Price Transparency Against Market Power

Felix Montag and Christoph Winter
Department of Economics
University of Munich

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Abstract

Mandatory price disclosure can reduce market power caused by informational frictions, but in markets prone to collusion can also harm consumers. This paper studies under what conditions policymakers should mandate price disclosure and analyses what factors determine whether such a policy is likely to be pro- or anti-competitive. First, we set up a theoretical search model with collusion and imperfectly informed consumers and producers and characterise under which circumstances increasing price transparency benefits consumers. Second, we construct a unique data set to study how mandatory price disclosure in the German petrol market affected retail margins. We find that this policy led to a decrease in retail margins by about 13 percent. A subsequent analysis of the mechanisms confirms our theoretical results, that the level of ex ante consumer and producer transparency, as well as the number of consumers adopting the price information determines whether mandatory price disclosure has a pro- or anti-competitive effect.

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1 Introduction

Many firms derive their market power and ability to price above the perfectly competitive level from informational frictions. At the same time, modern information technologies allow collecting and diffusing vast amounts of information at a low cost. In some markets, price comparison platforms have formed. In others, they have not. One important obstacle for the creation of price comparison platforms can be the cost of collecting prices. If the state wants to foster the creation of such platforms, it could help overcome this by mandating firms to disclose prices.

However, the existing theoretical literature shows that in markets prone to collusion, mandatory price disclosure can be harmful to consumers.[1] A nascent empirical literature studying the effect of mandatory price disclosure policies has found mixed evidence.[2] Overall, the theoretical and empirical literatures suggest that the effect of mandatory price disclosure depends on market specificities and the design of the policy. In this paper, we ask under what conditions mandatory price disclosure is likely to be pro- or anti-competitive.

Studying how market specificities influence the effect of mandatory price disclosure empirically is difficult because data on prices before the introduction of the price disclosure policy is usually not available and often there is no observable variation in the policy design and the market characteristics. We overcome those obstacles by exploiting the introduction of the Market Transparency Unit for Petrol (MTU) in Germany as a quasi-natural experiment. Since September 2013, a law forces all petrol stations in Germany to disclose all price changes in real-time to a central database and allows information service providers to defuse this information to consumers. Using a difference-in-differences approach, we causally identify the effect of mandatory price disclosure on retail margins. We do this by comparing retail margins for the universe of petrol stations in France and Germany for the years 2013 and 2014. While for France data is available for the full observation period, we combine price data from the MTU after its introduction with a novel data set of 11 million price notifications for German petrol stations in the 6 months up to the introduction of mandatory price disclosure. To understand what drives the effect of mandatory price disclosure on competition, we set up a theoretical model that allows for collusionary behaviour. We find that the share of producers and consumers that are informed about prices before mandatory price disclosure and the intensity of the treatment are important determinants of the effect of mandatory price disclosure. We then use variations in the treatment intensity coming from local media reports, as well as observable differences in market characteristics, to test the predictions of our model. Finally, we contrast our results

[1] See, for example, Kühn and Vives (1995) or Schultz (2017).

[2] See, for example, Luco (2019), who finds that mandatory price disclosure increased retail margins and Ater and Rigbi (2017), who find that mandatory price disclosure decreased prices.

to findings in the literature and provide explanations on why mandatory price disclosure may sometimes be pro- and sometimes anti-competitive.

Overall, we find that the introduction of the MTU in Germany led to a decrease in retail margins by approximately 1 Eurocent or 13 percent of retail margins. We furthermore find that if local radio reports about petrol prices, which are a complementary information campaign intensifying the treatment, accompany mandatory price disclosure, average retail margins decrease by a further 0.5 Eurocent. Additionally, we find that the share of consumers that are already informed about prices before the introduction of the policy leads to significant heterogeneities in the treatment effect. We find suggestive evidence of a U-shaped relationship between the ex ante level of informed consumers and the treatment effect. The higher the level of ex ante informed consumers, the larger the magnitude of the treatment effect. For very high levels of ex ante informed consumers, this relationship is reversed. This is because if most consumers are already informed before its introduction, the information set of consumers does not change much by the MTU. For the entire domain of ex ante informed consumers, the increase in transparency due to the introduction of the MTU led to a decrease in retail margins. Finally, we contrast our results to findings by Luco (2019) for the Chilean petrol market, where mandatory price disclosure increased retail margins by 9 percent. The differences in results and policy design confirm the predictions of our theoretical model, that the level of ex ante producer transparency, as well as the share of adopting consumers are key determinants on whether mandatory price disclosure is pro- or anti-competitive. In particular, two results of our model help explaining the differences that we find: Firstly if producers are well informed about prices before mandatory price disclosure, it is less likely that such a policy is anti-competitive. Secondly, in some cases a marginal increase in consumer transparency can be anti-competitive, whereas a large increase is pro-competitive. Thus, it is important that competition authorities do not only provide the information, but also push for its large-scale adoption.

The effects of mandatory price disclosure can have important welfare implications, as can be seen in the case of the MTU in Germany, where a decrease in average prices by 1 Eurocent amounts to savings of 460 million Euro to private households every year.[3] In contrast, the costs of operating the MTU are low.[4] Thus, the benefits of mandatory price disclosure to consumers in the German petrol market greatly outweigh its costs to the public.

We combine data from multiple sources for our empirical analysis. Firstly, we construct a unique panel data set with station-level retail margins in Germany before and after the MTU

[3] According to Destatis (2018), private households consumed 46 billion litres of fuel in Germany in 2016.

[4] The most important cost is 6.5 full-time equivalent employees needed to ensure the day-to-day operations of the MTU (German Ministry for Economic Affairs, 2018).

introduction. A unique feature of our data is that, to the best of our knowledge, we are the first to construct station-level retail margins before the introduction. These are calculated using a set of 11 million price notifications by consumers during the six months before the MTU introduction to a price comparison app.[5] To causally identify the effect of the MTU, we combine this with station-level data on retail margins in France for the entire observation period. We exploit the fact that France introduced mandatory price disclosure for petrol stations already in 2007 and makes this data publicly available. Secondly, we construct a dataset on radio reports by local radio stations in Bavaria, the largest of 16 regions in Germany, about petrol prices. Using geocoded reception areas for these radio stations, we can then match which petrol stations lie within the reception area of a radio station reporting local petrol prices and thus intensifying the treatment. We find that regular radio reports about local petrol prices following the introduction of mandatory price disclosure lead to a further decrease in retail margins. Finally, we follow Pennerstorfer et al. (2017) and proxy the share of ex ante informed consumers of a petrol station by the station-level share of commuters amongst potential customers of a station. Whereas commuters are assumed to know all prices on their daily commute, non-commuters do not.

The paper makes three contributions. Firstly, we develop a new theoretical model for the analysis of the effect of mandatory price disclosure in homogeneous goods markets with imperfectly informed producers and consumers, sequentially searching consumers and the potential for collusive behaviour by producers. Secondly, we are the first to causally estimate the average effect of the introduction of the MTU in Germany on retail margins. Thirdly, we analyse the mechanisms that drive the effect of mandatory price disclosure and provide evidence on factors that make such policies pro- or anti-competitive.

Our work relates to several different literatures. Firstly, it contributes to the broad theoretical literature on competition under imperfect information, started by Stigler (1961), Diamond (1971) and Rothschild (1973).[6] Moreover, it contributes to the rich theoretical literature on collusion under imperfect information. The pioneering works by Green and Porter (1984) or Kühn and Vives (1995) analyse imperfect information on the producer side with potentially colluding firms. Schultz (2005) analyses the effect of increasing the share of informed consumers in collusion models in which firms are perfectly informed, and consumers are either perfectly informed or completely uninformed about prices, like in the search model by Varian

[5] There already existed some apps that allowed users to self-report petrol prices, which were then collected and diffused to users in a similar fashion to the price information from the MTU, but the usage of these apps before the MTU was considerably lower than after its introduction. This is why the introduction of the MTU nevertheless led to an important change in the the information set of market participants.

[6] For a review of this literature, see Baye et al. (2006).

(1980). Rasch and Herre (2013) extend this model, and Petrikaite (2016) allows uninformed consumers to search for prices sequentially, as in the unit-demand version by Janssen et al. (2005) of the Stahl (1989) model. This literature shows that slightly changing assumptions on the search protocol, the nature of goods or the elasticity of demand can have a great influence on whether increasing consumer information about prices is pro- or anti-competitive. Schultz (2017) builds upon Schultz (2005) and allows firms to be imperfectly informed about the prices of their rivals, but does not allow consumers to search sequentially. He finds that under these conditions, increasing a common factor of transparency, affecting producers and consumers, is always anti-competitive in homogeneous goods markets. We extend the model for homogeneous goods by allowing consumers to search sequentially, as in Petrikaite (2016), and show that under these conditions mandatory price disclosure can also be pro-competitive.

Secondly, the paper contributes to the empirical literature on policies increasing price transparency. Albæk et al. (1997) and Luco (2019) find that increasing price transparency in homogeneous goods markets, namely the cement industry in Denmark and the petrol industry in Chile, led to an increase in prices. Ater and Rigbi (2017) find that mandatory price disclosure of supermarket prices for mostly differentiated goods in Israel led to a decrease in average prices. Brown (forthcoming) finds that a government website reducing informational frictions in the market for medical procedures led to a 3 percent reduction in spending. Martin (2018) uses price data from the MTU for petrol stations in Bavaria in 2017 to estimate a structural model and simulate the effect of limiting price transparency to only a few petrol stations. He finds that restricting transparency to showing only below-median prices, as opposed to full transparency, decreases consumer expenditures and increases consumer welfare. His findings are complementary to our study, as they highlight further possibilities to optimise the design of mandatory price disclosure policies. A limited number of studies have studied the effect of the MTU introduction. Dewenter et al. (2017) evaluate the MTU using weekly average prices aggregated at the country-level for 27 European countries for 8 years before and 2 years after the introduction of the MTU and find that prices in Germany increased after the MTU compared to other European countries.[7] Haucap et al. (2017) use simple and volume-weighted average prices before and after the MTU introduction, to show that the difference between the two averages increased and hence conclude that consumers use the additional information provided by the MTU to fuel at lower price stations. To the best of our knowledge, we are the first to provide causal evidence of the pro-competitive effects of mandatory price disclosure in homogeneous goods markets, and to causally estimate the effect of the MTU in Germany on average prices

[7] An important drawback to this methodology is that macro shocks, such as the sovereign debt crisis, which affected some European countries more than others between 2010 and 2012, could bias the estimates.

and margins. Also, we extend this literature by providing theoretical and empirical evidence on factors which make it more or less likely for mandatory price disclosure to be pro-competitive in homogeneous goods markets.

