Price Transparency and Retail Prices:

Evidence from Fuel Price Signs in the Italian Motorway

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Abstract

Price transparency initiatives are typically undertaken by third parties to ensure
that consumers can compare the prices of competing offers in markets where
obtaining such information is costly. Such practices have recently become widespread,
yet it is unclear whether the increased price competition due to lower search costs
overcomes the potential for collusion between competitors due to lower price
coordination costs. Motivated by this question, we investigate the effect of mandatory
price posting (on large electronic signs) by competing gas stations on their pricing
behavior in the Italian motorway. When prices are posted, the average price of
gasoline decreases by 1 cent per liter, which represents about 20% of stations'
margins. About half the price decrease can be attributed to the introduction of a sign
posting a station's own price and those of its nearest neighbors, with the other half
coming from the introduction of other signs posting the prices of other stations on the
same road. Despite the price reduction, however, the introduction of signs seems to
have little impact on price dispersion, suggesting that price uncertainty persists even
after the policy is implemented. Analysis of customer transaction data confirms this
finding, showing that less than 10% of consumers use the posted prices effectively.

Keywords: price transparency, posted prices, retail competition, price
information, difference-in-differences.

1 INTRODUCTION

Consumers often make their choice decisions under conditions of price uncertainty; e.g., a household making a grocery store choice decision typically does not know the prices of the items in the store. To reduce the level of uncertainty, firms engage in a variety of communications that can either inform consumers about specific prices (e.g., feature advertising) or change price perceptions in favor of their products (e.g., Wal-Mart advertising their everyday low prices). The marketing literature has investigated several forms of price communication, including price advertising (Kaul and Wittink 1995) and sale signs (Anderson and Simester 1998). With this research we now understand the use of such practices and how consumers respond to them.

In recent years, however, another phenomenon, price transparency, has become more widespread. Internet websites such as *Kayak*, *College Affordability and Transparency Center*, and *Gasbuddy* allow consumers to discover and compare the prices of similar products across multiple options. Price "posting" is usually the initiative of an independent party which publishes information on prices to inform consumers about competing offers. The Internet represents the ideal platform for enabling price transparency and where such a practice is flourishing: the information on prices can be constantly updated, it is easily accessible, and in some cases it can be sourced from the firms, from users, etc.

As the practice of posting prices increases in popularity, a question of both academic and practical interest that arises is: how do firms respond to such information? Different from traditional forms of price communication, the practice of price posting is *not* the result of a firm's strategic decision to reveal price information about its product. Instead, the firm is a third party to the initiative of other independent parties (i.e., other companies in the case of *Kayak*, the government in the case of the *College Affordability and Transparency Center*, and consumers in the case of *Gasbuddy*), which post its price up against the prices of competitors. How the firm reacts to this information is therefore not

the result of an intended marketing investment (e.g., advertising), but ultimately depends on the mechanisms by which *independent* price information influences the market.

The effect of price transparency on retail prices is theoretically ambiguous. On one hand, increasing the availability of price information lowers consumers' search costs which in turn induces competing firms to lower prices. For example, Brown and Goolsbee (2002) find that the price of term life insurance decreases with the diffusion of the Internet and the ability of consumers to compare prices online. More price information could also lead to lower dispersion in observed prices (Baye, Morgan, and Scholten 1996). On the other hand, price signs might serve as a platform for rival firms to coordinate their prices since information on prices at other stations is more easily available. For example, Albaek et al. (1997) argue that the decision by the Danish Antitrust Authority to publish firm-specific transaction prices in Denmark contributed to increase the price of ready-mix concrete. In absence of field evidence, other authors have used laboratory experiments, reaching similar conclusions (Hong and Plott 1982). The uncertainty over the effect of price transparency has grown skepticism over policies promoting such practice. For example, in the health industry legislation has been proposed to increase price transparency for consumers and curb health costs; however, scholars and analysts have argued against such policies, fearing that price knowledge might favor collusion and lead to higher prices (Hahn, Klovers, and Singer 2008; Kyle and Ridley 2007).

In this study we exploit the introduction of a mandatory price disclosure policy to investigate the effect of price transparency (or price information availability or price posting; terms we use interchangeably) on market prices and on consumers' purchase behavior. In 2007 the Italian Parliament approved a law that required the installation of large electronic signs along the road near gas stations in the Italian motorway system. Each sign posted the fuel prices of several gas stations located nearby. Gas stations were required to update their prices on the sign. In view of the scarce availability of price information along the motorway, the law aimed to increase price transparency for the

benefit of motorway drivers, and also to promote competition among stations inside the motorway. Specifically, we use the temporal variation in prices at a gas station to measure the effect of posted prices on both the level of and the dispersion in prices charged.

The concern about collusion due to transparency has arisen previously in the Italian gasoline market, after a different policy was adopted. Since 1994, oil companies were forced to publicly disclose their suggested retail price. The intention of the policy was to inform consumers of differences between the prices suggested by the oil company and the actual prices charged by the stations. On January 2007, however, the Italian Antitrust Authority terminated this practice, claiming that the announcement of adjustments to the suggested prices was helping oil companies coordinate market prices (disciplinary measure n. 16370, 01/18/2007). Different from such a policy, which involved gasoline producers, the transparency policy discussed here involves the retail market, which is less concentrated. At the same time, price signs provide stations with the opportunity to monitor more easily the prices charged by the same group of stations over time, leading to the possibility of price coordination. The theoretical ambiguity stemming from the opposing forces of competition and coordination generated by the signs motivates our empirical analysis.

The introduction of the price signs was completed in several periods. In each period a new set of signs was installed. The progressive installation of the signs allows us to observe not only the station's response to the introduction of its "own sign" (i.e., a sign where its own price and the prices of its nearest competitors are posted), but also the station's response, if any, to the introduction of a "cross sign" (i.e., a sign where the prices of other stations are posted). Note that when a cross-sign for a station is introduced, the market does not acquire any new information about that station's price since it is not posted on the sign. Nonetheless, the station might still adjust its price due to new information available on other stations' prices. To further understand how the effect of price transparency propagates in the market, we distinguish between cross signs *preceding* and cross signs *following* a station on the same direction of travel.

The stations assigned to the price posting condition were selected from the pool of stations not yet posted based on a variety of factors and hence, in a potentially non-random fashion. For this reason, to measure the impact of price transparency on retail prices, we exploit the variation of the treatment within each station over time while accounting for station-specific unobserved factors that might have influenced a station's presence on an electronic sign. At the same time, since the installation occurred mainly at 3 time points and since the timing was driven largely by drivers' safety considerations, there is less of a concern regarding the presence of unobservable *time-varying* drivers of prices that might be correlated with the timing of the installations. As with the own sign effect, the cross sign effect is also identified using within-station variation, by comparing a station's prices before and after other stations' prices are posted. Our identifying assumption is that conditional on the various controls and fixed effects we introduce, the price signs installed represent an exogenous shock to information and consequently, are orthogonal to any residual unobservables in prices charged by the gas stations.

We find that enhancing transparency by posting prices decreases gasoline prices on average by 1 (euro) cent per liter. This amount represents about 20% of the gas stations' margins documented in the industry (Tabarelli 2010). These findings are consistent with the theory on lower search costs stemming from the installation of the signs. The own sign effect, which accounts for about half the total price decrease we observe, is for the most part due to the price response of the two stations located immediately after the sign (of the typical 4 stations whose prices are posted on a sign). This result suggests that the information acquired through the posting is effective over a relatively short distance. Such a limited effect also helps explain why we find the effect of a *preceding* cross sign to be insignificant; by the time the information acquired on the cross sign might be used to evaluate the price of the focal station, it is no longer effective. It also helps explain why a focal station that is third or fourth on its own sign (and is hence more distant from the own sign), responds instead to a *following* cross sign. Since consumers expect to find low

prices only from stations located right after a sign, stations located further away will have to reduce their prices once the following cross sign is introduced, in order to attract consumers away from the stations right after that sign. By the time all price signs are introduced, the price of fuel decreases by 0.8%; in just one year this reduction is worth €15M to motorway consumers. The estimated posting effect is "long-lasting", in that it is measured over an average period of 16 months after the price signs are installed.

We also investigate the effect of price transparency on price uncertainty. Information theory predicts that, if market conduct does not change over time, we should observe a reduction in price dispersion across stations with the posting of the signs (Baye, Morgan, and Scholten 1996). The signs should be particularly effective when stations are less distant, due to the higher competitive pressure between stations. Our data supports this prediction and shows evidence of a reduction in price dispersion when stations are proximally located. However, the overall level of price dispersion is in large part unaffected by the introduction of price signs. Even after the implementation of the policy, prices posted on the same sign differ by several cents.

