with support from regulators, to avoid E10. More than half of the increase in the premium market share, 10.3%, was due to "other aversion", i.e. by consumers whose vehicles were listed as compatible and safe with E10 but who avoided it anyway. The corresponding figures based on Wilson et al. in column 2 are 7.6% and 12.6%, respectively.

The implication is two-fold. First, regulators either knew or should have known, based on their own recommendations, that as many as 9.9% of consumers by this time would be forced off of regular and onto premium, at a cost to them of up to $162 million (half the total cost of premium switching). As regular continues to be phased out, the cost will continue to escalate.

This cost could have been mitigated in several ways. To the extent that the FCAI list is mostly accurate and there are truly many incompatible vehicles, then the mandate could have been delayed until the vehicle fleet was newer and more able to handle E10, as discussed in the introduction. To the extent the FCAI list is overly conservative and many vehicles are mis-listed as incompatible, greater efforts could have been made to test older vehicles and produce a more accurate, and shorter list. A combination of both could also have been considered.

Second, regulators may not have expected that another 10.3% of consumers, whose vehicles were listed as compatible and safe with E10, still rejected E10 and switched to premium at an additional cost to them of \$169 million. But regulators could have done a better job gauging consumer sentiment, and the cost could have been mitigated in several ways. To the extent there is consensus that these vehicles can safely use E10, they could have better educated consumers with test results and other hard evidence of E10's safety in their vehicles. They could have provided warranties, which were requested by various stakeholders and denied. To the extent that consumers could not be convinced, regulators could again have delayed the mandate until the vast majority of vehicles in the vehicle fleet were compatible with E10. At that point there would be no further need for a selective mandate and all unblended gasoline could be switched out for E10, as with the universal U.S. mandate. The fact that regulators still moved forward on the mandate before either vehicles or consumers were ready for it meant that a selective mandate was necessary – and this led to significant cost consequences and ultimately the failure of the mandate. The total increase in the cost of fuel exceeded \$300 million over five years and 96% of that cost was spent by consumers just avoiding the mandate.

5 Conclusion

This article analyzes consumer reactions to the selective ethanol mandate in New South Wales, Australia. The purpose of this and other mandates is to increase the amount of ethanol or renewables contained in fuel. The New South Wales mandate was an E10 mandate, but it was implemented at a time when either not all vehicles were able to safely use the new blend or, at least, were not believed to be able to safely use the new blend. To avoid delaying, it was deemed necessary by regulators to implement the mandate selectively, making both E10 and an ethanol-free gasoline simultaneously available, while at the same time ensuring the price of the ethanol-free option was higher to discourage consumers who did not really need it. While there are various ways to do this, all means to the same end, the NSW mandate chose to leave premium grade gasoline as an ethanol-free almost-perfect substitute.

We show that ethanol averse consumers widely rejected the mandate. There was an exodus away from the new ethanol blend and towards the ethanol-free almost-perfect substitute. The market share of premium more than doubled in less than six years to become the number one selling grade of gasoline in New South Wales. The cost these consumers paid was high. They paid an additional 12 cents per liter (43.1 U.S. cents per gallon), or $152 per car per year, or $331.1 million over the first roughly six years of the mandate, to avoid E10.

We show how the seemingly smooth adoption of E10 in the early days of the mandate was a misleading indicator of what was to come. As increasingly ethanol averse consumers lost access to regular, the diversion ratio from regular to premium rose significantly over time and the diversion ratio from regular to E10 fell. By the 6% mandate period, three out of every five consumers who lost access to regular chose premium over E10. The monthly cost rose from $1.2 million in 2009 to $12.3 million in 2013, and the incremental cost of adding one more liter of E10 into the fuel supply was forty-five times greater in 2013 than in was in 2009.