Finally, the paper contributes to the empirical literature on consumer search and price dispersion in the petrol industry (e.g. Chandra and Tappata, 2011 or Pennerstorfer et al., 2017) and to collusionary behaviour in petrol markets (e.g. Byrne and de Roos, 2017 and Byrne and de Roos, 2019). It also contributes to a nascent literature of pricing patterns in the German petrol market using data from the MTU since its introduction (e.g. Wilhelm, 2016).

The remainder of this paper is structured as follows: Section 2 describes the specificities of the German petrol market and the introduction of the MTU. Section 3 outlines the theoretical model. Section 4 presents the data used in this paper. Section 5 explains the empirical methodology and findings. Section 6 analyses potential mechanisms, section 7 discusses the results and Section 8 concludes.

2 Background

Retail fuels are products with a very high degree of homogeneity within their product category. Although petrol filling stations also sell other products, we focus our attention on the sale of fuel. The two main fuel categories are diesel and petrol. Consumers cannot substitute between the two in the short-term, as vehicles can only either run on one or the other type. Within petrol, there is differentiation according to the octane rating and the share of ethanol. Even between these sub-categories, there is only very limited substitution. In our analysis, we, therefore, focus on petrol with an octane rating of 95 and an ethanol share of 5 percent, which had a market share of 82 percent in Germany in 2017 (BDBE, 2018).

Examining the vertical structure is important to understand competitive dynamics in the petrol industry. In the upstream market, crude oil is directly transported to oil refineries, which then process the crude oil into retail products. These are sold and distributed to the downstream market, where petrol filling stations sell the retail product to motorists.

According to the GFCO (2011), both the upstream and downstream markets are highly concentrated. The main firms active in the German upstream market are BP, ConocoPhillips, ENI, ExxonMobil, Rosneft, Shell and Total. In the downstream market, all of these firms with the exception of ENI and Rosneft also have a large network of petrol filling stations spread across Germany.[8] Access to refinery capacities is an important competitive advantage

[8] ENI also has a small network of petrol filling stations in Germany, but its smaller size and reduced geographic reach gives it less clout.

in the downstream market for petrol and therefore these five vertically integrated firms form an oligopoly with significant market power towards outside competitors, although there are also many other petrol filling stations.

In 2011, the five oligopolists had an aggregate market share of around 47 percent in retail petrol from petrol stations that they owned directly. This is an underestimate of the share of the market they control. A further 18 percent of the market is served by petrol stations that are owned and operated by independent dealers, but for which the oligopolists have some price discretion. These usually operate under the brand of the oligopolists (see German Ministry for Economic Affairs, 2018). Other vertically integrated competitors (mainly ENI, Orlen, OMV and Tamoil) and independently owned filling stations, which often buy their petrol from the oligopolists, serve the rest of the market.

Before the introduction of the MTU, price transparency among producers was high, but not perfect. Since the oligopolists have price discretion over their stations and, to some degree, about their partner petrol stations, they observed these prices before the MTU. Additionally, employees of company-owned stations, as well as dealer-owned partner stations, were often contractually bound to report prices of neighbouring stations to the oligopolist several times a day (GFCO, 2011). Finally, some oligopolists also posted prices of their petrol stations on their website, which allowed other oligopoly members to see this. However, price transparency on the producer side was not as comprehensive as after the MTU introduction. Many stations, in particular independent stations and small chains, did not follow the practice of posting prices online and only had limited knowledge of rivals' prices.

Before the MTU, consumers were much less informed about prices than firms and hence found it difficult to assess the competitiveness of a particular petrol price. In the absence of an information clearinghouse, there are significant search costs for consumers. To find the prices of all potential sellers, she would need to drive to all stations.[9]

A market investigation ending in 2011 lead the German Federal Cartel Office (GFCO) to find that the oligopolists have a dominant position in regional petrol markets and that prices are higher than under functioning competition. Although the GFCO (2011) does not provide evidence of the existence of a hardcore cartel, there is significant evidence for tacit collusive behaviour. Among the most important pieces of evidence are the price cycles found during the investigation. The GFCO found that a price increase at most stations of one of the oligopolists in a region usually starts a price cycle. Aral and Shell are commonly found to be the price

[9]There were already some apps that allowed users to self-report petrol prices, which were then collected and diffused to users in a similar fashion to the price information from the MTU, but the usage of these apps before the MTU was considerably lower than after its introduction.

leader. Following a price increase, the other price leader (i.e. either Shell or Aral) reacts in 90% of cases by also increasing prices within 3 hours. This is usually followed by a price increase by Total, Jet or Esso only a few hours later. These price movements lead to price cycles with repeating patterns, which are primarily reflected in retail margins and thus not cost-driven. This is in line with the findings of Byrne and de Roos (2019), who describe how dominant firms use price leadership and price experiments to create focal points that coordinate market prices, soften price competition and increase retail margins in the Australian petrol market.

The market investigation was thus followed by calls by the GFCO and the Monopolies Commission for an increase in price transparency in the downstream market because they concluded that a lack of price transparency on the consumer side caused the lack of competition. In 2012, parliament passed a law which set out the creation of the market transparency unit under the management of the GFCO and on 12 September 2013 the operation of the MTU began. This is an information clearinghouse that collects prices in real-time and allows app creators to diffuse the information to users. It hence provides consumers and producers access to live price data and increases price transparency on both sides of the market.

At the same time, increasing the degree of visibility of actions of the competitors could potentially further facilitate collusive behaviour. A debate therefore began around the introduction of the MTU about whether its introduction would benefit consumers.

3 Theoretical Model

This Section outlines a theoretical model, which should serve as a framework guiding the empirical analysis. We derive theoretical results on the effect of increasing price transparency (e.g. through mandatory price disclosure) and later provide empirical evidence on these theoretical results.

In the following model, a homogeneous good is sold by a small number of firms that could potentially engage in collusive behaviour. At the same time, some consumers and producers are perfectly informed about prices, whereas others are not.[10] Since producers are imperfectly informed about prices of their rivals, it is possible for deviations from the collusionary agreement to remain undetected. This is a plausible description of the search process by consumers in the retail petrol market and allows us to analyse how prices are affected when mandatory price disclosure affects the information sets of producers and consumers.

[10] In modelling consumer information, our model builds on the collusion model for homogeneous goods markets proposed by Petrikaite (2016), however, in contrast to her model, we allow for imperfectly informed producers.

3.1 Setup

There is a finite number of n symmetric price-setting firms competing in an infinitely repeated game and producing at a normalised marginal cost of zero.

There is a unit-mass of consumers. Each consumer has the same valuation v for the good and inelastically demands $\xi > 0$ units of the product. ξ is distributed according to the cumulative distribution function $\psi(\xi)$ with mean equal to one. It is constant within a period but varies between periods. Firms thus do not perfectly know aggregate demand in a particular period.

A fraction ϕ of consumers consists of fully informed shoppers and $1-\phi$ are non-shoppers, who can search sequentially. Shoppers know prices of all sellers and therefore always buy from the lowest price seller. Non-shoppers only know the distribution of prices and draw a first price for free. They can then choose to randomly draw prices of additional sellers at an incremental search cost s, in the hope of finding a lower price. Non-shoppers buy the good as soon as the price they draw is weakly below the reservation price p_r, at which non-shoppers are indifferent between accepting the price and drawing a new price at search cost s, because the expected price savings of drawing another price are equal to the search cost s. Finally, we assume that the search cost s is such that it does not exceed the reservation price, i.e. $s \leq p_r$.[11]

3.2 Static Equilibrium

In the static Nash equilibrium, all firms play mixed strategies in which they draw a price from the interval $[\underline{p}, p_r]$ according to the distribution $G(p)$, where p_r is the reservation price of non-shoppers and $\underline{p}$ is the minimum price a firm will charge. Shoppers always buy from the lowest price firm, whereas non-shoppers draw a single price and buy at this price. In equilibrium, non-shoppers hence do not search sequentially, because any price they draw is below their reservation price. In Appendix A, we derive expressions for the equilibrium objects p_r, $\underline{p}$, $G(p)$ and π_i^*.

3.3 Dynamic Equilibrium

After analysing the equilibrium of the one-shot game, we now look at an infinitely repeated version of this game, in which firms are allowed to collude and where deviations may remain undetected.

We assume its rivals observe the price of a firm with a probability η. Since aggregate demand is stochastic, firms cannot infer the prices of their rivals based on their own price and

[11] The model is solved in detail in Appendix A.

their quantities sold. A deviation from the collusionary agreement by a firm will therefore only be detected by its rivals with probability η.[12]

We assume that collusionary agreements are enforced by playing the grim-trigger strategy proposed by Friedman (1971). This means that if a deviation from the collusionary price is observed, all firms enter the punishment phase and charge the static equilibrium price forever.

A firm will charge the collusionary price as long as its expected discounted profit from collusion is at least as high as its expected discounted profit from deviation. This is the case if and only if:

$$\frac{1}{1-\delta}\pi^c \geq \pi^d + \frac{\delta}{1-\delta}(\eta\pi^* + (1-\eta)\pi^c)\,, \tag{1}$$

where δ is the discount factor, π^c is the profit under collusion and π^d is the deviation profit.

In case a firm deviates from the collusionary agreement, it will receive the deviation profit π^d in the deviation period. In future periods, it expects to receive the competitive profits if its rivals detect its deviation and the collusionary profits if its deviation remains undetected.