To further investigate the effect of signs on price uncertainty, we also look at the policy from the demand side. We obtain, from one oil company, individual purchase data of loyalty cardholders for all purchases made at gas stations affiliated with that company. Although we do not have purchase data at competing stations, we do observe price information from competitors that we use to derive the empirical relationship between market prices and purchases at the affiliated stations. In particular, the analysis of consumers' purchase data confirms that consumers are more price sensitive after the signs are introduced. However, only a small group of frequently purchasing consumers, representing less than 10% of all the consumers according to our estimates, seems to be using the price information available. Given the selected nature of this sample, it is possible that such customers are less price sensitive than the general population. Nevertheless, the large difference in purchase frequency between consumers using and not

using the price information seems to suggest that frequent travelers find it easier to access the information provided on the signs. This finding further confirms the persistence of price uncertainty even after the transparency initiative.

Considering the relatively modest cost of the investment (the installation of the signs costs about €2M), from a policy perspective the introduction of price signs was effective. However, both the limited effect of the information provided by signs and the evidence of price uncertainty after their introduction suggest that installing a larger number of price signs, for example one before each stations, could further improve the policy's effectiveness.

We believe these insights contribute to the marketing literature by documenting the effects of third-party induced price transparency, which by means of technology, is becoming increasingly popular, but has not been previously investigated. These insights are of practical value for third parties such as independent firms or policy makers, who are considering implementing similar policies. At the time of writing of this paper, the UK government was considering legislation that made price posting mandatory on UK motorways[1]. The results from this paper speak directly to the consequences of such legislation. They also speak more largely to the potential effectiveness of this policy in other markets, such as healthcare or education, where price uncertainty is high and the cost of introducing a price posting mechanism is relatively low.

1.1 Related Research

A large body of literature in marketing has studied the effect of price advertising on the behavior of consumers. For example, Bolton (1989) uses consumers' transaction data to relate the price sensitivity response of consumers to observable marketing characteristics. Popkowski-Leszczyck and Rao (1989) show that local advertising of prices makes demand more price sensitive. These and several other similar findings have led to the conclusion that price advertising has a positive effect of consumers' price sensitivity (Kaul and

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[1]www.theguardian.com/money/2013/may/14/motorway-service-stations-fuel-prices

Wittink 1995).

A number of studies have also investigated the reaction of market prices to price advertising. For example, Kwoka (1984) compares the effect of price advertising intensity and price of optometric services across U.S. cities. He finds that, after controlling for service quality, cities with higher advertising investments tend to have lower market prices.

To identify the effect of advertising on market outcomes, such as the purchase behavior of consumers or the pricing behavior of firms, most of the literature on price advertising employs cross-sectional variation of price advertising across markets. Advertising intensity is considered the "treatment" in an "experiment" across markets. As noted in several studies (Kaul and Wittink 1995; Bagwell 2007), the treatment most likely correlates with some unobserved characteristics of the market, so the estimated effect of advertising are likely to be biased.

A few studies have instead examined variables that exogenously change advertising intensity in some markets *over time.* Milyo and Waldfogel (1999), for example, use the elimination of a state-level advertising ban, which gives liquor stores in Rhode Island permission to advertise. Our study is similar as it also takes advantage of exogenous longitudinal variation in price information available to consumers. What separates our study from the price advertising literature is the mandatory nature of price disclosure, which is a typical feature of price transparency. The studies discussed above address the question of how investing in advertising affects market prices. This implies that the impact on prices is not just a function of price knowledge, but also of the decision by the firm to advertise. In such contexts, the price information is provided only for selected offers, and its effect is confounded with the interest of firms to advertise their products. The mandatory nature of the price disclosure observed in our data eliminates the discretionary choice of firms and allows us to measure the effect of price disclosure of all offers on retail prices.

Devine and Marion (1979) use data on an experiment conducted by Canadian authorities involving the temporary disclosure on a local newspaper of prices for a number

of supermarkets in a selected metropolitan area. They compare prices in this market with those from other untreated metropolitan areas (the control group). During the 6-week disclosure period, prices drop by 7% in the treated market compared to the control group. The test on a single market does not allow the authors to control for the different events which occured in treatment and control markets (Lesser and Bryant 1980; Devine and Marion 1980). The mandatory policy observed in our study affects multiple markets at different times. This idiosyncratic timing of the treatment allows us to better control for unobserved factors that might confound the causal link; it also allows us to investigate the mechanism by which price posting affects other stations' pricing behavior.

A large number of empirical studies in marketing have shown the effects of sales signs on consumer behavior; investigating both the psychological phenomenon and rational economic behavior behind sale signs. Inman, McAlister and Hoyer (1990) find that individuals who rely on peripheral cues tend to respond to sale signs and choose the discounted products even when their price is not reduced. A rational economic explanation for sale signs is provided by Anderson and Simester (Anderson and Simester 1998). Their study is based on the price signaling of sale signs; the effectiveness of sale signs is due to the credibility of price information they provide to uninformed customers. An extensive study by Anderson and Simester (2001) across different data sources further supports this theory, providing evidence that the effect of sale signs is driven by credibility, and that their effectiveness decreases as many products have them. In contrast with sale signs, price posting is for the most part beyond the control of the firm. For this reason, credibility does not play a significant role on the effectiveness of price transparency. Moreover, while sale signs usually inform consumers about the (discounted) price of a specific offer, price posting allows consumers to observe and compare the price of multiple offers.

2   *INSTITUTIONAL BACKGROUND*

2.1   *The Motorway System*

The Italian motorway system, called *Autostrada*, is a system of highways, mainly toll ways, covering more than 5,000 km and connecting large cities across the country. The system is accessible through toll gates. Inside the motorway system, approximately every 27 km (i.e. 16.6 miles), there are service areas (called Motorway Service Areas, MSAs henceforth), specific to each direction of travel, which allow motorists to rest, purchase fuel and food, and access other services. The MSAs are open 24 hours a day, 7 days a week.

Autostrade per l'Italia (*Autostrade* henceforth), a private company owned by the international holding firm *Atlantia*, is concessionaire for the largest and busiest portion of the motorway system, covering 2,965 km (57% of the network) and offering transit to approximately 5 million motorists every day[2]. At the time of the introduction of the signs 208 MSAs were located in this part of the network. According to *Autostrade's* estimates, each day 1 million customers patronize these areas. It is estimated that each station sells on average 10 million liters (i.e. 2.64 million gallons) of fuel per year. Each MSA is assigned in sub-concession to a gas station retailer by *Autostrade* through competitive bidding; a separate bidding is also done for the assignment of sub-concessions of a cafeteria or restaurant. The Italian Antitrust authority takes part in the sub-concession process by evaluating the effect of each contract on market concentration and competition. Table 1 reports the market shares for gasoline and catering for the operators on the motorway system. This information refers to the year 2006, two years before the period covered by our data. Both markets are fairly concentrated. The gasoline market shares are somewhat similar to the market shares at the national level, also reported in the Table, except for a lower presence of minor companies and independent networks.

- INSERT TABLE 1 ABOUT HERE -

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[2]Source: `www.autostrade.it/en/chi-siamo`.

Each gas station is affiliated with one oil company through an exclusive distribution contract. The oil company supports the station's sales with marketing investments such as advertising and reward programs, which are very popular in this industry. The station, however, makes independent retail pricing decisions. The oil company is only allowed to suggest a price; contracts regarding the final price to consumers between oil companies and retailers are considered illegal.

Motorway customers are informed about the *location* of the closest MSAs with regular traffic signs alongside the road, especially when an MSA is approaching. The relatively regular distance between MSAs along the motorways (one every 27 km) also makes it easy for travelers to approximate the distance from the next MSA. Before the introduction of fuel price signs however, information on fuel prices at the MSAs was not available along the road; motorists could learn about prices charged at a gas station only by stopping at the MSA and checking the price at the pump. Stopping at an MSA is inconvenient to motorway customers, mainly because they need to decelerate from their cruise speed, enter the MSA at low speed, and check prices at the pump. Even after stopping, customers could not compare prices across stations, because there was no way to know the prices at the other following stations.

2.2   The Introduction of Price Signs

In Spring 2007, the Italian Parlament approved a bill (law decree) promoting price transparency in markets where price information available to consumers was scarce. One of the new policies introduced by this measure specifically required *Autostrade* to install devices that could inform consumers about the prices set by the gas stations operating along the motorways. The policy also required the managers of the gas stations located along the motorway to communicate any changes in price (for regular gasoline and diesel) in real time using the motorway information system. Failing to do so would result in legal prosecution.