We find that the extra cost paid by those who switched to premium gasoline dwarfed the typical source of increased fuel costs generally associated with an ethanol mandate. The typical focus is on the extra cost of fuel from consumers who switched from regular to the blend intended to replace it, E10. Yet the latter consumers paid only an additional $14.0 million, or 4% of the cost. In contrast, consumers who diverted to premium paid $331.1 million, or 96% of the cost. In other words, the cost to consumers diverting away from the unpopular mandated good and towards its almost perfect substitute, which has previously received little attention, accounts for the lion's share of the total cost.

A little under half of the consumers who switched to premium were advised even by the regulator against using E10 for potential vehicle incompatibility reasons, and directed to premium. Perhaps less expected was the other half of consumers who passed over E10 for premium even though regulators and manufacturers assured them E10 was safe in their vehicles. To a large extent, this may have been unanticipated, but a better of understanding of consumer sentiment in advance of implementing the mandate would have revealed the strength of consumers' aversion.

In the end, the mandate was very costly and it still failed to reach its goals. The market share of E10 stalled after only a few years and regulators could not meet even the second phase of the four phase plan. Regulators postponed the third phase to no avail and abandoned the fourth phase altogether.

Now E10 is on track to reach just a 45.4% market share if regular were eliminated entirely.

Meanwhile, the 8% more expensive premium grade gasoline, once only at an 18.2% market share, is on track to reach 54.6%, triple its pre-mandate share. Ironically, this tripling of the premium share does little to advance the goals of the NSW mandate, since premium by design has no ethanol in it.

There are implications for New South Wales and to regulators considering new or more aggressive ethanol mandates everywhere. To the extent that there truly are many incompatible vehicles, then the mandate can be delayed until the vehicle fleet is newer and able to better handle the new blend. To the extent vehicles are truly compatible but consumers are not convinced, greater efforts can be made to convince them through additional testing and education or warranties. To the extent that consumers cannot be convinced, regulators can only delay the mandate until the vehicle fleet is deemed compatible, obviating the need for a selective mandate. When regulators move too quickly, the potential for significant avoidance by averse consumers is real, as occurred in New South Wales.

The New South Wales mandate is an interesting and extreme example of the unintended consequences of regulation. An effort to implement the mandate before all vehicles were ready to handle it or, alternately, before consumers were fully confident in adopting it, led to significant ethanol avoidance and cost. The avoidance was made tractable because both ethanol blends had to simultaneously coexist at different prices at the same time. The simultaneous coexistence of both blends – regulated and unregulated almost-perfect substitutes – was in turn made necessary by the aggressiveness of the mandate relative to the state of the vehicle fleet. We conclude that the potential for consumer avoidance and consumer aversion costs, largely ignored in past calculations, should be given serious consideration in the greater cost-benefit analysis whenever a mandate, and a selective ethanol mandate in particular, is being contemplated.

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Table 1. Summary Statistics

	Mean	Std. Dev.	Minimum	Maximum
Premium Volume	61.43	42.45	11.74	204.12
Regular Volume	222.65	107.69	82.72	457.50
E10 Volume	28.28	50.75	0.00	208.56
Premium Price	136.01	17.08	96.63	169.19
Regular Price	126.69	16.14	89.49	162.59
E10 Price	128.92	12.31	101.50	159.89
Terminal Gate Price	120.96	15.30	82.78	154.93
New Vehicle Registrations	16.23	8.11	4.13	37.19
Unemployment Rate	5.00	0.73	2.70	6.60

Volumes in millions of liters per month. Prices, including terminal gate prices, in Australian cents per liter (approximate exchange rate 1 AUD = 0.95 USD from 2009 to 2013.) New vehicle registrations in thousands of vehicles per month.