To see what determines whether collusive behaviour is profitable, we need to analyse the critical discount factor $\underline{\delta}$. If the discount factor of a firm is above $\underline{\delta}$, it values the future sufficiently to make a deviation, and thus the possibility of future punishment, unprofitable. If $\delta < \underline{\delta}$, a firm finds it profitable to deviate from the collusionary price. The critical discount factor is hence the discount factor at which Equation 1 holds strictly and can be written as:

$$\underline{\delta} = \frac{\pi^d - \pi^c}{\pi^d - \eta\pi^* - (1-\eta)\pi^c}\,. \tag{2}$$

The profit in punishment periods, π^*, corresponds to the competitive profits in the static game and the punishment price to the competitive price. In collusionary periods firms charge the monopoly price, which, because consumers are perfectly inelastic, is equal to the valuation of the good by consumers, i.e. $p_c = \upsilon$. Since all firms charge the same price in collusionary periods they all have an equal share of demand and the collusionary profits of a firm are $\pi^C = \frac{\upsilon}{n}\xi$. When a firm undercuts the collusionary price by charging $p^d = \upsilon - \epsilon$, where ϵ is a very small positive number, it attracts all shoppers and keeps its share of non-shoppers. The deviation payoff is, therefore, approximately $\pi^d = \upsilon(\frac{1-\phi}{n} + \phi)\xi$.

3.4 Comparative Statics

Now that we know what determines prices, profits, and the incentives to collude, we can analyse how these are affected by changes in transparency and search costs.

[12]Note that allowing collusion and imperfect information on the producer side has no effect in the static game, because in a one-shot game deviation is always profitable since it can never be punished in a subsequent period.

Two special cases are worth analysing. If $\eta = 0$, deviations from the collusionary agreement will never be detected. The critical discount factor to sustain collusion becomes 1. Firms will never adhere to the collusionary agreement, because a deviation is never detected and hence never punished. If $\eta = 1$, a deviation from the collusionary agreement will always be detected. In this case, mandatory price disclosure would only have an effect on the degree of price transparency on the consumer side. We will, therefore, analyse this special case in the context of a change in the share of shoppers, ϕ. For the rest of the analysis, we focus on the case where η is strictly between zero and one.

Proposition 1. *A marginal increase in producer transparency, η, decreases the critical discount factor $\underline{\delta}$.*

If producer transparency increases, the likelihood that a rival detects a deviation from the collusionary agreement increases. Since the punishment phase starts only after detection of a deviation, an increase in producer transparency leads to an increase in the likelihood of punishment and thus makes deviation less attractive.[13]

Proposition 2. *A marginal increase in consumer transparency, ϕ, decreases the critical discount factor $\underline{\delta}$ for small values of ϕ, $\phi \leq \bar{\phi}$, and increases the critical discount factor $\underline{\delta}$ for values of ϕ, $\phi \geq \bar{\phi}$ for $n = 2$.*

Consumer transparency is modeled as the share of perfectly informed shoppers. If the market becomes more transparent for consumers, the share of shoppers increases. Analysing the effect of a change in ϕ is more complicated than a change in η because ϕ enters the deviation and punishment profits.

An increase in the share of shoppers, ϕ, increases the number of consumers that would buy from a firm that marginally undercuts the collusive price and hence makes a deviation more attractive. To illustrate this point, let us focus on two extreme cases: If the share of shoppers is close to zero, then if ϕ converges towards zero, the deviation profit converges towards the collusive profit. This is because if no consumer observes the deviation, then as many consumers randomly see the price of the producer and buy its good as under the collusive price. Producers thus have no incentive to deviate from the collusive agreement in the absence of informed shoppers and the critical discount factor becomes zero. If the share of shoppers is close to one, then if ϕ converges towards one, the deviation profit converges towards the monopoly profit, thus maximizing the incentive to deviate from the collusive agreement, coming from the deviation profits.

[13] We prove this Proposition in Appendix A.

At the same time, a higher share of shoppers decreases expected profits in the static Nash equilibrium, i.e. the punishment profit. This is because the higher the share of shoppers, the more consumers will go to the lowest price producer in a punishment phase. Furthermore, the domain of prices over which firms mix, moves towards lower prices if the share of shoppers increases.

The deviation profits increase linearly in the share of shoppers, whereas the punishment profits decrease in ϕ but do this more strongly for small values of ϕ than for larger ones. Overall, marginally increasing consumer transparency decreases the critical discount factor $\underline{\delta}$ for small values of ϕ, $\phi \leq \bar{\phi}$, and increases the critical discount factor $\underline{\delta}$ for values of ϕ, $\phi \geq \bar{\phi}$. We prove this for $n = 2$ in Appendix A.[14]

So far, we treated consumer and producer transparency as dichotomous. In reality, unless producers are already perfectly informed ex ante, an increase in consumer transparency often also increases transparency on the producer side. We introduce a common factor of transparency α such that $\phi = \phi(\alpha)$ with $\phi'(\alpha) > 0$ and $\eta = \eta(\alpha)$ with $\eta'(\alpha) > 0$. Before analysing the effect of a change in α on the profitability of engaging in collusive behaviour, it is helpful to introduce the elasticity of η with respect to α:

$$e_{\eta,\alpha} \equiv \frac{\partial \eta}{\partial \alpha} \frac{\alpha}{\eta}, \tag{3}$$

and the elasticity of ϕ with respect to α:

$$e_{\phi,\alpha} \equiv \frac{\partial \phi}{\partial \alpha} \frac{\alpha}{\phi}. \tag{4}$$

Proposition 3. *A marginal increase in common transparency α can increase or decrease the critical discount factor $\underline{\delta}$, depending on the ex ante levels of transparency η and ϕ, as well as the elasticities of η and ϕ with respect to α.*

If a common factor of transparency α increases, for example, because after mandatory price disclosure producers and consumers have access to the disclosed prices and both were not perfectly informed ex ante, then η and ϕ both increase. An increase in common transparency thus affects the critical discount factor through the channels described in Propositions 1 and 2. In Proposition 1, we show that an increase in producer transparency decreases the critical discount factor $\underline{\delta}$ and is thus always anti-competitive. In Proposition 2, we show that for low values of ϕ, $\phi \leq \bar{\phi}$, a marginal increase in ϕ also decreases the critical discount factor. If the ex ante level of consumer transparency is sufficiently low, i.e. $\phi \leq \bar{\phi}$, a marginal increase in common transparency always decreases the critical discount factor, and hence stabilises

[14] Petrikaite (2016) shows numerically that this is also the case for $n = 3$, $n = 4$ and $n = 6$.

collusionary agreements, for any ex ante level of producer transparency.

A marginal increase in common transparency increases the critical discount factor if the pro-competitive effect of marginally increasing α through increasing consumer transparency ϕ, when $\phi \geq \bar{\phi}$, is greater in magnitude than the anti-competitive effect of marginally increasing α through increasing producer transparency. In Appendix A, we derive conditions under which this is the case. This means that, under certain conditions, a marginal increase in common transparency can make collusive behaviour more fragile.

This result is in strong contrast to previous findings in the theoretical literature, which showed that in homogeneous goods markets, increasing a common factor of price transparency is always anti-competitive. To the best of our knowledge, increasing common transparency has so far only been analysed theoretically by Schultz (2017) and in settings where non-shoppers are not allowed to search sequentially. This leads to an outcome where, for homogeneous goods, increasing consumer transparency never increases the critical discount factor. We show that by allowing non-shoppers to search sequentially, increasing consumer transparency, i.e. the share of perfectly informed shoppers, can increase the critical discount factor and thus increasing common transparency can be pro-competitive. This has important policy implications because if increasing price transparency on both sides of the market was always anti-competitive, such a policy should never be considered by a consumer-centric policymaker.

At the same time, Proposition 2 shows that even if producers are perfectly informed ex ante (i.e. $\eta = 1$), a marginal increase in consumer transparency can be pro- or anti-competitive. Thus, even if firms are perfectly informed ex ante, the direction of the effect of mandatory price disclosure on prices is still an empirical question.

Finally, an interesting result of the theoretical model is the U-shaped relationship between consumer information and the profitability of collusive behaviour. This implies that, under certain circumstances, it is possible that a marginal increase in consumer information is anti-competitive, whereas a large increase is pro-competitive. However, if a marginal increase in consumer information is pro-competitive, then a large increase is always pro-competitive. Therefore, if a competition authority finds that the market is in a situation where a marginal increase in consumer information induces collusive behaviour, it should nevertheless assess how large of an increase in consumer information would be necessary to make it pro-competitive and whether this is feasible. A large increase in consumer information could, for example, be encouraged by fostering large scale adoption of the information through complimentary information campaigns.

Three theoretical results should thus guide policymakers in assessing the implications of

mandatory price disclosure and on which we will provide empirical evidence:

Result 1. *The marginal effect of increasing consumer information depends on the share of ex ante perfectly informed consumers and can be anti-competitive, even if producers are already perfectly informed.*

Result 2. *If a marginal increase in the informedness of consumers is pro-competitive, then a large increase in their level of information will benefit consumers even more.*

Result 3. *Holding everything else equal, increasing transparency among producers is anti-competitive, because it facilitates collusive behaviour.*

4 Data

To analyse the introduction of the MTU, we combine data from multiple different sources. Our core data set contains station-level retail margins for most petrol stations in Germany and France for the years 2013 and 2014. We supplement this with information on local media reports about local petrol prices by radio stations and a proxy for the station-level share of ex ante perfectly informed consumers based on commuter data.

4.1 Retail Margins and Petrol Station Characteristics

We construct our primary data set containing station-level retail margins for *E5* petrol on weekdays at 9 am and 5 pm between 1 January 2013 and 31 December 2014 in Germany.[15] To calculate retail margins, we subtract the daily average ex-refinery wholesale price across refineries in Germany from the station-level retail petrol prices. Station-level retail margins are complemented by station characteristics such as information on the firm name, brand, address and geographic coordinates.

The price panel after the MTU introduction is constructed based on all station-level notifications of price changes to the MTU since 1 October 2013. Each time a new price for a station is notified, we update the price of the station in our panel data set.