The fuel price signs are large electronic signs (13' 5" tall and 15'1" wide) installed alongside the motorway, posting the price of four consecutive MSA stations. The next sign would then be seen after the fourth of these stations. In a few cases, such as on short motorway routes where only few MSAs are located, or at the end of longer routes, only the prices of three or two stations are posted. An example of a price sign is shown in Figure 1 as seen by vehicles driving along the motorway. Each sign reports information on (1) the brand of fuel sold in the next four MSAs, (2) the distance from each MSA, and (3) the current price charged by each station for a liter of regular gasoline and a liter of diesel without service at the pump[3]. Unlike the other information reported on the sign, the price information is reported through an LED display that can be updated remotely by gas station managers. To help motorists compare prices, green bubbles appear next to the lowest prices of gasoline and diesel. Before the policy implementation, gas stations had no immediate access to the prices set by other nearby stations. After the introduction of signs they observe competitors' prices using this system of price disclosure.

- INSERT FIGURE 1 ABOUT HERE -

In total, 49 price signs were introduced during the period between 2007 and 2011, posting the prices of 184 MSA stations[4]. The locations of the price signs were chosen by *Autostrade* with the criterion of posting the prices of most MSAs with the least number of signs. Starting from the beginning of each motorway route, each sign (containing prices of the upcoming stations) was installed every four MSAs for each direction of travel. Table 2 shows some descriptive statistics for the installed signs.

- INSERT TABLE 2 ABOUT HERE -

Most signs post the prices of four MSAs, with the exception of four signs advertising only three, and four signs advertising only two MSAs; these signs are located on shorter

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[3]The service at the pump is optional and means that an attendant operates the pump and collects the payment. For this service, a fee of about €0.02 is charged for each liter sold. Also, gasoline in Italy is almost exclusively sold with a 95 octane rating.

[4]The installation involved 53 price signs, but 4 were not activated during the period of analysis.

routes with fewer MSAs, or at the end of a motorway route[5]. The four MSA stations listed on the price sign are usually located within a road segment between 90 and 130 km long. The average distance between the first and the last MSA listed is 115 km. The positioning on the sign does not appear to be dominated by any of the eight main gasoline brands: each brand has at least one station for each of the four positions, except for Shell which does not have any station in the first position[6]. In some cases, especially when signs are located close to junctions, the MSAs listed on the sign are not consecutive; instead, they are on different routes which can be reached from the point where the sign is located. Finally, a few MSAs are listed on two different signs because they can be accessed from multiple routes. In Table 3 we report the total number of MSAs whose prices are posted for each motorway route. The two longest routes of the motorway, *A1* and *A14*, include more than half of the total stations involved. The distances covered by most of the other routes are much shorter. This means that most of the other routes only include one price sign.

- INSERT TABLE 3 ABOUT HERE -

The introduction was completed in three periods, in order to allow the management of *Autostrade* to monitor the effect of the signs on the traffic flow and to protect the safety of motorists. The first period involved the activation of 10 signs, which was completed in July 2007; except for one case, all these signs were located on the two longest routes, *A1* (8 signs) and *A14* (1 sign). In December 2008, during the second period, 20 more signs were activated. This time, the signs installed covered all the MSAs on the *A1* route and on other less popular routes in the north and center of Italy. A third group of 19 signs was finally activated during 2009; the signs covered the remaining MSAs on the *A14* route and other MSAs in the south of Italy, and a few other MSAs in the northeast part of the country. There is also a group of 52 MSAs whose prices are not advertised; 32 of them are inside the network controlled by *Autostrade*. For the most part these areas cover parts of

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[5]Given the specific characteristics of these routes, the stations posted on these signs are excluded from the analysis.

[6]Notice that Shell has also a small share in the market.

the network with relatively less traffic and were built more recently, some even after the sign installation. The other 20 MSAs are located on motorway routes that are outside the control of *Autostrade*.

Since 2009, the prices posted on the signs have also been reported on the website of *Autostrade* to help customers plan their trips and find the stations with the lowest prices. The website could partially contribute to more information being available to consumers. However, the diffusion of smartphones occurred for the most part after the period observed in our data. Moreover, the website does not follow the timing of the introduction of the price signs, but shows the prices of all stations, therefore its presence is unlikely to invalidate our results.

3 RESEARCH DESIGN

How do we measure the effect of the introduction of own and cross signs on a station's pricing behavior? Ideally, a researcher would select a random sample from a cross-section of gas stations. As "treatment", the researcher would then post prices of the sampled stations, while prices for the other "control" stations would not be posted. The random assignment of price posting to stations ensures orthogonality between retail price levels observed and any other variable that could potentially affect prices. This isolates the causal effect of price information on retail prices as the observed difference in price levels between treatment and control stations.

Random assignment is not possible in our context, for two reasons. First, the management of *Autostrade* has selected the stations using a number of different criteria. Second, even if gas stations were randomly assigned to the treatment, the resulting "cross effect" that the posting generates across competing stations would not be assigned in a random fashion, but according to their position on the motorways, which is potentially correlated with stations' pricing decisions.

Instead of relying on the random treatment *across stations*, to identify the effects of

price posting we exploit the variation in the treatment for a given station *over time*. The potential correlation between any treatment and a station's unobserved characteristics is now captured by station-specific fixed effects. Since a change in the unobserved characteristics due to the treatment is unlikely, it is reasonable to consider the estimated effects free from bias due to such omitted variables.

The control group used in the study is the group of motorway stations not treated for the own sign effect; and the group of stations whose competitors are not treated for the cross sign effect. The group of stations not treated includes both stations never treated and stations treated in a subsequent period. For robustness, we also test alternative control groups, such as a sample of gas stations located outside the motorway system.

First, consider the identification of the own sign effect. A change in the station's price between when the sign posting its own price (which we call *own sign*) is not installed and when it is installed identifies this effect. In difference-in-differences terminology, the own sign effect is recovered through a pre- and post- comparison of motorway stations with prices posted (treatment group) and motorway stations with prices not yet posted (control group), conditional on cross sign effects, and on station and time fixed effects. For example, in December 2008, during the second phase of introduction, 20 signs were installed. Consider the 3 signs installed on route A1 West/South. For the 12 stations whose prices are posted on these signs we can identify the own sign effect by comparing their price response with the price response of the stations whose prices are not posted, conditional on the same cross effects from competing stations, discussed below. Note that the own sign posts both the station's own price and the prices of the proximal stations. Therefore, the own sign effect includes both the effect of posting a station's own price and the price of the proximal stations.

Second, the cross sign effect on a station's price is identified by a change in whether another price sign (which we call *cross sign*), that posts the prices of other competing stations (i.e., besides those posted on the *own sign*), is introduced on the same route. Here

we define competitors as other stations within 100 km of the focal station on the same route and direction of travel[7]. In difference-in-differences terminology, the cross sign effect is recovered through a pre- vs. post- comparison of prices between motorway stations that have other stations within 100 km on the same route whose prices are posted (treatment group), and motorway stations that have other stations within 100 km on the same route whose prices are not posted (control group), conditional on own sign effects and on station and time fixed effects. Most of the cross sign effect is identified through the response of the stations located on the two longest motorway routes, *A1* and *A14*, where multiple price signs have been installed.

Note that if on each route all signs were installed at the same time, there would be no separate identification of the own and cross sign effects. Instead, on several routes we observe changes in the introduction of signs over time, both for stations whose own prices are posted in previous periods, and for stations whose prices have not yet been posted. Besides this benefit of the staggered installation of price signs, the idiosyncratic timing of treatments across stations provides an additional advantage in terms of identification. Since the signs are installed at different times, the treatment effect is estimated as an average across the effects observed at each of these times. By averaging the effect at various time points, the effects of idiosyncratic factors that might coincide with the treatment at one point in time, if any, will be dampened.

In addition to measuring the effect of price transparency on gasoline prices, we also evaluate its effect on price uncertainty. To assess whether the price posting increases consumers' knowledge about prices, we conduct both a price dispersion analysis and a consumer transaction analysis, which we discuss in detail in Section 7.

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[7]We will later use other distances as well to test the robustness of our results to different cutoffs.