Table 2. Mandate Impact on Volume of Each Fuel Grade

Dep. Var. = VOLUME	Premium		Regular		E10	
	(1)	(2)	(3)	(4)	(5)	(6)
NSW	50.359*	11.735*	196.421*	32.875	1.057	-12.881
	(11.597)	(4.075)	(58.306)	(13.554)	(3.136)	(17.504)
2%-PERIOD	3.657**	3.990*	-21.127	-19.935	12.088	11.737
	(0.780)	(1.156)	(10.879)	(8.946)	(10.379)	(10.476)
4%-PERIOD	3.789*	0.789	-15.830	-27.724*	6.234	3.985
	(1.235)	(1.453)	(8.368)	(8.298)	(4.262)	(3.924)
6%-PERIOD	5.203	6.695*	5.629	3.611	-10.391	-8.899
	(2.024)	(2.181)	(5.226)	(3.758)	(8.628)	(8.782)
2%-PERIOD*NSW	-0.513	0.480	-49.368*	-41.819*	50.235**	50.561**
	(0.780)	(1.169)	(10.879)	(10.812)	(10.379)	(10.389)
4%-PERIOD*NSW	47.470**	47.721**	-128.916**	-131.498**	89.704**	91.777**
	(1.235)	(1.318)	(8.368)	(8.414)	(4.262)	(3.933)
6%-PERIOD*NSW	37.910**	31.001**	-63.384**	-88.752**	26.226*	23.888*
	(2.024)	(1.541)	(5.226)	(3.383)	(8.628)	(8.246)
NEW VEHICLES		1.844**		7.193**		0.624
		(0.212)		(0.325)		(0.603)
LAGGED NEW VEHICLES		1.357**		6.051**		0.398
		(0.235)		(0.153)		(0.527)
UNEMPLOYMENT		12.038		9.802		15.687
		(8.291)		(13.126)		(10.408)
LAGGED UNEMPLOYMENT		-11.185		-5.921		-13.0509
		(7.652)		(11.141)		(9.756)
TGP (RACK)		-0.202**		-0.277		-0.145
		(0.021)		(0.125)		(0.099)
MONTHLY DUMMIES	N	Y	N	Y	N	Y
R-SQUARED	0.746	0.969	0.380	0.957	0.845	0.866
NUM. OBS.	485	485	575	570	485	485

Standard errors in parentheses. * Significant at 5% level, ** Significant at 1% level.

Table 3. Mandate Impact on Price of Each Fuel Grade

	Premium		Regular		E10	
Dep. Var. = PRICE	(7)	(8)	(9)	(10)	(11)	(12)
NSW	-0.062	0.115	-0.883	-0.196	-0.676	-0.142
	(1.311)	(0.156)	(1.053)	(0.221)	(1.562)	(0.341)
2%-PERIOD	4.844**	1.457**	2.065**	0.749*	3.606**	1.258*
	(0.661)	(0.146)	(0.413)	(0.235)	(0.576)	(0.255)
4%-PERIOD	1.319	-0.783*	0.578	0.177	0.477	0.322
	(0.661)	(0.331)	(0.562)	(0.249)	(0.345)	(0.216)
6%-PERIOD	2.990*	1.332**	0.884	0.192	1.155	0.310
	(0.848)	(0.139)	(0.587)	(0.264)	(0.613)	(0.291)
2%-PERIOD*NSW	-0.349	0.083	-0.532	0.073	-0.996	-0.058
	(0.723)	(0.104)	(0.361)	(0.156)	(0.378)	(0.165)
4%-PERIOD*NSW	0.801	0.186	0.867	-0.018	0.238	-0.173
	(0.673)	(0.254)	(0.552)	(0.322)	(0.188)	(0.143)
6%-PERIOD*NSW	-1.194	-0.614**	-0.951	-0.261	-1.078	-0.228
	(0.956)	(0.111)	(0.748)	(0.192)	(0.641)	(0.308)
NEW VEHICLES	-0.017	-0.088	-0.048	-0.098	-0.079	-0.108*
	(0.073)	(0.046)	(0.058)	(0.040)	(0.083)	(0.023)
LAGGED NEW VEHICLES	0.168**	0.106	0.187**	0.129*	0.148*	0.116**
	(0.030)	(0.042)	(0.020)	(0.034)	(0.032)	(0.019)
UNEMPLOYMENT	2.795	-0.878	1.236	-0.617	0.253	-1.183
	(1.340)	(0.411)	(0.979)	(0.448)	(2.044)	(1.190)
LAGGED UNEMPLOYMENT	-2.559	0.701	-0.945	0.561	-0.497	0.999
	(1.249)	(0.430)	(0.923)	(0.419)	(1.892)	(1.202)
TGP (RACK)	0.937**	†	0.993**	†	0.951**	†
	(0.014)		(0.006)		(0.025)	
MONTHLY DUMMIES	Y	Y	Y	Y	Y	Y
R-SQUARED	0.98	0.993	0.986	0.990	0.976	0.986
NUM. OBS.	565	545	565	545	288	268