A novel and unique feature of our data is that, to the best of our knowledge, we are the first to use rich station-level price information before the introduction of the MTU. Before the introduction of the MTU, some apps existed that allowed their users to self-report station-level petrol prices. Although the usage of these apps was only a fraction of the usage of price comparison apps after the MTU introduction and the publicity that came with it, the pre-MTU

[15] *E5* is standard petrol with an octane grade of 95 and an ethanol share of up to 5%.

apps contain rich price information.[16] We use price data for the pre-MTU period supplied by one of the app providers collecting self-reported prices. This data set comprises 17 million price reports for more than 13,500 stations between 1 January and 12 September 2013. Although the MTU went into operation on 12 September 2013, we only have access to its data from the 1 October 2013 onwards. Since our self-reported pre-MTU data only goes until the 12 September 2013, the period in between is not subject of our analysis.

For most days in the pre-MTU period, we have prices for more than 80% of petrol stations.[17]

In case the reporting of prices is not random, selection could harm the validity of our estimation results. The most natural selection mechanism is that petrol stations themselves report prices onto the apps when they are low to attract shoppers. At the same time, they could refrain from posting prices when they are high in order not to discourage consumers from driving to their petrol station and discover the price. In this case, prices in our sample before the MTU introduction should be downward-biased. However, since we find that prices decreased after the introduction of the MTU, this selection mechanism would work against us, and our estimates should be seen as a lower bound.

Another concern could be that the composition of brands in our sample before and after the introduction of the MTU changed significantly. Table 1 presents summary statistics of our data. As can be seen in Panel A, the composition of petrol stations in our data does not change significantly between the pre- and post-MTU periods concerning the share of integrated stations, the share of oligopoly stations, the share of commuters or the number of competitors in local petrol markets. A detailed split of petrol stations by brand before and after the MTU introduction can be found in 5 of Appendix B.1. Overall, the composition of brands is very similar.[18]

The majority of the retail price for petrol in Germany consists of taxes and input costs. To analyse the share of the petrol price that can be influenced by petrol stations, we focus on retail margins. Firstly, we subtract taxes and levies to compute net petrol prices. Thereafter,

[16] Figure 10 in Appendix B shows for three mobile price comparison applications for which data is available in 2014, that the number of page impressions increased strongly over the course of the year 2014.

[17] The daily number of petrol stations with price reports and the number of daily price changes are reported in Figures 4 and 5 in Appendix B. We exclude days after the MTU introduction from our analysis, where the number of price changes compared to the previous day drop by more than 40%. Since we observe the universe of price changes after the introduction of the MTU, and the average number of daily price changes is usually stable, we conclude that these days are affected by technical difficulties. In total, this affects ten days during the 15 months of data used from the MTU.

[18] To exclude the possibility that small changes in the brand composition drive our results, we repeat the analysis for different sub-samples such as integrated and non-integrated stations, as well as for the two largest brands Aral and Shell in Appendix C.4. These additional analyses show that our results are robust to changes in the sample.

Table 1: Summary Statistics

A. Station characteristics			
	D pre-MTU	D post-MTU	France
Number of Stations	13,704	14,414	7,240
Share of integrated stations	59%	58%	
Share of oligopoly stations	48%	47%	
Median # comp. (5 km catchments)	4	3	
Share of local monopolists	15%	15%	
Average share of commuters	34%	34%	

B. Prices and Margins					
	D pre-MTU at 9 a.m.	D post-MTU at 9 a.m.	D pre-MTU at 5 p.m.	D post-MTU at 5 p.m.	France at 5 p.m.
Average prices	1.62	1.55	1.59	1.50	1.54
Average retail margins	0.10	0.11	0.08	0.06	0.19
Average daily spread	0.09	0.09	0.09	0.07	0.15

Notes: "D pre-MTU" and "D post-MTU" refer to petrol stations in Germany before and after the introduction of the MTU, respectively. The pre-MTU phase goes from 1 January 2013 until 12 September 2013. The post-MTU phase goes from 1 October 2013 until 31 December 2014. For France, all figures are for the full period 1 January 2013 until 31 December 2014. The average daily spread is measured as the average of the difference between the retail margin at the 95^{th} percentile and the 5^{th} on each day.

we subtract the daily average ex-refinery price of *E5* at German oil refineries to obtain retail margins. Daily ex-refinery prices are taken from Oil Market Reports, a business intelligence firm, generally regarded as the most reliable source for refinery prices and used as a data source by the GFCO.

Since January 2007, all petrol stations in France selling more than $500m^3$ of petrol per year have to report all price changes to a government agency similar to the MTU in Germany. Regular checks are carried out and fines imposed on petrol stations that do not comply with this rule. To the best of our knowledge, France is the only other European country for which station-level petrol prices are available during this period.[19] The French government makes all price information since 2007 publicly available on a government website.[20] We thus observe the universe of price changes of these petrol stations in France over our observation period. The data is regarded to be of very high quality and has previously been used by other researchers.[21]

The data set contains information a list of price notifications with the price, the type of fuel, the address and geographic coordinates of the petrol stations and the opening times. In

[19] Austria introduced mandatory price disclosure in 2011, however only published the five lowest prices in a local market. In addition, daily average prices at the state level are available for Austria. We, therefore, show descriptive results of the effect of the MTU introduction using Austria as a control group in Appendix C. These results are consistent with our main results.

[20] https://www.prix-carburants.gouv.fr/rubrique/opendata/

[21] Gautier and Saout (2015), for example, use this data to study the speed at which market prices of refined oil are transmitted to retail petrol prices.

contrast to the data of the MTU in Germany, it does not contain any information on the brand of the station or any other company-related information.

To compute retail margins, we also need a measure for input prices in France. To the best of our knowledge, there is no comparable data to the ex-refinery prices for Germany by Oil Market Reports available for France. We thus use daily market prices for refined oil at the port of Rotterdam as a proxy for ex-refinery prices in France.

4.2 Exogenous Information Shocks

To study the effect of a follow-on information campaign, we analyse the impact of local radio reports about petrol prices in the radio station's reception area. These reports are ideal to study the effect of a follow-on information campaign, which further diffuses price information to consumers. The creation of the MTU made it easy for local radio stations to access real-time information on the distribution of petrol prices in their reception area. Although the MTU introduction changed the information sets of consumers, this does not mean that all consumers suddenly knew all prices. Follow-on radio reports thus constitute additional shocks to consumer information. At the same time, it seems plausible that petrol stations immediately incorporated the price information by the MTU and hence were unaffected by additional radio reports. We, therefore, consider these reports to be pure shocks to ϕ in our theoretical model.

To study the impact of local radio reports, we hand-collected data on regular broadcasts of local petrol prices by local radio stations in Bavaria. After contacting program directors of around 60 radio stations, we know which radio stations broadcasted petrol prices at which point in time between 2012 and 2017. There are two local radio stations regularly broadcasting petrol prices after the introduction of the MTU. *Radio Arabella*, which started its broadcast on 25 April 2014, and *Extra Radio*, which started its broadcasts on 2 February 2014. Using geo-coded reception areas for the radio stations provided by *fmlist.org* and combining this with the geo-coded location of petrol stations, we know for which petrol station potential customers were affected by these broadcasts on which day.[22]

4.3 Consumer Search and Information

Theory suggests that the effect of an increase in transparency depends on the ex ante share of informed consumers. We follow Pennerstorfer et al. (2017) to compute the share of ex ante informed consumers of a station. Out-of-municipality commuters are assumed to be perfectly informed about petrol stations which they drive past on their daily commute. Drivers that

[22] A detailed description of the radio station reports can be found in Appendix B.2.

do not leave their municipality on their way to work are uninformed about prices and have to search. The share of ex ante informed consumers is thus the share of commuters among potential customers of a station. To calculate this, we use social security data on the number of commuters from one municipality to another, collected by the German Federal Employment Agency. Since we are interested in the ex ante level of information, we use commuter data on 30 June 2013, which is less than three months before the introduction of the MTU.[23]

5 Empirical Analysis

We begin by studying the average effect of mandatory price disclosure. We do this by comparing the evolution of retail margins of petrol stations in Germany before and after the introduction of the MTU to retail margins in France. In terms of our theoretical model, the MTU introduction is a shock to α, since producers and consumers are affected by it. In Section 6 we disentangle the mechanisms underlying this average effect.

5.1 Empirical Setup

The introduction of the MTU in Germany led to the creation of a large number of new websites and smartphone applications diffusing petrol price information and was accompanied by numerous reports in the press. In the months following the introduction of the MTU, the number of drivers using price information services strongly increased, and petrol station managers universally had easy access to real-time price information of their rivals.

To study the average effect of the MTU on retail margins, we use a difference-in-differences (DiD) framework in which we compare retail margins of petrol stations in Germany to those in France. Specifically, we estimate the following fixed effects regression:

$$Y_{it} = \beta_0 + \beta_1 MTU_{it} + \mu_i + \gamma_t + \epsilon_{it} \tag{5}$$

where Y_{it} corresponds to the retail margin of station i at time t and MTU_{it} is a dummy equal to one, if petrol station i has to report its prices to the MTU at date t. This affects all petrol stations in Germany after the 1 October 2013. μ_i are petrol station fixed effects, and γ_t are date fixed effects.

[23] The methodology to compute the share of ex ante informed consumers is described in Appendix B.3.

France as a Control Group

To identify the causal effect of the introduction of the MTU, we use the evolution of retail margins at petrol stations in France as a comparison. To the best of our knowledge, France is the only other country for which station-level petrol prices and retail margins are available for most stations for the full observation period.

Two assumptions need to be met to identify the causal effect of the MTU in our framework: There cannot be any other transitory shocks affecting petrol stations in France and Germany differently before and after the introduction of the MTU other than the introduction of the MTU itself. There are no spillovers from the treatment onto the control group. Subsequently, we provide evidence that suggests that both assumptions hold.

Firstly, we want to understand whether there are any transitory shocks which affected French and German petrol stations differently. The station fixed effects capture time-invariant differences between petrol stations in France and Germany. The date fixed effects capture transitory shocks that affect French and German petrol stations equally. Due to its similarities in size, wealth and geographic location, as well as our narrow observation period, there should not be any additional transitory demand and supply shocks that affect France and Germany differently. We nevertheless discuss the most obvious candidates in the following.