4   DATA DESCRIPTION AND SUMMARY STATISTICS

Our data contain the daily prices set by gas stations on the motorway system.[8]. The data runs from January 2008 until September 2010, and was provided by the *Italian Ministry of Economic Development*. The prices refer to the retail price for one liter of gasoline without service at the pump. Since prices are self-reported, some stations might strategically communicate an incorrect price, although such behavior is illegal. To check the data we compared the price data with prices reported by the crowdsourced website *Prezzibenzina*. Here users upload price information observed at gas stations across the country. The MSA price data matched the price data provided by *Prezzibenzina* quite well[9]. Although we cannot rule out occasional mis-reporting of prices, it is unlikely that this has any systematic effect on our results. From *Quotidiano Energia*, we obtained the daily average price of gasoline by brand from a large sample of stations representative of the national average price outside the motorway system[10].

Table 4 provides summary statistics of the price dataset assembled. The price levels are provided in euros, and refer to the price of one liter (0.264 gallons) of gasoline without service at the pump. The last row in Table 4 shows that in our data stations change their gasoline price on average every 6.96 days, i.e. once per week.

- INSERT TABLE 4 ABOUT HERE -

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[8]We thank Stefano Catolino at *Autostrade per l'Italia* for useful conversations over the policy implementation. We also thank for providing data: Massimo Greco at the *Italian Ministry of Economic Development*, Stefano Bittante at *Prezzibenzina*, Diego Gavagnin and Romina Maurizi at *Quotidiano Energia*, and Giovanni Borromeo and Azzurra Pacces at *Staffetta Quotidiana*.

[9]We found 1628 valid entries which refer to the motorway stations for the period under analysis. 82.9% of these entries match exactly with our data, while 17.1% do not. There could be several reasons for these discrepancies. One major reason could be attributed simply to the differences in the time when prices are recorded on the days that these prices are changed. For example, our price refers to the updated price whereas the reported price could be one recorded prior to the update. Another reason for the discrepancy could be mistakes made by consumers when submitting the observed price levels and the station at which prices are recorded.

[10]Different from the MSAs' prices, these prices originally include service at the pump, which consists of assistance at the pump, and is worth an additional fixed fee of €0.02 per liter on average across stations. We therefore subtract this fee from the national average in order to obtain the average national price without service outside the motorway.

In addition to the price data, we assembled a dataset with the locations and the dates when each price sign was installed, the MSAs referred to on each sign, and other characteristics specific to the MSAs (see Table 2).

We obtained transaction data from a reward program of a major oil company; this data tracks the liters of gasoline purchased daily by each cardholder at any station affiliated with the oil company, including some of the MSA stations in our study. The data spans the period from October 2008 to May 2009. The advantage of having individual data is that we can better control for consumer heterogeneity; since consumers travel long distances, they cover areas over which market demographics vary considerably. This makes uncovering the relationship between demographics and purchase behavior challenging. We recognize that the sample might not be representative of the customers of these stations, as we expect cardholders to exhibit more loyalty to this brand's gasoline. Nonetheless, given the potentially lower price sensitivity of cardholders, this data provides a conservative test for the effect of price transparency on consumers' price sensitivities.

One noteworthy point about the purchase data is that it spans the period of the economic recession, which started around the middle of 2008. We feel that this will not be an issue for our analysis. Consumers' price elasticities are estimated using the *difference* between the price of the focal station and the price of the other competing stations. Therefore, price levels will not directly affect the analysis. To test the robustness of our findings, we estimate alternative specifications with time fixed effects and a dummy for the recession, in order to capture potential demand shifts during to the recessionary period.

5   MODEL-FREE EVIDENCE

In this section we provide evidence of the effect of price signs on gas stations using model-free analysis. We divide our analysis into three parts. First, we show evidence of the overall effect of price signs. Next, we document the stations' response due to own signs. Finally, we show response due to cross signs.

5.1   Overall Effect of Price Signs

In Figure 2 we plot the average price of the group of stations on the motorways whose prices have been posted on a sign. The average price for the stations whose prices have been posted before the period observed or have never been posted is also plotted as control. In the top panel, we plot the average retail price for one liter of gasoline, aggregated by quarters (solid line), and we compare it with the average retail price for a liter of gasoline charged by the control group (dashed line). The vertical line divides the observed periods before price signs are posted with the periods after price signs are posted. In the bottom of the Figure we report the difference between the average price of the stations "treated" and the stations in the control group. We report the quarters available before most stations' signs are introduced and after signs are introduced. The significant price drop observed in the graphs between the third quarter of 2008 and the first quarter of 2010 is the result of the effect of the economic recession on fuel prices. The pre-treatment and post-treatment trends of treatment and control stations are fairly similar, so the control group appears to be an adequate counterfactual to the group of treated stations. Notice that the order of prices for the two groups of stations is inverted as we move from periods before most signs are introduced to periods after signs are introduced, i.e. the prices of stations whose prices are posted are higher before posting, but on average lower after posting. In the period right before treatment, the prices are on average about 0.3 (euro) cent higher than the prices of motorway stations not treated during that period; after posting, they drop on average below the prices of the control group. This evidence suggests that the introduction of price signs generates a price reduction of about 0.5 cent per liter for the motorway stations whose prices are posted. Overall, the model-free evidence provides preliminary evidence that the installation of price signs is associated with a visible price drop for the stations whose prices are posted.

- INSERT FIGURE 2 ABOUT HERE -

5.2   Effect of Own Sign

In Figure 3 we plot the price of the two groups of stations whose own signs were introduced during the observed period. The first group (left graphs of Figure 3) consists of stations whose prices were posted during the first wave of sign introduction (December 2008). The second group (right graphs of Figure 3) consists of stations whose prices were posted during the second wave of sign introduction (December 2009)[11]. As control group we consider motorway stations that have neither own nor cross signs during the period observed. The graphs on the left of Figure 3 indicate that in the period before the treatment (the first vertical line), the prices of the treated stations are half to one cent lower than the stations in the control group. After own signs are introduced, the difference drops below 1 cent. By comparing the pre-treatment period (i.e. three quarters before treatment) with the post-treatment period (i.e. three quarters after treatment) we measure a reduction of about 0.5 cents due to the presence of the own sign. This effect is even sharper in the graphs on the right of Figure 3. In this case, the own sign is introduced at the second vertical line. The difference between treated and control group is above 0.5 cents before the introduction, but drops below 0 after it. The price difference between pre-treatment and post-treatment period is about 0.8 cents.

- INSERT FIGURE 3 ABOUT HERE -

5.3   Effect of Cross Signs

We next consider both cross signs preceding and following a station on the same route and direction of travel. The first two graphs of Figure 4 plot the price of stations that had a preceding cross sign introduced in December 2008 (first graph) or in December 2009 (second graph). The control group consists of stations that did not have any preceding cross sign nor own sign during the period observed. Both graphs show some price decrease

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[11]For simplicity, we exclude the price of 8 stations related to three price signs installed at different dates between these two periods.

over time. However, it is not obvious how much of the price change is due to the introduction of the cross sign.

The next two graphs of Figure 4 plot the prices of stations that had a following cross sign introduced in December 2008 (third graph) or in December 2009 (fourth graph). The control group consists of stations that did not have any following cross sign or own sign during the period observed. The third graph shows a sharp price decrease of about 0.7 cents occurring immediately after the introduction of the cross sign (first vertical line). Similarly, the fourth graph shows a price drop of more than 1.0 cents immediately after the cross sign is introduced (second vertical line).

- INSERT FIGURE 4 ABOUT HERE -

6   EFFECT OF PRICE POSTING ON RETAIL PRICES

We now provide a formal analysis of the gas stations' response to price transparency. We begin with the analysis of price levels, and use a difference-in-difference model to measure the stations' response to price signs. We then discuss the marketing implications of the estimated response, and the robustness checks we undertook.

6.1   Difference-in-difference Model

We now measure changes to prices, if any, corresponding to the introduction of own and cross signs. As discussed in Section 3, in a difference-in-difference model identification is achieved by comparing the price behavior of the group of "treated" stations with the group of "control" stations before and after the treatment. The control group provides the pricing behavior of the treated group in the counterfactual case signs were not introduced. Their price difference is picked up by dummies indicating the introduction of signs. Fixed effects, both across stations and over time, absorb cross sectional and time-specific price variation that could be due to unobserved characteristics of stations or time periods. The time period in our analysis is a day - the frequency at which our data are recorded. We use the

longitudinal variation in price posting to identify the effect of a station's own sign, preceding cross-sign, and following cross-sign. In particular, with respect to the cross-sign, we distinguish between the case when the prices of at least another *station* within 100 km *before* of the focal station are posted, and the case when the prices of at least another *station* within 100 km *after* of the focal station are posted. We also provide other cutoffs (50 km, 150 km, 200 km, 300 km), to check the robustness of the results. Longer cutoff distances result in the inclusion of a larger number of stations in the estimation of the cross effects.