Standard errors in parentheses. * Significant at 5% level, ** Significant at 1% level. † The remaining results of the VAR model, including lagged price, terminal gate price, and lagged price and terminal gate prices changes, are presented in Table A1.

Table 4. Total Burden of the Ethanol Mandate

	Total Dollars	Cents per Liter
CV-Type Calculation		
Increased Cost to All Switching Consumers for the Same Amount of Energy that Would Have Been Used Absent the Mandate	$ 345,212,889	3.42 ¢
	(5,228,300)	(0.05)
Increased Cost to Those Consumers who Switched from Regular to Premium Grade Gasoline	$ 331,177,249	12.01 ¢
	(5,385,200)	(0.20)
Increased Cost to Those Consumers who Switched from Regular to E10 Grade Gasoline	$ 14,035,640	0.19 ¢
	(177,080)	(0.01)
EV-Type Calculation		
Increased Cost to All Switching Consumers for the Same Amount of Energy Actually Used With the Mandate	$ 337,194,383	3.44 ¢
	(1,349,700)	(0.01)
Increased Cost to Those Consumers who Switched from Regular to Premium Grade Gasoline	$ 323,484,758	12.44 ¢
	(1,659,900)	(0.06)
Increased Cost to Those Consumers who Switched from Regular to E10 Grade Gasoline	$ 13,709,624	0.19 ¢
	(315,330)	(0.01)

Total dollars and cents per liter calculated October 2007 to June 2013.

Table 5. Incompatibility Aversion and Other Aversion

	IPART	Wilson et al.
Listed Compatible Vehicles	78.1%	83.2%
Potentially Incompatible Vehicles	21.9%	16.8%
Potentially Incompatible Vehicles that Do Not Require Premium Already	17.6%	13.5%
Potentially Incompatible Vehicles that Do Not Require Premium Already and Do Not Have Ready Access to Regular	9.9%	7.6%
Total Estimated Premium Switching from Inception of Mandate to mid-2013	20.2%	20.2%
Switching from Incompatibility Aversion	9.9%	7.6%
Switching from Other Aversion	10.3%	12.6%