Important transitory demand shocks in the petrol market are school and public holidays, as well as local economic shocks. School and public holidays in France and Germany are highly correlated. In addition, since holidaymakers in Europe often cross several countries on the way to their holiday destination and France and Germany are popular holiday destinations and important transit countries, they are usually hit similarly and at the same time by these demand shocks. A second concern could be local economic shocks affecting cargo shipping and thus the demand for petrol. Since commercial vehicles, such as trucks transporting cargo and company cars, usually, run on diesel our analysis of the effects of the MTU on prices of *E5* should be unaffected by transitory local shocks to the economy.

Transitory supply shocks affect petrol station much in the same way. Due to their geographic proximity, petrol stations in France and Germany procure most of their petrol from similar sources. Furthermore, the European Single Market and the Schengen Agreement mean customs, border controls or other regulatory hurdles do not restrict arbitrage possibilities between the two countries. To nevertheless ensure the elimination of any transitory shocks to input prices and to restrict our analysis to the portion of the petrol price that can be affected by petrol stations, we use retail margins as outcome variables instead of prices. These retail

margins are net of taxes, levies and ex-refinery petrol prices on a given day.[24]

Also, petrol stations in France constitute a good control group because there were no important regulatory changes in the French petrol market over our observation period. The impact of the introduction of mandatory price disclosure in 2007 should have stabilized by 2013 and thus not affect different French petrol stations differently over our observation period. In contrast to other countries, France, like Germany, did not restrict its petrol stations in their price-setting behaviour other than by imposing mandatory price disclosure.[25]

There are also no significant spillovers between treatment and control group. Since consumers driving to a faraway petrol station incur high costs, petrol markets are usually very local. It, therefore, seems implausible that the introduction of the MTU in Germany affected petrol stations in France that are more than 20 km away from the Franco-German border.

A further concern could be that there may still be idiosyncratic developments, which add random noise to the data and thus lead to an underestimation of the absolute value of the effects. We, therefore, re-run our analysis for a subsample of the data around the Franco-German border, for which the economic conditions should be similar due to geographic proximity, but where there should nevertheless not be spillover effects. Firstly, we restrict our analysis to petrol stations that are 40 km left and right to the border. Petrol stations in the treatment and control groups are thus in the same economic area and only exposed to common transitory shocks. Secondly, to eliminate any potential spillover effects, we drop all petrol stations that are less than 20 km left and right of the border. We are left with a Donut-DiD, where stations on both sides of the border are geographically close, but stations that are potentially subject to spillover effects are dropped.

Finally, we use alternative identification strategies to test the robustness of our estimates. These include petrol stations in Austria, as well as German petrol stations that are local monopolists, as control groups. We report our results in Appendix C and find that these are consistent with our main findings.

Retail Margins at 5 pm

Although there are no restrictions on the number of times petrol stations can change prices in France or Germany, there are strong differences in the number of times they do. Whereas petrol stations in Germany change their prices on average four times a day over our observation

[24]Since we do not have ex-refinery prices for France, we use the wholesale price of Brent oil in Rotterdam as a proxy. The station fixed effects should capture time-invariant differences between ex-refinery prices and the wholesale price in Rotterdam.

[25]In 2011, Austria, for example, introduced a rule banning petrol stations from raising prices more than once a day.

period, French petrol stations change prices less than once a day.[26] Since we do not observe volume data, we cannot compute volume-weighted average retail margins over the day. We could thus either pick a particular time of day at which to measure retail margins or calculate a simple average of margins at different times of the day. Since petrol prices in France stay fairly constant during the day, either approach should lead to a similar result for France. The frequent price changes in Germany however, make it important to select the right time for which to calculate retail margins.

We choose to use prices at 5 pm to construct retail margins for our analysis. A representative survey among motorists commissioned by the German Ministry for Economic Affairs (2018) in 2016 found that around 60 percent of respondents buy petrol between 4 pm and 7 pm, of which two-thirds buy petrol between 5 pm and 6 pm. At the same time, less than 5 percent of respondents buy petrol before 10 am.[27] The German Ministry for Economic Affairs (2018) furthermore documents daily price cycles with high prices in the morning, which fall over the day and rise again in the evening at around 8 pm.[28] This suggests that consumers are aware of these price cycles and fuel during low price period in the late afternoon.[29] To gauge the effect of introducing mandatory price disclosure on consumers, it is therefore sensible to focus on retail margins at times where consumers buy petrol in large volumes.

5.2 Results

Figure 1 shows the evolution of indexed retail margins in France and Germany between April 2013 and December 2014. Since the MTU was introduced on the 12 September 2013, our observation period begins 5 months before its introduction.[30] At first, the MTU was in a test phase, which lasted until 1 December 2013, after which the MTU was fully launched. The beginning of the test phase is represented by the solid line and the beginning of the full-scale phase by the dashed line. We normalise the retail margins in France and Germany by their level on the first day of our observation period, to account for differences in the levels of retail margins.[31]

[26] This is consistent with findings by Haucap et al. (2017) for Germany and Gautier and Saout (2015) for France.

[27] The daily fuelling patterns are described in detail in Figure 8 in Appendix B.1.

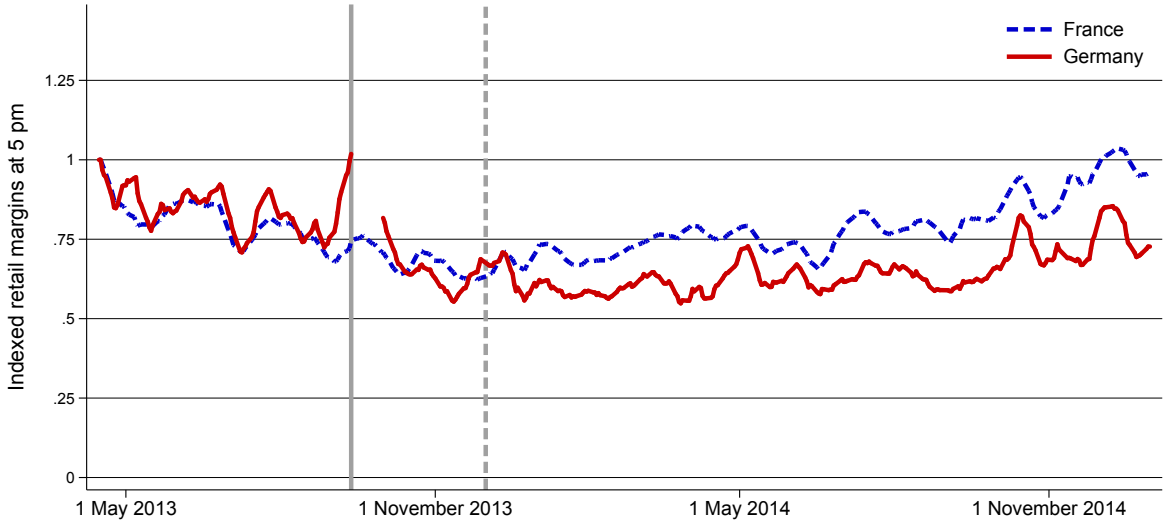
[28] This is consistent with pricing patterns in the data described in Figure 9 in Appendix B.1.

[29] There are numerous newspaper articles on intertemporal price dispersion during our observation period, which suggest that consumers are aware of these patterns.

[30] Including March 2013 would significantly add noise to our estimations. There is a large, short-term drop in retail margins in Germany at the beginning of March, which increases and a reversion to previous levels during the second half of the month. This is not an artefact of our data, since the same spike can be seen in the Weekly Oil Bulletin by the European Commission for Germany only, but cannot be observed in ex-refinery prices.

[31] Note that we are using ex-refinery prices as input costs for Germany (i.e. after transportation to the refinery and refining), whereas we use the wholesale Brent oil price as input costs for France (i.e. without transportation and refining costs). We would therefore expect estimated margins to be higher for France, which is what we

Figure 1: Evolution of Retail Margins



Notes: The solid line shows the evolution of the eleven-day moving average indexed daily average retail margin of petrol stations at 5 pm in Germany between April 2013 and December 2014. The dashed line shows the evolution of the eleven-day moving average indexed daily average retail margin of petrol stations in France at 5 pm over the same period. The average retail margins at the beginning of the observation period, on 12 April 2013, are indexed to one. The solid vertical line shows the beginning of the test phase of the MTU, on 12 September 2013. The dashed vertical line shows the beginning of the full-scale phase of the MTU, on 1 December 2013.

We see that before the introduction of mandatory price disclosure in Germany, the relative evolution of retail margins in both countries was similar. The parallel evolution of retail margins continues until December 2013, after which normalised retail margins in Germany fall significantly below normalised retail margins in France. This trend persists until the end of our observation period. It suggests that the effect of the MTU did not set in immediately, but caused a persistent decrease in retail margins. In particular, normalised retail margins only separate substantially after the beginning of the full-scale phase of the MTU.[32]

Between 12 September and 1 December 2013 the MTU was in a test phase. During this time, petrol stations, the competition authority and information providers diffusing the price information were experimenting with the technical implementation. We therefore exclude the test phase from our analysis and compare retail margins before the beginning of the test phase to after the MTU was fully implemented.

Table 2 shows the results of estimating the regression model presented in Equation 5. To allow for the treatment effect to take some time to set in, we estimate the model for three different lengths in time after the introduction of the MTU. Column (1) shows the estimates

observe.

[32]There is a strong temporary increase in relative retail margins shortly before the introduction of the MTU in September 2013. To show that our results are not driven by this temporary increase in Germany relative to France, we re-estimate our main results dropping September 2013. The results of this analysis are presented in Table 9 in Appendix C.5 and are in line with our main results in Table 2.