The regression is specified as follows

$$p_{it} = \mu + \alpha_i + \lambda_t + \beta_1 PostOwn_{it} + \beta_{2i} PostPrec_{it} + \beta_{3i} PostFoll_{it} + \epsilon_{it} \qquad (1)$$

where p_{it} is the retail price (expressed in euro cents) for a liter of regular gasoline at station i on date t; μ is a constant; α_i are station-specific fixed effects; λ_t are time-specific fixed effects; $PostOwn_{it}$ is an indicator for if a price sign is activated and station i's price is posted on it; $PostPrec_{it}$ is an indicator for if another station preceding the focal station i within 100 km on the same motorway route and direction of travel has its prices posted on a different sign; $PostFoll_{it}$ is an indicator for if another station following the focal station i within 100 km on the same motorway route and direction of travel has its prices posted on a different sign; ϵ_{it} is an i.i.d. error term.

The results are shown in Table 5. In each column we allow for a different definition of cross effect by varying the max distance from the focal station to the competing station advertised on cross signs. The estimated coefficient of $PostOwn$ suggests that, regardless of the specification adopted, the introduction of the own sign causes a significant price decrease. Before the installation of the signs, gas stations benefit from market power due to consumer price uncertainty and the cost of visiting an MSA. The introduction of a sign that provides information on a station's prices reduces search costs: consumers can now

observe prices without visiting the MSAs. Moreover, they can compare prices across subsequent stations. This information shock induces gas stations to reduce their prices.

- INSERT TABLE 5 ABOUT HERE -

In particular, in the specification reported in the first column, we consider in the cross sign dummy stations that are less than 50 km away from the focal station. We find that the own sign is highly significant and causes a price decrease of 0.6 cents per liter. The estimates of this coefficient decrease slightly for higher cutoffs.

The cutoff of 100 km, proposed in the second column of Table 5, allows us to include many more of the stations facing cross signs. The estimates for this specification suggest that the own price effect reduces stations' prices by 0.50 cents. Seemingly small, this amount actually represents about 10% of the margins documented in the industry (Tabarelli 2010). By increasing the cutoff even further, we allow a few more stations to help identify the cross effects; the own effect does not change significantly.

Our results also provide some evidence as to the effects of cross signs on the focal station after controlling for the own sign effect (if any). Since a sign induces the advertised stations to reduce their prices, the preceding cross sign might induce higher price pressure on the focal station located further down the road. For example, a consumer who has encountered a preceding cross-sign might form a low reference price. Accordingly, we should observe a negative effect of the introduction of preceding cross signs on the focal station. The coefficient for the cross signs preceding the focal station on the same route ($PostPrec$) is negative, but not significant. This result is robust across the proposed specifications. When the cross sign is located after the station, instead, the station's potential customers might be induced to wait by the prospect of obtaining price information (or by its effect on prices). The focal station might reduce its price in an attempt to convince them not to postpone their purchase. Therefore, we should observe a negative effect of the introduction of cross signs following the focal station. In the first column of Table 5, the coefficient for the cross sign following the focal station on the same

route ($PostFoll$) is negative but not significant. As we allow for a wider cutoff (100 km), a larger number of stations (60% more) contribute to the identification of the coefficient. This provides a more precise estimate of cross effects and a better control over the own effects. The coefficient now becomes statistically significant. This result means that the prospect of a following cross sign induces consumers to wait, and stations to reduce prices. The effect is measured between 0.5 and almost 0.8 cents of price reduction, depending on the specification adopted.

6.2   The Effect of Distance

To investigate the effect of price transparency on spatial competition between stations and understand the effect of cross signs, we next assess the role of distance between stations and signs. We consider the same model specification adopted in (1), but we allow the coefficients associated with $PostOwn$, $PostPrec$, and $PostFoll$ to vary across stations depending on their distance from signs. We also control for the intensity of competition, i.e. whether a sign is posting prices of stations located on different routes. Stations located closer to the own sign are also closer to the preceding cross sign and further away from the following cross sign.

In Figure 5 we report the effect of own sign and following cross sign on gas stations, based on their position with respect to the own sign. The effect of preceding cross signs are not reported because they are not significant. To preserve statistical efficiency, the effects are computed parametrically, multiplying the distance effect with the median distance of each position from the sign, and adding the common effect across stations. We report the most common scenario where stations listed on the signs are located on the same route, which is the case when competition is more intense. Considering first the own-sign effect, we find that stations located first and second after the sign reduce their prices by 1.10 and 0.73 cents, respectively. In contrast, stations more distant from the sign do not respond significantly. These results suggest that the first two stations listed on a sign are those

which contribute to the own sign effect. It appears therefore that the information that consumers acquire from the price sign is effective over a relatively short distance. This evidence could be due to several reasons. For example, traffic flow. Consumers enter/exit the motorway through toll gates located after each station. Therefore, the number of consumers who have seen the sign decreases as we move along the motorway. Stations more distant from the sign are patronized by a smaller percentage of informed consumers, so they can afford a lower response to signs. Another reason could be the limited processing capability of consumers, who might find it hard with time to recall the price information acquired from the sign. Our data does not allow us to disentangle the reasons behind this evidence.

Considering next the effect of following cross signs, we find the opposite result, i.e. stations located last are responsible for most of the cross-sign effect. Our estimates suggest that only stations in the third and fourth position respond significantly (-0.7 and -1.0 cents, respectively) to the following cross sign. These stations are in fact closer to that cross sign.

Overall, these results provide insights on the spatial competition between gas stations, and on the mechanism by which the effect of price information propagates. The information acquired on the signs appears to be effective only for a distance of less than 60 kilometers, which is the median distance in our data between the sign and the third station. This finding might explain why the price information acquired on the preceding cross sign, which is located further away, does not induce any significant effect on focal stations. The lack of response to the own sign may also help explain why focal stations (especially stations more distant from the own sign) respond instead to following cross signs. Consumers might learn that the own sign has an effect only on stations that are located nearby, and not on stations that are more distant. These beliefs rationalize the focal stations response to cross signs following on the same route. Stations that are more distant from the own sign (i.e., third and fourth) have the incentive to reduce their prices as a response to the cross sign introduction, in order to induce consumers to stop before

reaching the stations right after the cross sign.

6.3 Marketing Implications

Own sign and cross sign effects together are worth a price reduction of 1.0 cents per liter. The average margin of gas stations in the Italian market is estimated to be around 5.0 cents (Tabarelli 2010), therefore this price adjustment represents about 20% of stations' margins. Since the data analyzed covers a relatively long period of time (about 16 months on average for each station after the relative price sign is introduced), this result does not just capture a short-term reaction, but a long-lasting price response to price posting by the gas stations.

After the introduction of all price signs, the price of a liter of fuel decreases by $0.01/1.33 = 0.8\%$. Since *Autostrade* estimates that the yearly average sales per motorway station is 10M liters per year, in one year the price reduction is worth €15M to motorway consumers. We contacted the manufacturing company commissioned by *Autostrade* for procuring the price signs, to learn the costs of the operation. The costs are approximately €2M for manufacturing and installing the signs, and a fraction of it for maintenance each year, which means that the policy benefits consumers even after accounting for the program's costs. Note that the magnitude of the effect is comparable to the findings of other research in the same industry; for example, Hastings (2004) shows that the vertical integration observed in a number of retail gasoline markets in California generates an increase in average prices of 5 (US$) cents per gallon, i.e. about 1 (euro) cent per liter.