Table A1. Additional VAR Results

Dep. Var. = PRICE	Premium (7)	Regular (9)	E10 (11)
ΔTGP^{+}_{t}	0.603**	0.916**	0.919**
	(0.015)	(0.013)	(0.023)
ΔTGP^{+}_{t-1}	0.270**	0.408**	0.519**
	(0.030)	(0.067)	(0.089)
ΔTGP^{+}_{t-2}	0.3256**	0.429*	0.569*
	(0.053)	(0.128)	(0.122)
ΔTGP^{+}_{t-3}	0.112**	0.182**	0.249**
	(0.021)	(0.051)	(0.027)
ΔTGP^{+}_{t-4}	0.052	0.110	-0.029
	(0.029)	(0.057)	(0.084)
ΔTGP^{-}_{t}	0.735**	0.905**	0.957**
	(0.032)	(0.030)	(0.011)
ΔTGP^{-}_{t-1}	0.337**	0.665**	0.734**
	(0.024)	(0.103)	(0.093)
ΔTGP^{-}_{t-2}	0.186*	0.205*	0.296
	(0.058)	(0.068)	(0.114)
ΔTGP^{-}_{t-3}	0.276**	0.181*	0.193
	(0.061)	(0.049)	(0.077)
ΔTGP^{-}_{t-4}	0.211*	0.162**	0.133
	(0.053)	(0.020)	(0.081)
$\Delta PRICE^{+}_{t-1}$	-0.075	-0.384**	-0.344*
	(0.063)	(0.066)	(0.098)
$\Delta PRICE^{+}_{t-2}$	-0.390**	-0.325*	-0.374
	(0.056)	(0.103)	(0.122)
$\Delta PRICE^{+}_{t-3}$	-0.140	-0.186**	-0.179**
	(0.058)	(0.041)	(0.017)
$\Delta PRICE^{+}_{t-4}$	-0.072	-0.075	0.018
	(0.069)	(0.053)	(0.080)
$\Delta PRICE^{-}_{t-1}$	-0.307**	-0.556**	-0.744**
	(0.046)	(0.117)	(0.116)
$\Delta PRICE^{-}_{t-2}$	-0.162	-0.274*	-0.343
	(0.094)	(0.082)	(0.131)
$\Delta PRICE^{-}_{t-3}$	-0.328*	-0.167*	-0.235
	(0.091)	(0.045)	(0.084)
$\Delta PRICE^{-}_{t-4}$	-0.143	-0.141**	-0.029
	(0.058)	(0.028)	(0.033)
$PRICE_{t-1}$	0.885**	0.770**	0.795**
	(0.027)	(0.064)	(0.099)
TGP_{t-1}	0.069	0.225*	0.178
	(0.027)	(0.062)	(0.094)
R-SQUARED	0.993	0.990	0.986
NUM. OBS.	545	545	268

Standard errors in parentheses. * Significant at 5% level, ** Significant at 1% level.