Table 2: The Effect of the MTU on Retail Margins

	(1)	(2)	(3)	(4)	(5)	(6)
MTU Introduction	-0.38***	-0.89***	-1.63***	-0.77***	-1.18***	-1.88***
	(0.02)	(0.02)	(0.03)	(0.17)	(0.18)	(0.23)
Date Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Station Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	4,881,426	6,219,486	7,573,657	86,605	111,319	136,561
Adjusted R^2	0.355	0.319	0.300	0.341	0.302	0.294
Mean Retail Margin	11.00	10.90	11.15	10.50	10.42	10.71

Notes: The test phase of the MTU (12 September 2013 until 30 November 2013) is dropped in all specifications. Column (1) uses data for all stations in Germany and France until 30 June 2014. Column (2) uses data for all stations in Germany and France until 30 September 2014. Column (3) uses data for all stations in Germany and France until 31 December 2014. Column (4) uses only data for stations 20 to 40 km away from the Franco-German border only until 30 June 2014. Column (5) uses only data for stations 20 to 40 km away from the Franco-German border until 30 September 2014. Column (6) uses only data for stations 20 to 40 km away from the Franco-German border until 31 December 2014.
Standard errors are in parentheses.
Standard errors clustered at petrol station level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

using data until 30 June 2014, Column (2) until 30 September 2014 and Column (3) until 31 December 2014. In Columns (4), (5) and (6), we re-estimate the model for the different time-periods only using a sub-sample of petrol stations 20 to 40 km away from the Franco-German border.

The results in Columns (1), (2), and (3) show that the MTU led to a statistically and economically significant decrease in retail margins and that this effect grew over time. Considering data until June 2014, we find that the MTU decreased retail margins by 0.38 Eurocent. This effect increases to 0.89 Eurocent if we consider the period until September 2014 and 1.63 Eurocent if we go until December 2014.

These results suggest a slow onset of the effect of the MTU, which becomes stronger over time. The findings are in line with evidence on the evolution of monthly page impressions for three smartphone applications presented in Appendix B.1. Although the applications already had a combined number of 9 million monthly page impressions in April 2014, this increased to more than 70 million monthly page impressions in December 2014.[33]

Columns (4), (5) and (6) shows the results for the Donut-DiD regression, using only the sub-sample of petrol stations 20 to 40 km away from the Franco-German border.[34] As expected, the absolute value of the coefficients is larger comparing the results to those in Columns (1) to (3). As explained before, this is likely due to idiosyncratic changes in retail margins, which are

[33]Monthly page impression data for the smartphone applications is only available starting in April 2014.
[34]The results are robust to changes to the distance thresholds. We provide estimates for alternative thresholds in Appendix C.1.

independent of the MTU and the treatment and control groups, but add random noise to the data and thus lead to an underestimation of the absolute value of the treatment effect.

Overall, the results suggest that mandatory price disclosure led to a significant and persistent decrease in average retail margins in Germany. Considering that retail margins in Germany were 7.9 Eurocent on average during our observation period, the estimated effects of the MTU are economically significant. If we assume that the true treatment effect is approximately 1 Eurocent, which is around the middle of the range of our estimated coefficients, this would mean that the MTU led to a decrease in retail margins of 13 percent.

6 Mechanisms

Our main interest lies in understanding what determines whether mandatory price disclosure is beneficial for consumers or not. The theoretical model in Section 3 showed that two factors drive the effect of mandatory price disclosure: The number of consumers adopting the information from mandatory price disclosure and the share of consumers that are already informed about prices before the information shock. In the following, we provide evidence on these mechanisms.

6.1 Effect of a Follow-On Shock to Price Transparency of Consumers

Using local radio reports about petrol prices, we study empirically how follow-on information campaigns affect retail margins. A few months after mandatory price disclosure was introduced, some local radio stations started broadcasting the lowest petrol prices in their reception area. Although only some consumers adopted the information of the MTU directly, it is reasonable to assume that producers immediately adopted the available price information. Thus, local radio reports affect the information sets of consumers, but not producers and can be considered as pure shocks to consumer transparency, ϕ.

Petrol prices are an often discussed topic amongst drivers, of which many listen to local radio stations on their daily commute. Petrol prices have therefore always been a recurring segment for local radio stations, but only after the introduction of the MTU did they have a tool to view the distribution of petrol prices in their reception area at low cost. Some of these radio stations, therefore, started diffusing the cheapest petrol stations in their reception area and their respective prices several times a day. Although for some listeners the listed stations might not be sufficiently close by, the broadcasts nevertheless inform them about the current lower end of the price distribution in their region.

To estimate the effect of local radio reports on petrol prices, we collected information for all radio stations in Bavaria whether they started regular broadcasts of petrol prices after the

introduction of the MTU and which petrol stations lie within their reception area.[35] We identify four radio stations that reported the lowest petrol prices in their reception area regularly. Two of these radio stations allowed listeners to call in petrol prices before the MTU and then reported the lowest called in prices. We exclude all petrol stations in their reception areas from the analysis, as they are treated throughout the observation period. Using a DiD framework, we estimate the following fixed effects regression model:

$$Y_{it} = \beta_0 + \beta_1 Radio_{it} + \mu_i + \gamma_t + \epsilon_{it} \tag{6}$$

where Y_{it} corresponds to the retail margin of station i at time t and $Radio_{it}$ is a dummy equal to one, if petrol station i lies in the reception area of a radio station broadcasting local petrol prices at date t. μ_i are petrol station fixed effects, and γ_t are date fixed effects.

Since we only have information on radio reports in Bavaria, we restrict our analysis to petrol stations in Bavaria. We can thus exclude that petrol stations in the control group are affected by reports of radio stations we have not surveyed. We restrict our analysis to the period October 2013 until September 2014, which is the twelve months after the beginning of the test phase of the MTU.

To estimate the causal effects of radio reports on retail margins, we need to ensure that there are no spillovers of radio reports onto petrol stations in the control group and that the decision of radio stations to report was not because they anticipated evolutions in their local market that would also affect petrol prices. As we will see below, radio stations starting reports about petrol prices in Bavaria are located in urban areas. Although we control for differences in levels between the petrol stations using petrol station fixed effects, we are only estimating an average treatment effect on the treated.

There are two possibilities which could lead to spillover effects between the treatment and control groups: Firstly, motorists outside of the reception area of the radio station could listen to the radio station via the internet. Secondly, commuters driving through the reception area of the radio station could update their information set by listening to the broadcasts and change their behaviour accordingly after leaving the reception area. Both of these threats to identification are unlikely to be strong. Radio stations were still predominantly listened to via short-wave in 2013 and 2014. In particular, in more rural areas, mobile internet reception was still weak, making it difficult to listen to radio via the internet when on the road. Furthermore, although commuters learn something about the distribution of prices by listening to the radio, which may still be valuable outside the reception area, the value of this information is likely

[35] We define "regularly" as at least once a day over a period of more than a month.

decreasing with distance to the reception area. In any event, both of these stories would mean that petrol stations in the control group may also partially be affected by the treatment and would thus lead us to underestimate the treatment effect.

Another potential threat to identification could be that radio stations anticipated a trend that would create local demand for reports about petrol prices and that also affected petrol prices. This seems unlikely for two reasons: Firstly, after multiple interviews, we learned from programme directors that the decision of broadcasting petrol prices was not based on a market analysis, but rather made based on the fit of such a segment to the existing programme. Secondly, to bias our estimates, the shock affecting the programming decision and petrol prices would need to be present in the treatment, but not in the control period. However, the timing of including petrol price reports into the programme was driven by the exogenous availability of such information due to the MTU. The reports did not start immediately after the MTU was introduced, since there was a certain lag until radio stations were familiar with the MTU data and took a programming decision.

We now turn to the radio stations that define our treatment group. We consider radio reports about petrol prices by *Extra-Radio*, which broadcasts in and around Hof, a city in North-Eastern Bavaria, close to the Czech border, and *Radio Arabella*, which is a radio station broadcasting in and around Munich. Whereas *Extra-Radio* broadcasted the lowest petrol prices in its reception area daily between 2 February 2014 and 5 March 2017, *Radio Arabella* started reporting the lowest prices several times a day on 25 April 2014 and reports are still ongoing at the time of writing.

Similar to our discussion in Section 5, the presence of a country border is important. In particular, the reception area of *Extra-Radio* is very close to the border with the Czech Republic, the focal city Hof being less than 10 km away from the border. Since Germany and the Czech Republic are both members of the Schengen Area, there are no border controls and shopping in the neighbouring country is frequent. Due to lower taxes and levies on petrol, petrol prices are consistently 20 Eurocent lower in the Czech Republic. It therefore seems plausible that independent of price reports by radio stations or the MTU, price-sensitive shoppers always buy petrol in the Czech Republic, whereas only inelastic consumers buy from petrol stations treated by *Extra-Radio*. We would therefore expect that reports by *Extra-Radio* have little to no effect on retail margins. To test this hypothesis and disentangle heterogeneities in the treatment effect on stations in the reception areas of *Extra-Radio* and *Radio Arabella*, we estimate the regression model for both radio stations separately. In each of these regressions we exclude petrol stations within the reception area of the other radio station from treatment and control group.

Table 3: The Effect of Radio Reports on Retail Margins

Treatment Group:	Both	Extra-Radio	Radio Arabella
Radio Reports	-0.42***	0.56	-0.56***
	(0.08)	(0.35)	(0.05)
Date Fixed Effects	*Yes*	*Yes*	*Yes*
Station Fixed Effects	*Yes*	*Yes*	*Yes*
Observations	516,417	455,802	502,270
Adjusted R^2	0.130	0.128	0.132
Mean Retail Margin	6.54	6.65	6.51

Notes: Column (1) compares retail margins of petrol stations in the reception areas of *Radio Arabella* and *Extra-Radio* to retail margins of other petrol stations in Bavaria before and after the beginning of petrol price reports. Column (2) compares the retail margins of petrol stations in the reception area of *Extra-Radio* to retail margins of other petrol stations in Bavaria before and after the beginning of petrol price reports. Column (3) compares the retail margins of petrol stations in the reception area of *Radio Arabella* to retail margins of other petrol stations in Bavaria before and after the beginning of petrol price reports. Standard errors are in parentheses.
SEs are clustered at petrol station level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3 shows the results from the regression analysis. The regression in Column (1) classifies petrol stations in the reception area of *Extra-Radio* and *Radio Arabella* as treated. Using this identification strategy, we find that radio reports on average decreased retail margins by 0.4 Eurocent. This effect is statistically significant at the 1 percent level. Columns (2) and (3) show the results of regressions only classifying petrol stations in the reception areas of *Extra-Radio* and *Radio Arabella* respectively as treated. For *Extra-Radio* we find a positive coefficient, but which is statistically indistinguishable from zero. For *Radio Arabella*, we find a statistically significant decrease in retail margins of 0.5 Eurocent. This suggests that, as expected, consumers and petrol stations in the reception area of *Extra-Radio* did not react to radio broadcasts of petrol prices, whereas consumers and petrol stations in the reception area of *Radio Arabella* did.