6.4 Robustness Checks

We tested the robustness of our results in several ways. (1) We used alternative control groups, such as stations located outside the motorway system. Stations outside the motorway are not directly affected by the transparency policy, as during the period under analysis there are no price signs outside the motorway. Using this group as control we find an even larger effect of price signs. We believe, however, that using the stations on the

motorway is a better control for unobserved macroeconomic factors such as recessionary periods. (2) Following Busse, Silva-Risso, and Zettelmeyer (2006), we also checked the validity of the control group selected by testing the statistical difference between its price and the price of the treatment group during the period *before* the treatment effect. We tested several intervals, such as two, four, six, etc. weeks before the installation of own and cross signs. We found no significant difference. We also individually checked for each quarter reported in Figure 2, 3, and 4, the difference between prices of treatment and control group (i.e. the size of the grey bars in the bottom panel of each Figure). These differences are for the most part not statistically significant. (3) We used different cutoffs beyond those reported in Table 5 for the distance between focal point and station with prices posted on cross signs. We also allowed for more generous cutoffs only for preceding cross signs, but the results do not change substantially. (4) Another issue is whether these cross sign effects manifest gradually over time. We tested this by including an interaction with various time period-specific indicator variables (the first 3 months of a sign's installation, next 3 months etc.). Since we did not find any evidence of a differential effect, we report the more parsimonious specification. (5) We checked whether traffic congestion, which should increase the ability of consumers to read signs, increases the response of gas stations to price signs. We did not find any significant result. This could be in part due to the noisy measure of traffic congestion. (6) We also checked for the presence of consumer heterogeneity. In particular, we tested whether stations located on routes used by foreigners traveling from the Alps would be less responsive to signs due to the potential lower price sensitivity of these customers. The results support the heterogeneity of response hypothesis. However the small number of stations involved does not allow us to investigate this effect any further. Unfortunately we cannot test for other consumer types such as business customers. There are several industrial districts across the country, but there are no specific motorway segments with a preponderance of such customers. (7) Our data does not include the period before the first wave of 10 installations. Therefore, our

results do not include the own effect of the first group of stations whose prices were posted on those signs. One might wonder whether the own-sign response of these stations was different from the response of the other stations for which we measure the response. We tested this difference in two ways. First, we compared their cross-sign response with the cross-sign response of the other stations. We found no significant difference. Second, instead of considering their response to own sign, which is not observable, we considered the stations adjacent to them but in the other direction of travel. Presumably, these stations share similar characteristics (e.g., similar consumers and off-motorway competitors) with the stations whose prices are posted on the first 10 signs. Again, we found no significant difference. These results suggest that the stations for which we do not measure the response to their own sign do not seem to behave differently from the stations for which we measure the own sign. (8) Finally, we used different specifications, including fixed/random effects, both for stations and for time periods. The specification we report provides the most flexible controls for unobserved station and time period characteristics.

7   EFFECT OF PRICE POSTING ON PRICE UNCERTAINTY

Our objective in this Section is to test whether the price reduction documented above also translates into an increase in consumers' price knowledge and a reduction in price uncertainty. We do so by analyzing price dispersion and purchase behavior before and after the installation of signs.

7.1   Price Dispersion

According to theory (Stigler 1961), as price information increases, gas stations are less likely to find uninformed consumers from whom they can extract informational rents. Therefore, assuming same market conduct over time, the price variation observed across competing stations should decrease. We first compute price dispersion across stations within pre-defined groups of stations; each group consists of those stations that after the

introduction of price signs have their prices posted on the same sign. Then, we regress the group-level measures on an indicator variable which specifies whether the price sign is introduced or not in any time period, and on group and time fixed effects.

The results are reported in Table 6. In the first column we report the coefficient for the price sign activation. We use the price range across stations within the group, i.e. the difference between the highest and the lowest prices in the group as our measure of dispersion. The coefficient of the price sign indicator is not consistent with the theoretical prediction, as the presence of price signs should decrease the range; further the coefficient is statistically indistinguishable from zero. In the next column we use price variance as an alternative measure of price dispersion. Once again, the coefficient of the price sign variable is positive and not statistically significant.

<center>- INSERT TABLE 6 ABOUT HERE -</center>

To investigate whether heterogeneity plays a role in these results, we next control for observed sign characteristics. In particular, we select two variables that reflect the level of competitive pressure between stations: the distance (in $km \times 100$) between the first and the last station in the group, and an indicator of whether the sign is posting prices of stations located on different routes. We call these variables $DistanceStations$ and $MultipleRoutes$, respectively. When the stations are located far apart or on different routes, they might compete less intensely, so these variables could moderate the effect of price posting on price dispersion. Note that the main effects of these variables are included through the stations' fixed effects.

The results of this new specification are reported in the next two columns of Table 6. The coefficient of the interaction $Posted * DistanceStations$ is positive and significant, suggesting that price dispersion decreases after prices are posted when stations are more proximally located. However, even in cases of high competitive pressure (i.e. considering the situation in which stations listed on the signs are located on the same route, and using the first quartile of the distance between stations, which equals 69.3 km), the price posting

decreases the gap between highest and lowest prices by an insignificant amount[12]. Similar results are found in the last column, where we use price variance as a measure of price dispersion. Considering that during the period under analysis the average price range observed across stations whose prices are posted on the same sign is 4.0 cents, the effect of the sign appears relatively ineffective. The result that price dispersion persists even after the price transparency policy suggests that price uncertainty remains even after the introduction of price signs. The analysis of transaction data, discussed next, will help us further understand this result by documenting whether consumers use the price information conveyed on the signs effectively.

7.2   Purchase Behavior

If consumers are truly using the posted information effectively, as the price reduction documented above suggests, their price elasticities should increase after the introduction of the signs. Since the introduction of price signs does not affect consumers' marginal utility from income, a change in the elasticity after signs' introduction is evidence of more price information available to the consumer at the time of purchase.

We estimate a demand model of gasoline retail choice with individual level data. The consumers in our sample are cardholders of a reward program administered by one of the major oil companies in this industry. The transactions data allow us to observe consumers' purchases made at the gas stations affiliated with the focal brand and that are located on the motorways. Although we cannot observe competitors' transactions, we do observe their prices, so we can derive the empirical relationship between competitors' prices and the focal station's purchases.

To control for stations' unobserved characteristics, we associate each consumer randomly to one of the visited motorway stations for all the observed periods. This means that the consumer-specific intercept controls for her preference toward the affiliated

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[12]The predicted change is -2.484 (1.401) + 0.693 * 3.527 (1.634) = -0.422 (0.803).

station. Also, the price sensitivity of each consumer is identified by the variation over time in the price difference between the station and the other stations whose prices are posted on the same sign. We model her daily decision to purchase at that gas station s, or not to purchase. The decision not to purchase implies that the customer has chosen either to purchase gasoline from one of the competing stations or not to purchase gasoline at all. As competing stations in the customer's consideration set (Siddarth, Bucklin, and Morrison 1995) we consider the other stations whose prices are posted on the sign where station s' prices are also posted. These stations can be reached by consumers who potentially drive past the price sign.

The utility that consumer i derives when she purchases fuel at station s in period t is specified as follows:

$$U_{it} = \theta_{i1} + \theta_{i2}Price_{st} + \theta_{i3}Post_{st} + \theta_{i4}Price_{st} * Post_{st} + \xi_{it} \tag{2}$$

where $Price_{st}$ is the retail price for a gallon of regular gasoline at station s; $Post_{st}$ is an indicator for if a price sign is installed and station s' price is posted on it in period t; ξ_{it} is an i.i.d. (logistic) error term.

The utility derived from the outside good is specified as $U_{it}^0 = \theta_{i2}Price_{-st} + \xi_{it}^0$, where $Price_{-st}$ is the lowest retail price for a gallon of regular gasoline at the other stations listed on the price sign where the price of station s is posted. Note that the lowest price is particularly salient to the consumer because it is marked with a green light on the sign. ξ_{it}^0 is a (logistic) idiosyncratic error term. This specification allows the model to account for competitors' price changes, as noted above.

The vector of parameters θ_i is individual specific. In order to understand how consumers differ in their ability to use the price sign effectively, we adopt a (non-parametric) discrete model of consumer heterogeneity, where consumers are clustered into vectors with different probability masses. The parameters are estimated using

maximum likelihood ((Kamakura and Russell 1989)).

The results are reported on Table 7. We estimate models with up to 3 mass points. For models with 4 points, the mass of the new segment collapses to zero. The coefficients for *Price* are negative and significant in each specification. The model with 1 segment uses a common vector of parameters across consumers; this specification shows that after the introduction of price signs, consumers show higher price sensitivity[13]. When we move to models with more segments, however, we notice that only a small percentage of consumers are responsive to price posting. In particular, if we consider the model with three segments, we find that the coefficient $Price * Post$ is only significant for Segment 2, i.e. only the second segment of consumers change their price sensitivity significantly after the introduction of price signs. According to the estimates, this segment accounts for only 8% of the consumers. Unfortunately, we do not have demographics data on consumers that could help further explore the identities of consumers in the three segments. The comparison of the intercept parameter across segments suggests that the consumers in the second and third segment are frequent travelers. The first segment, accounting for 88% of consumers, purchases less frequently; and the third segment accounting for 4% of consumers are not affected by the introduction of price signs. Overall, signs increase price elasticity[14] by 50%, from -3.16 to -4.79, which is still significantly lower than the -10.8 price elasticity found for gasoline retail markets outside the highways (Rossi 2015).