FIGURE 1

Premium Market Share - Actual and Predicted

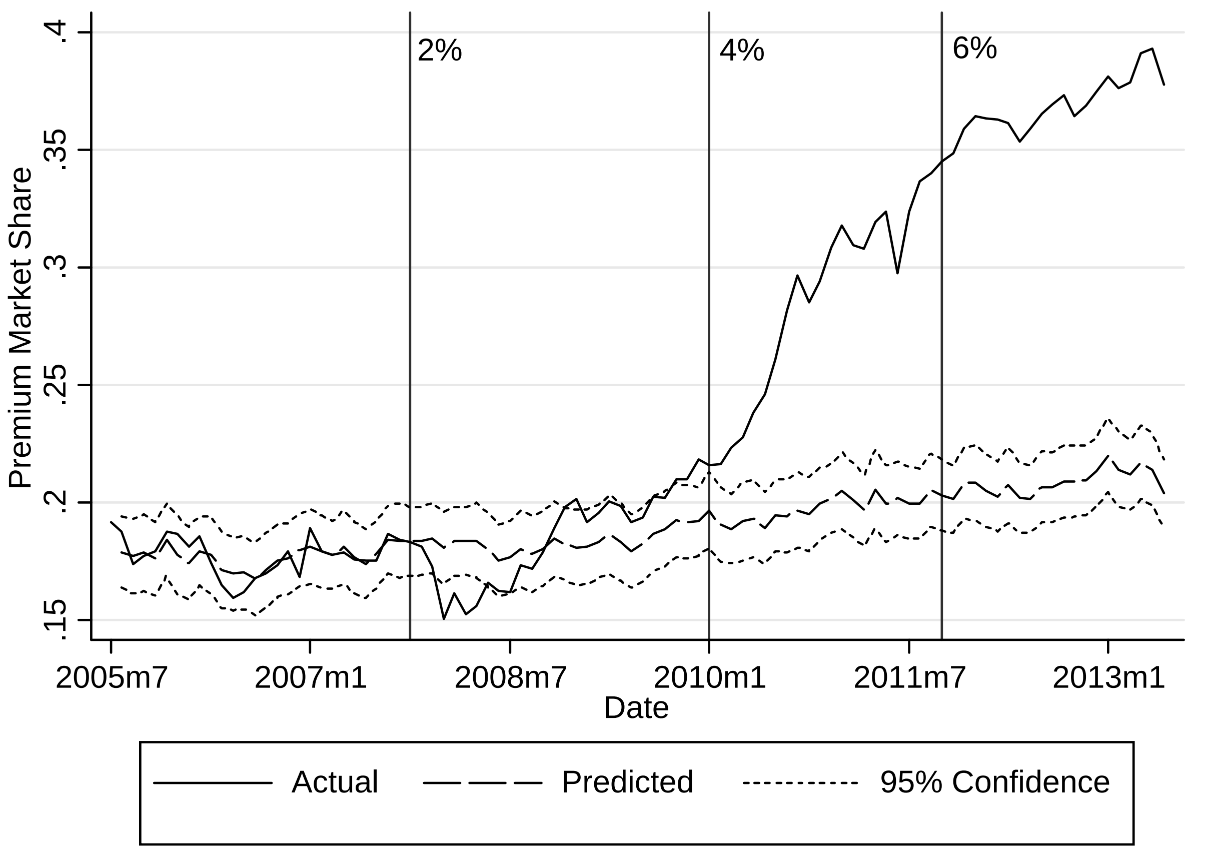

FIGURE 2

Regular Market Share - Actual and Predicted

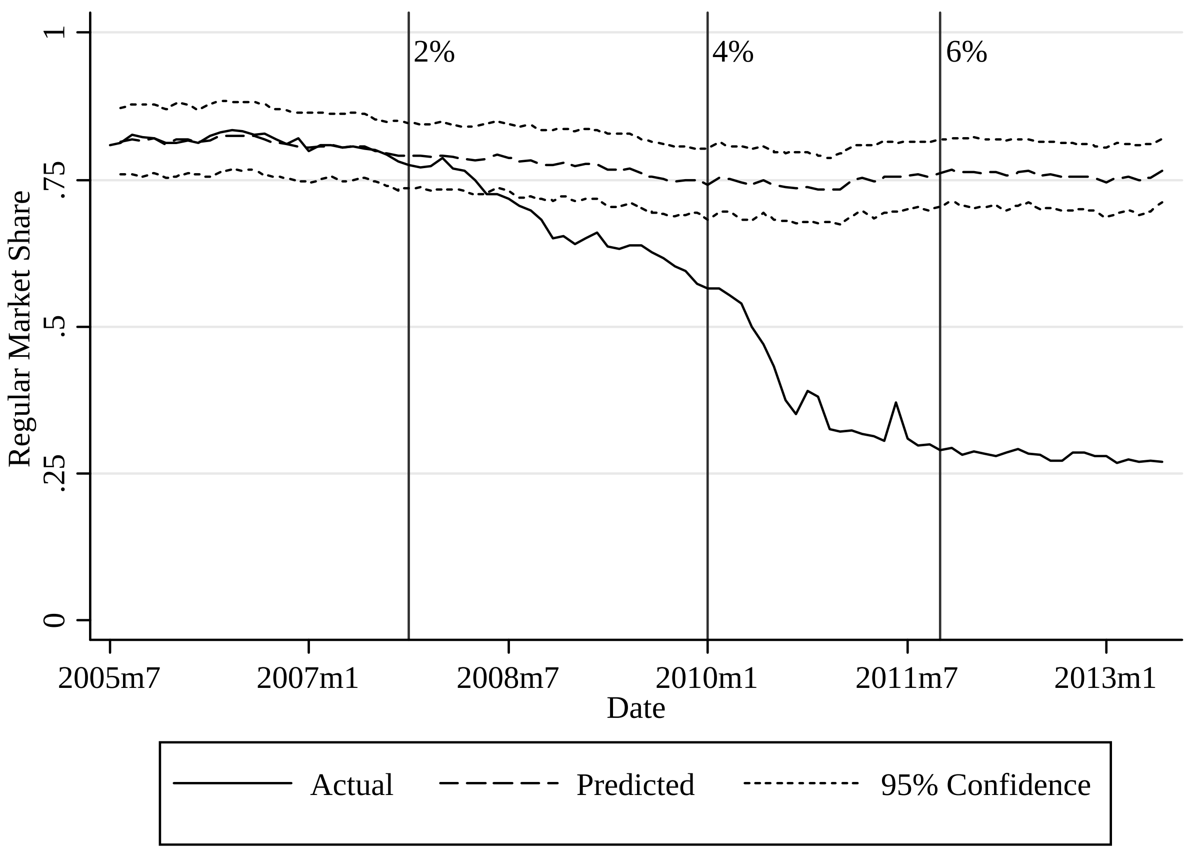