6.2 The Role of Ex Ante Informed Consumers

The second result of our theoretical framework is that the share of ex ante informed consumers plays an important role in whether a marginal increase in transparency makes collusive behaviour more or less profitable. In particular, we found that there is a U-shaped relationship between consumer transparency and the profitability of collusive behaviour. At the same time, increasing producer transparency always makes collusive behaviour more profitable.

The increase in transparency induced by the MTU is not marginal. This is noteworthy,

because if for a particular station a high share of consumers is already informed ex ante, this can mean that the intensity of the treatment (i.e. the number of consumers that become informed through the MTU) is lower. For stations with very high levels of ex ante consumer transparency we thus expect that the magnitude of the effect of an increase in consumer transparency is lower.

An important empirical challenge is how to measure the share of informed consumers among potential customers of a petrol station. We address this by following Pennerstorfer et al. (2017), and use the share of commuters among potential customers of a petrol station as the share of ex ante informed consumers in the market. The underlying assumption is that out-of-municipality commuters are perfectly informed about prices of petrol stations along their daily way to work, whereas motorists that live in a municipality, but do not commute outside of their municipality, are uninformed potential customers of petrol stations in their municipality.

In an ideal scenario, we would re-estimate our regression model in Section 5 and introduce interactions between the MTU introduction and the share of commuters. Unfortunately, we do not have commuter data for France and must thus resort to an alternative identification strategy. To this end, we exploit the daily price cycles and consumption patterns to identify times of the day which are treated by the introduction of mandatory price disclosure and others that are not.

Price cycles with low demand and high prices in the morning and high demand and low prices in the late afternoon suggest that petrol stations are practising third-degree price differentiation using intertemporal differences in price.[36] In the morning, the demand for petrol is low and inelastic, because most motorists are on their way to work and have little time to spare to shop for petrol. They therefore only buy petrol if it is absolutely necessary. In contrast, in the late afternoon, motorists are on their way back from work, have more time to fuel and shop for low prices and demand is thus higher and more elastic. A profit maximising oligopolist that can charge different groups different prices would charge the low elasticity group a higher price. In our case, the different groups are consumers buying petrol at different times of the day. We should thus observe higher prices in the morning than in the late afternoon if consumers in the morning react less elastically to price changes. This is in line with the data and reinforces the belief that demand in the morning is less elastic than in the afternoon.[37] From this, we derive our identifying assumption that retail margins at 9 am are not affected by the introduction of the MTU, whereas retail margins at 5 pm are, and thus can serve as a control group.

We thus estimate the effect that mandatory price disclosure had on petrol prices at 5

[36] Figures 8 and 9 in Appendix B.1 describe daily fuelling patterns and price patterns.

[37] Holmes (1989) extends the literature on third-degree price discrimination from the monopoly to the oligopoly case and shows that oligopolists would also want to engage in such behaviour.

pm using this alternative identification strategy. Doing so also allows us to check whether the estimated effect is in line with the results in Section 5. Specifically, we estimate the following fixed effects regression:

$$Y_{ith} = \beta_0 + \beta_1 MTU_{th} + \mu_{ih} + \gamma_t + \epsilon_{ith} \tag{7}$$

where Y_{ith} corresponds to the retail margin of station i at date t at hour h and MTU_{th} is a dummy equal to one, if petrol stations have to report prices to the MTU at date t and the price under consideration is reported at 5 pm. μ_{ih} are petrol station-hour fixed effects, and γ_t are date fixed effects.

To estimate heterogeneities in the treatment effect driven by differences in the ex ante share of informed consumers, we interact the treatment effect with the share of commuters among potential customers of a station. To allow for a more flexible relationship, we interact the treatment effect with a first- and second-order polynomial of the commuter share measure. We hence estimate the following model:

$$Y_{ith} = \alpha_0 + \alpha_1 MTU_{th} * commuters_i + \alpha_2 MTU_{th} * commuters_i^2 + \mu_{ih} + \gamma_t + \epsilon_{ith} \tag{8}$$

where all variables except $commuters_i$ are specified as in Equation 7. We use two different measures for $commuters_i$: Firstly, the share of commuters among potential customers of a petrol station and secondly, the percentile of the petrol station on the distribution of the share of commuters across stations.

Table 4 contains the results of the different regression models. In Column (1), we see that splitting treatment and control group according to the time of day, we estimate that the effect of mandatory price disclosure on retail margins is 1.8 Eurocent. It is possible that our estimate is slightly upward biased, because if some elastic consumers switched from buying fuel in the morning to buying fuel in the evening after having the additional information from the MTU, this would further decrease the absolute value of the average price elasticity of demand and thus lead to a higher optimal price in equilibrium. The estimated effect thus partially also captures a likely increase in price in the morning after the introduction of the MTU. In any event, the estimated effect of the introduction of mandatory price disclosure in Column (1) is in line with the findings in Section 5.

In Columns (2) and (3) the treatment effect is interacted with the share of commuters among potential customers of a petrol station and the percentile of the petrol station on the distribution of the share of commuters across stations, respectively. Both results show that there is a U-shaped relationship between the share of commuters and the effect of mandatory

Table 4: Retail Margins

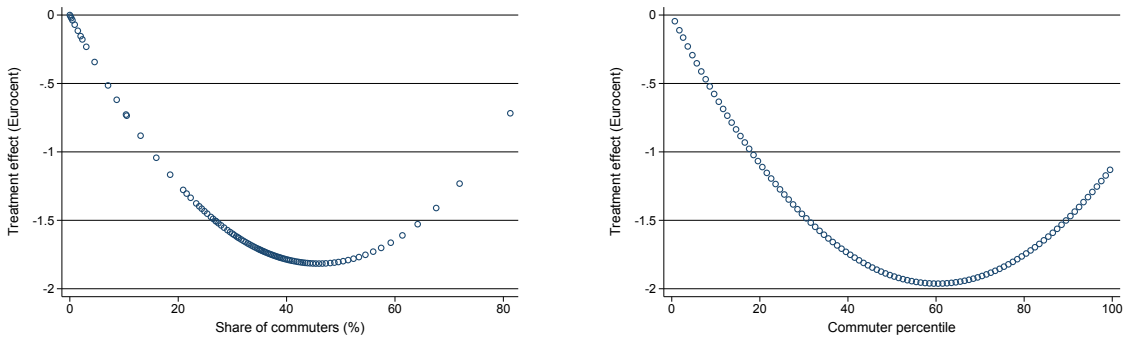
	(1)	(2)	(3)
MTU Introduction	-1.774***		
	(0.018)		
MTU × Commuter Share		-0.079***	
		(0.00)	
MTU × Sq. Comm. Share		0.001***	
		(0.000)	
MTU × Commuter Percentile			-0.065***
			(0.001)
MTU × Sq. Comm. Percentile			0.001***
			(0.000)
Date Fixed Effects	*Yes*	*Yes*	*Yes*
Station-hour Fixed Effects	*Yes*	*Yes*	*Yes*
Observations	7,884,076	7,884,076	7,884,076
Adjusted R^2	0.214	0.209	0.209
Mean Retail Margin	8.62	8.62	8.62

Notes: The test phase of the MTU (12 September 2013 until 30 November 2013) is dropped in all specifications. Column (1) considers margins at 5 pm as the treatment and margins at 9 am as the control group, using data until 30 September 2014. Column (2) interacts the treatment dummy with the share of commuters among potential customers, using data until 30 September 2014. Column (3) interacts the treatment dummy with the percentile of a petrol station on the distribution of the share of commuters among potential customers, using data until 30 September 2014.
Standard errors are in parentheses.
Standard errors clustered at petrol station level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

price disclosure on retail margins.

To illustrate this, Figure 2 plots these coefficients. The figure on the left shows that for petrol stations with a very low share of commuters the estimated treatment effect is very close to zero. For very high shares of ex ante informed consumers, the magnitude of the estimated treatment effect decreases again.

Figure 2: Treatment Effect of the MTU by Share of Commuters



Notes: The left graph plots the estimated treatment effect of the MTU depending on the percentage share of commuters of a petrol station based on the regression coefficients in Column (2) of Table 4. The right graph plots the estimated treatment effect of the MTU depending on the percentile of the commuter share distribution of a petrol station based on the regression coefficients in Column (3) of Table 4.

These findings could be explained by the theoretical model: For low levels of ex ante informed consumers the effect of increasing consumer transparency on the incentives to deviate from a collusionary agreement is strongly counteracted by the increase in severity of the punishment for deviation. For intermediate levels of ex ante informed consumers this counteracting force fades away because the punishment profits are already close to the perfectly competitive equilibrium. The absolute value of the estimated treatment effect, therefore, increases with the share of ex ante informed consumers for low to medium levels of ex ante informed consumers.

At the same time, we see that for intermediate to high levels of ex ante informed consumers the absolute value of the estimated treatment effect decreases again. A plausible explanation for this is that the share of ex ante informed consumers not only influences how the effect of increasing transparency for a given share of consumers affects prices but also how many consumers are informed by the MTU. If most potential consumers were already informed ex ante, the introduction of the MTU has a very small effect on the information set of consumers, and hence, the intensity of the treatment is low. At the same time, the intensity of the treatment of producer transparency stays constant. As can be seen in the right side of Figure 2, around 65 percent of stations are in the range where the magnitude of the estimated treatment effect of the MTU increases in the share of ex ante informed consumers.

7 Discussion and Policy Implications

The results in Section 5 show that mandatory price disclosure, through the introduction of the MTU, was beneficial to consumers in the German retail petrol market. This need not always be the case. For example, Luco (2019) showed that mandatory price disclosure in the Chilean petrol industry lead to an increase in retail margins by 9 percent.