Given that the price response documented above is triggered by just a subset of consumers, this evidence suggests that a potentially larger price reduction may be possible by making the information more accessible to consumers. We acknowledge however, that results obtained from cardholders may not be representative of how consumers may respond in general.

Overall, our analysis of purchase behavior confirms that consumers use the price information provided by the signs to make better purchase decisions. However, only a

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[13]Results hold when we use fixed effects or control for the effects of the recession.

[14]For the computation of the elasticity, see Kamakura and Russell (1989), pages 381-382.

small fraction of the motorway consumers appear to be using the information on the signs effectively. This result seems to support our previous findings that price signs have limited impact on price dispersion, and that price uncertainty is still significant even after the introduction of the price transparency policy.

8   CONCLUSIONS

Despite the increased prevalence of price transparency as a form of communicating price information to consumers, there is scant evidence on how firms respond to it. Using unique data we have measured the effect of price transparency on gas stations' pricing behavior in the motorway.

We have shown that when consumers are better informed about prices, gas stations respond by reducing their prices. The price reduction by a focal station is not only triggered by the price information consumers acquire about that station (and the other stations on that sign), but also by the availability of price information on subsequent stations posted on signs further down the road. At the same time, we have documented a limited impact of the signs on price uncertainty. The analysis of price dispersion shows that posting has little effect on the price difference between stations. Using a sample of loyalty cardholders, we have reached similar conclusions.

We believe that our paper contributes to the marketing literature by documenting how firms respond to price transparency. This knowledge is of interest to managers and policy makers who are considering transparency policies in similar and in other markets. When price information is difficult to obtain, a third party such as a firm or a public agency can introduce price posting to stimulate price competition between firms. For example, in the healthcare industry government agencies could introduce comparison sites in the attempt to reduce the price of drugs and medical procedures. Our results show that the price reduction generated by the price posting decreases market prices, and the savings realized by consumers largely compensates for the cost of the installation of signs. Given the

relatively low cost of online price posting, we believe that a similar tradeoff between benefits and costs is applicable to healthcare and other markets as well.

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TABLES AND FIGURES

Table 1: Market shares of gas station and food & beverage retailers, as of December 2006

Gas Stations				Restaurants/Cafeterias		
Retailer	MSAs (#)	Mkt Share (%)	Mkt Share Italy (%)	Retailer	MSAs (#)	Mkt Share (%)
Eni	53	25	28	Autogrill	140	62.5
Tamoil	42	20	6	Sarni	25	11.2
Esso	35	17	21	Moto	19	8.5
Total	26	12	6	Finifast	13	5.8
Kuwait	18	9	11	Ristop	8	3.6
Erg	14	7	7	My Chef	8	3.6
Shell	10	5	7	Camst	3	1.3
Api	8	4	5	Eni Cafè	2	0.9
Other	2	1	9	On The Run	2	0.9
				Festival	2	0.9
				D'Ambrosio	1	0.4
				Miramare	1	0.4
TOTAL	208	100	100	TOTAL	224	100

These companies operate as sub-concessionaires on the part of the motorway system administered by *Autostrade*. (Source: *Autostrade per l'Italia*)

Table 2: Descriptive statistics for MSAs with posted prices

Position on Sign	MSAs (#)	Distance from sign (Avg. km)	Unique brands (#)	Different route (#)	Another Sign (#)
First Position	49	13.2	7	5	4
Second Position	49	58.6	8	1	3
Third Position	45	95.3	8	7	3
Fourth Position	41	126.2	8	9	1

"Unique brands" indicates the total number of brands that are present at least once in the given position; "different route" indicates the number of MSAs that are on a motorway route different from the route where the price sign is located; "another sign" indicates the number of MSAs whose prices are also posted on another price sign.

Table 3: Number of MSAs with posted prices, by motorway route

Route	Length	MSAs involved		Signs	
	(km)	West/South	East/North	West/South	East/North
A1	803	25	33	6	8
A4	93	6	4	1	1
A7	50	0	3	0	1
A8	43	1	2	1	1
A9	32	0	2	0	0
A10	45	0	2	0	1
A11	82	3	3	1	1
A12	66	3	3	1	1
A13	127	4	4	1	1
A14	782	16	28	4	7
A16	172	6	6	2	2
A23	101	2	2	1	1
A26	245	3	6	1	2
A27	82	0	2	0	1
A30	55	1	1	0	0
Link roads	-	5	8	1	1
TOTAL		75	109	20	29

The letter "A" in front of the route number stands for "Autostrada" (i.e. motorway). Note: the length of *A4* is 517 km, but the segment under concession of *Autostrade* is only 93 km.

Table 4: Descriptive statistics of price data

	Mean	St.D.	Min	1Q	Med	3Q	Max
Price of MSA stations							
Posting in period I	1.32	0.11	1.04	1.25	1.34	1.39	1.58
Posting in period II	1.32	0.11	1.03	1.25	1.33	1.39	1.58
Posting in period III	1.34	0.11	1.04	1.27	1.34	1.41	1.59
Not Posting	1.33	0.11	1.04	1.26	1.34	1.40	1.58
Price of stations outside motorway	1.33	0.10	1.08	1.27	1.36	1.39	1.54
Price dispersion across MSA stations							
Daily price variance	0.02	0.01	0.00	0.01	0.01	0.02	0.11
Daily price interval	0.03	0.02	0.00	0.01	0.03	0.05	0.18
Price changes per MSA (# days between two changes)	6.96	5.73	2.86	4.44	5.64	6.78	55.78

We report statistics on the price levels, price dispersion, and number of price changes. For price levels, we aggregate the MSA stations with respect to the period when their prices are posted. For price dispersion, we report both daily price variance and difference between the highest and the lowest price of stations that appear or will appear on the same price sign.

Table 5: Estimates of price reaction of gas stations to price posting

	Cross Effect 50 km	Cross Effect 100 km	Cross Effect 150 km	Cross Effect 200 km	Cross Effect 300 Km
PostOwn	-0.616**	-0.497*	-0.477*	-0.512*	-0.495*
	(0.196)	(0.212)	(0.208)	(0.203)	(0.207)
PostPrec	-0.220	-0.312	-0.253	-0.223	-0.254
	(0.339)	(0.301)	(0.301)	(0.305)	(0.322)
PostFoll	-0.417	-0.531*	-0.680**	-0.755**	-0.760**
	(0.309)	(0.242)	(0.244)	(0.249)	(0.253)
Station F.E.	✓	✓	✓	✓	✓
Time F.E.	✓	✓	✓	✓	✓
Adjusted R^2	0.9752	0.9753	0.9754	0.9755	0.9755
N. obs.	195,349	195,349	195,349	195,349	195,349

OLS estimates of the effect of own and cross price posting on gasoline price levels. In each column we change the definition of cross effect by varying the max distance from the focal station to the competing stations advertised on cross signs. Clustered standard errors are reported in parenthesis.

Table 6: Estimates of change in price dispersion due to price posting

	No control		Control for competition	
Measure of price dispersion	Range	Variance	Range	Variance
Posted	0.043	0.214	-2.484	-9.173
	(0.376)	(0.761)	(1.401)	(4.712)
Posted*DistanceStations (km x 100)	-	-	3.527*	12.627*
			(1.634)	(6.116)
Posted*MultipleRoutes	-	-	-0.120	1.151
			(0.928)	(2.073)
Sign F.E.	✓	✓	✓	✓
Time F.E.	✓	✓	✓	✓
Adjusted R^2	0.5155	0.4446	0.5297	0.4744
N. Observations	34,309	34,309	34,309	34,309

OLS estimates of the effect of own price posting on gasoline price dispersion. In the first two columns we do not add any controls. In the next two columns we control for the intensity of competition. Clustered standard errors are reported in parenthesis.