FIGURE 3

E10 Market Shares - Actual and Predicted

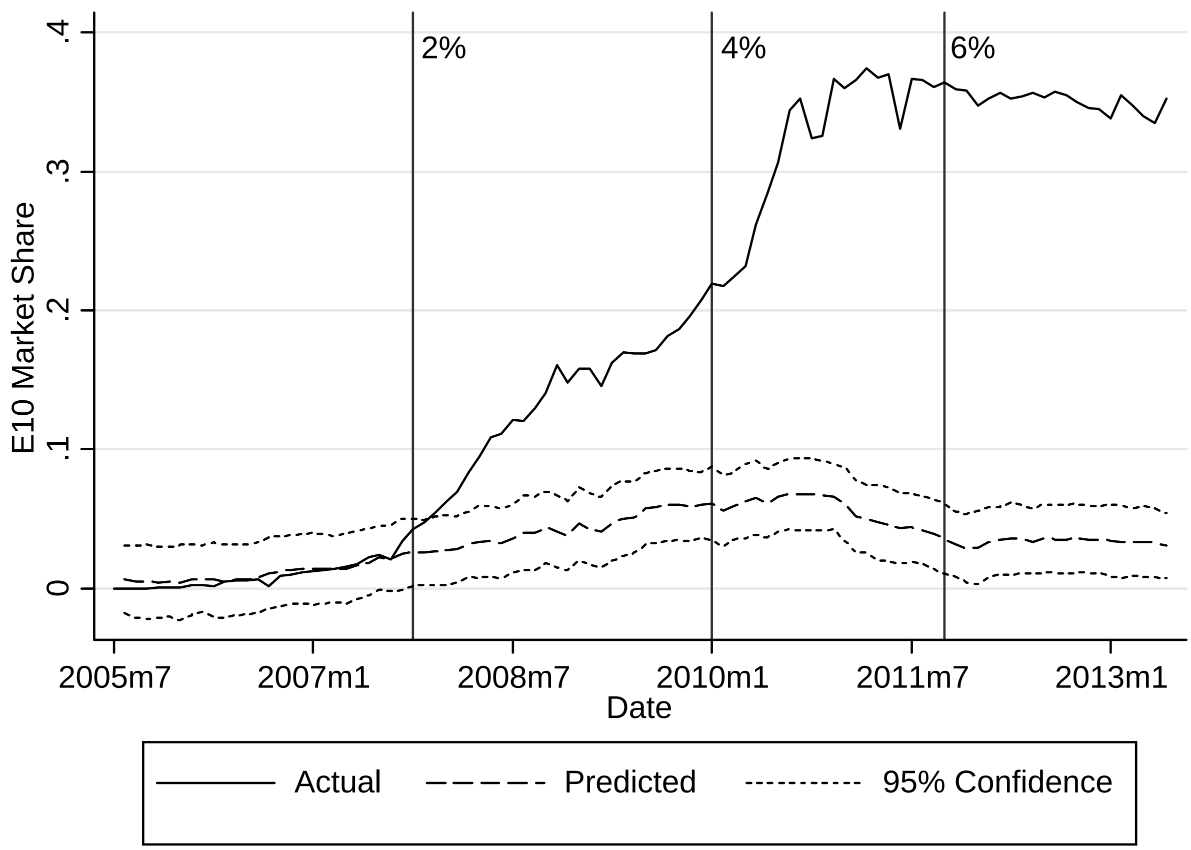

FIGURE 4

Predicted Volume Changes and Diversion Ratios for Each Mandate Period