Table 7: Estimates of purchase decision model

|	1 Segment	2 Segments		3 Segments		
		Seg 1	Seg 2	Seg 1	Seg 2	Seg 3
Intercept	-3.878**	-4.427**	-2.005**	-4.514**	-2.609**	-1.566**
	(0.007)	(0.011)	(0.014)	(0.012)	(0.025)	(0.020)
Price	-0.034**	-0.052**	-0.053**	-0.051**	-0.075**	-0.075**
	(0.005)	(0.007)	(0.008)	(0.008)	(0.013)	(0.011)
Post	-0.182**	-0.048*	-0.050	-0.046*	-0.146**	-0.037
	(0.014)	(0.019)	(0.027)	(0.021)	(0.043)	(0.039)
Price*Post	-0.072**	-0.025	-0.051**	-0.019	-0.094**	-0.031
	(0.010)	(0.013)	(0.018)	(0.015)	(0.029)	(0.023)
Seg. Size	-	0.913	0.086	0.88	0.08	0.04
Log-Lik	-164,860	-151,142		-150,253		
AIC	329,728	302,302		300,534		
BIC	329,778	302,414		300,708		

ML estimates of consumers' retail choice model. Each specification is estimated using 13,722 cardholders and 1,812,070 observations. *Post* is the indicator of whether the price sign is installed. Standard errors are shown in parenthesis.

Figure 1: Example of a price sign installed along the Italian motorways

(Source: *Google Maps*)

Figure 2: Comparison between price of stations before and after price signs are installed
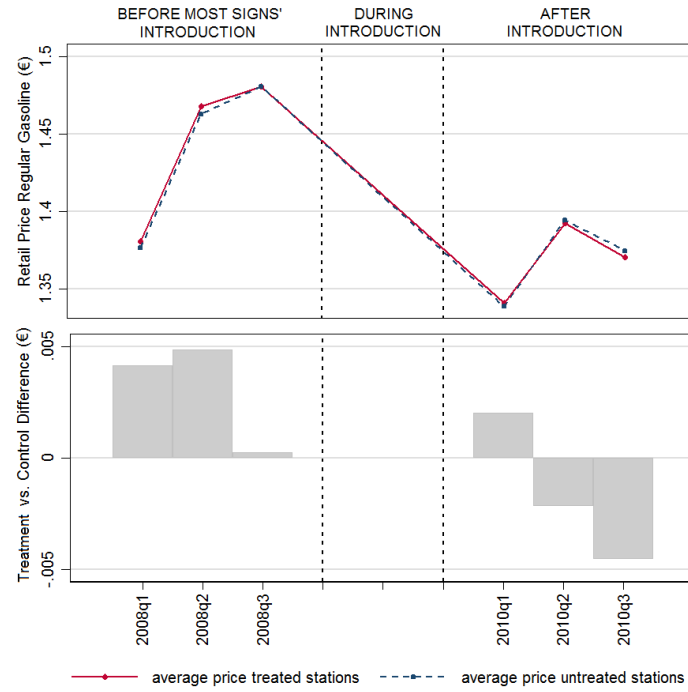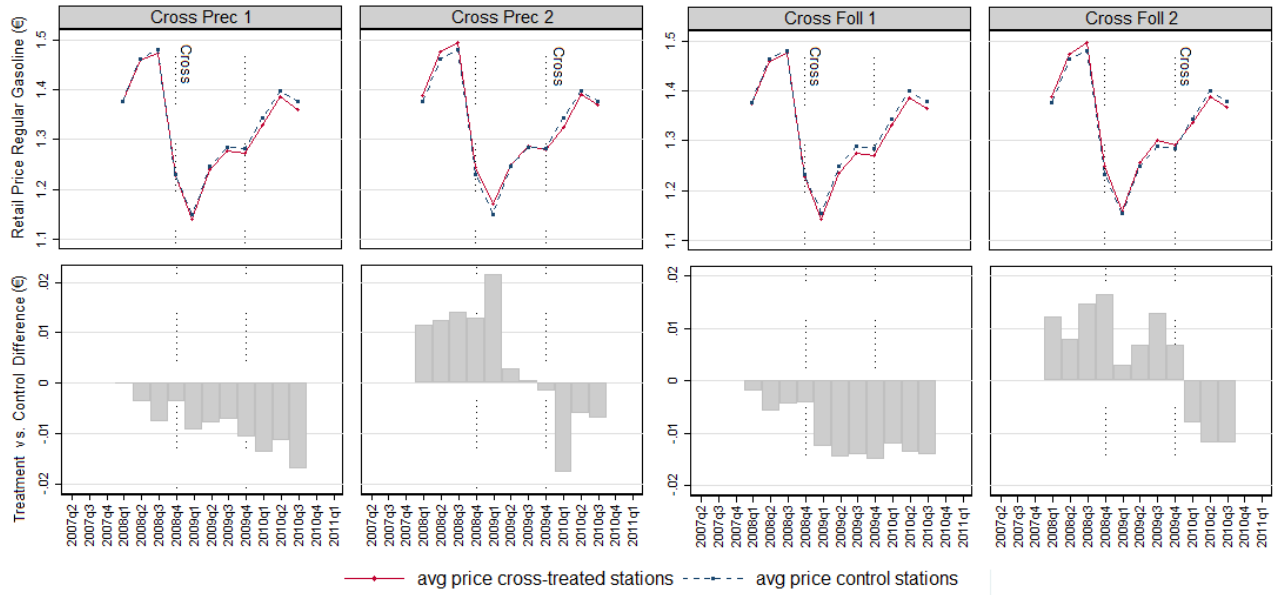

Comparison between the price series of stations whose prices are posted (treated stations), and stations whose prices have not been posted (control stations).

Figure 3: Comparison between price of stations before and after price signs, by groups
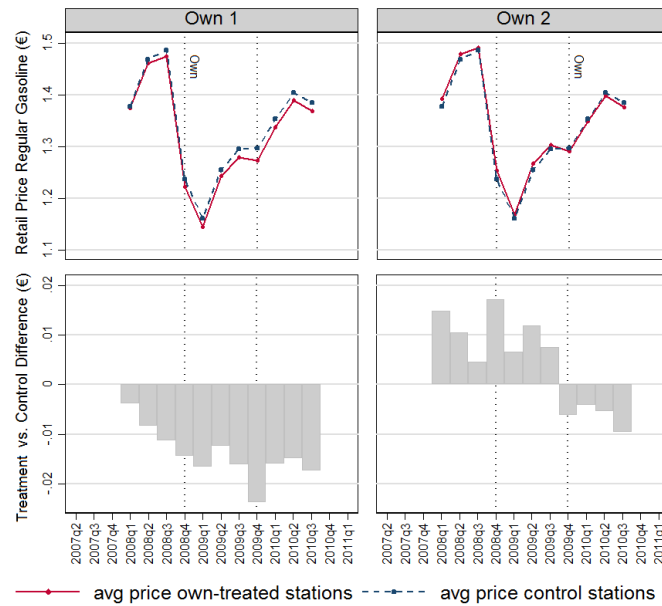
Comparison between the price series of stations whose prices are posted on own signs (own-treated stations) and a group of stations in the motorway with neither own signs nor cross signs.

Figure 4: Comparison between price of stations before and after price signs, by groups

Comparison between the price series of stations whose prices are posted on cross signs (cross-treated stations) and a group of stations in the motorway with neither own signs nor cross signs.

Figure 5: Effect of own sign and following cross sign, by position
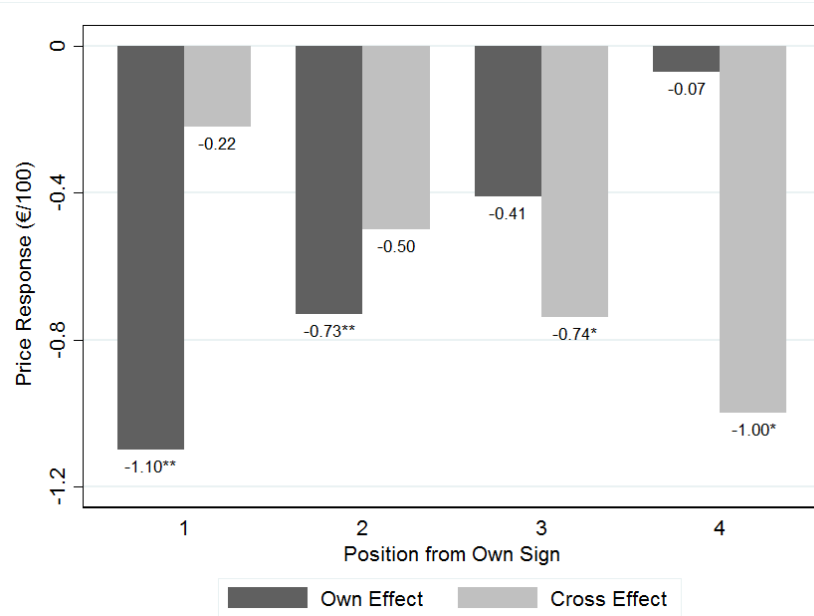
* = significantly different from zero, $p < 0.05$, ** = significantly different from zero, $p < 0.01$