Our main estimation strategy relies on a cross-country comparison of retail margins at petrol prices in Germany and France to causally estimate the average effect of mandatory price disclosure. Although it is unlikely that any transitory shocks are different in Germany and France and may thus bias our results, our data allows us to relax this assumption. First, by restricting our sample to petrol stations around the Franco-German border and second, by comparing retail margins for the same petrol stations in Germany in the morning and the evening. All of our results are consistent with our initial findings.

Finding that mandatory price disclosure in the retail petrol industry can be beneficial to consumers is good news for policymakers. Since there is uncertainty about the effect, a way forward could be to accompany the implementation of mandatory price disclosure with rigorous data collection and ex post evaluation. If it is found that prices increased as a result, mandatory price disclosure can then be taken back again. Albæk et al. (1997) discuss a case in the Danish ready-mixed concrete industry, where the Danish antitrust authority decided to gather and publish firm-specific transaction prices, after which average prices increased by 15-20 percent within one year and the antitrust authority decided to stop this practice again. Ideally, however, policymakers should be able to assess ex ante whether introducing mandatory price disclosure in the particular case under consideration is beneficial to consumers or not. The differences in our results and results in the previous literature highlight the importance of understanding when mandatory price disclosure is beneficial to consumers and when it is likely harmful. There are several insights that we can derive from our theoretical framework in Section 3 to answer this question and for which we provide empirical evidence.

Firstly, holding everything else equal, increasing transparency among producers is anti-competitive, because it facilitates collusive behaviour. Policymakers should therefore assess the level of information of producers before mandatory price disclosure. If this is already very high ex ante, then mandatory price disclosure is unlikely to harm consumers further through this channel. If producer information is low ex ante, then mandatory price disclosure could potentially lead to higher prices. This may also be an important reason for the difference in results found by Luco (2019) for Chile and in our analysis for Germany. Whereas he notes, that mandatory price disclosure likely improved the information set of producers significantly, there

is a lot of evidence suggesting that producers were already well informed before the introduction of the MTU.[38]

Secondly, the share of ex ante informed consumers matters for the size and direction of the treatment effect and in some cases a marginal increase in consumer information can be anti-competitive, even if producers are already perfectly informed. The results from our commuter analysis suggest that for petrol stations with a very low share of ex ante perfectly informed consumers the treatment effect is close to zero. For petrol stations with a medium level of ex ante informed consumers it is close to a reduction in retail margins of 1.9 Eurocent and for very high levels of ex ante informed consumers it is around 0.8 Eurocent. This is consistent with the model, which suggests that the marginal treatment effect increases in the share of ex ante informed consumers. Since our treatment is not marginal, however, and since there is a maximum limit as to how many people can be informed, the treatment size, and thus the treatment effect, decreases at the upper end of the distribution of the share of ex ante informed consumers of a petrol station. Policymakers should therefore consider the level of consumer information before mandating price disclosure.

Thirdly, if a marginal increase in the informedness of consumers is pro-competitive, then a large increase in their level of information will benefit consumers even more. Evidence in Section 6 suggests that strengthening the information shock to consumers, by further defusing price information via local radio reports can lead to a significant strengthening of the pro-competitive effects of mandatory price disclosure. Similarly, the different take-up of the information from mandatory price disclosure in Chile and Germany may also account for the differential effects. While Luco (2019) notes that the nation-wide median number of daily visits to the website listing petrol prices in Chile was only 947, in Germany more than 50 price comparison apps and websites are currently active, not counting many more apps and websites embedding these comparison platforms in their content. Although it is impossible to obtain an overall estimate of the usage of this data, we show in Appendix B that the three smartphone applications for which we have data on monthly page impressions already had a combined number of more than 70 million monthly users in December 2014. This suggests that information adoption, and thus the shock to consumer information, was significantly stronger in Germany. Finding that mandatory price disclosure was pro-competitive in Germany, but anti-competitive in Chile is thus in line with our theoretical predictions. If policymakers believe that mandatory price disclosure is beneficial, they should accompany it with public information campaigns, to fully reap the pro-competitive effects.

[38] This is discussed in depth by the GFCO (2011).

8 Conclusion

As we have shown for the case of the MTU in Germany, introducing mandatory price disclosure in homogeneous goods markets can be beneficial to consumers. By disentangling the mechanisms, both theoretically and empirically, we have also shown, that this is not a one-size-fits-all solution to remedy competition concerns in markets with informational frictions. Under certain conditions mandatory price disclosure has a pro-competitive effect, whereas under other conditions its effect is anti-competitive.

Based on our analysis, we offer two recommendations for policymakers: Before deciding whether to mandate price disclosure, policymakers should assess the level of ex ante producer transparency and the ease of informing consumers. If they decide to mandate price disclosure, they should not only make price information available, but also push for large-scale adoption by consumers – for example, through consumer information campaigns.

Future research should develop further methods which allow policymakers to assess the effect of mandatory price disclosure before introducing the policy.

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Appendix

A Theoretical Model

A.1 Static Equilibrium

Since all firms are symmetric, we solve the static game by looking for the symmetric Nash-equilibrium in mixed strategies. As we will see, the solution fulfilling the equilibrium conditions is unique.

Using an optimal stopping rule, the reservation price is such that the marginal gain of search for non-shoppers equals their marginal cost and must therefore solve:

$$\int_{\underline{p}}^{p_r} (p_r - p) dG(p) = s\,. \tag{9}$$

It is increasing in s, because the higher the incremental search cost, the higher is the price above which it is not profitable for non-shoppers to engage in sequential search.

Non-shoppers are homogeneous in their valuation of the good and search costs and therefore have the same reservation price. Since sellers never choose a price above the reservation price, non-shoppers never search in equilibrium and always go to the shop they know the price of already.[39]

To derive the equilibrium price distribution $G(p)$, we take advantage of the equiprofit condition, by which in a Nash equilibrium, all prices that are played with positive probability must yield the same expected profit. Shoppers will always buy at the cheapest firm, whereas non-shoppers buy at the firm they randomly draw a price from. The probability that a firm setting price p_i attracts shoppers is $(1 - G(p_i))^{n-1}$, which is the probability that all other firms set a higher price than firm i.[40] The expected profit of firm i is therefore:

$$\pi_i = \Big(\phi(1 - G(p_i))^{n-1} + \frac{1-\phi}{n}\Big) p_i \xi\,. \tag{10}$$

The first part of the equation is the sum of the share of shoppers in the population multiplied by the probability that firm i attracts these shoppers and the share of non-shoppers in the population divided by the number of firms (i.e. the share of non-shoppers shopping at firm i). This is multiplied by the market size ξ and the price chosen by firm i. For firms selling at the

[39] To avoid situations in which the reservation price is higher than the valuation of the product by consumers v, we assume that the search cost s is sufficiently low.

[40] Note, that since prices are continuously distributed and the distribution has no mass point, the probability of two firms setting exactly the same price and sharing shoppers is zero.

reservation price p_r this boils down to $\pi(p_r) = p_r \frac{1-\phi}{n}\xi$, because the probability that no other firm chooses a lower price is zero and thus $G(p_r) = 1$.

Since by the equiprofit condition the expected profits of firm i have to constant for all prices it chooses with positive probability, in equilibrium $\pi(p) = \pi(p_r)$. Solving this equation for the distribution of prices yields:

$$G(p) = 1 - \Big(\frac{(p_r - p)(1-\phi)}{np\phi}\Big)^{\frac{1}{n-1}} . \tag{11}$$

Finally, we can also use the equiprofit condition to derive the lower-bound price $\underline{p}$. Expected profits of charging p_r or $\underline{p}$ must, again, be equal. This time we can exploit the fact that the likelihood that any firm chooses a price below the lower-bound price is zero and thus the likelihood that a firm charging $\underline{p}$ attracts all shoppers is $G(\underline{p}) = 1$. Setting $\pi(\underline{p}) = \pi(p_r)$ and solving for $\underline{p}$ yields:

$$\underline{p} = \frac{p_r(1-\phi)}{1 + (n-1)\phi} . \tag{12}$$

The competitive profit π^* in the dynamic model is therefore the expression in Equation 10, where p_i is drawn from a distribution $G(p)$ over the domain $[\underline{p}, p_r]$. $G(p)$, $\underline{p}$ and p_r are the unique solution to Equations 9, 11 and 12. Together, the optimal stopping rule of non-shoppers and the equiprofit conditions are thus sufficient to characterize the unique equilibrium of the one-shot Nash equilibrium game.

A.2 Proof of Propositions

Proof of Proposition 1. Producer transparency is modelled as the likelihood that a deviation from the collusionary agreement is detected by rivals. η does not enter the profit function and only increases the likelihood of entering a punishment phase in the next period if the firm deviates. It hence follows that increasing transparency on the producer side always fosters collusive behaviour:

$$\frac{\partial \underline{\delta}}{\partial \eta} = -\frac{\pi^c - \pi^*}{(\pi^d - \eta\pi^* - (1-\eta)\pi^c)^2} < 0 . \tag{13}$$

□

Proof of Proposition 2. In a first step, we differentiate the critical discount factor with respect to ϕ and get:

$$\frac{d\underline{\delta}}{d\phi} = \frac{(\frac{\partial \pi^d}{\partial \phi} - \frac{\partial \pi^c}{\partial \phi})(\pi^d - \eta\pi^* - (1-\eta)\pi^c) - (\frac{\partial \pi^d}{\partial \phi} - \eta\frac{\partial \pi^*}{\partial \phi} - (1-\eta)\frac{\partial \pi^c}{\partial \phi})(\pi^d - \pi^c)}{(\pi^d - \eta\pi^* - (1-\eta)\pi^c)^2} . \tag{14}$$

To prove Proposition 2, we need to determine the sign of Equation 14. Since the denominator is always positive, we can focus our attention on the numerator. After some simplifications the numerator becomes:

$$\Big[\frac{\partial \pi^d}{\partial \phi}(\pi^c - \pi^*) + \frac{\partial \pi^*}{\partial \phi}(\pi^d - \pi^c)\Big]\eta\,. \tag{15}$$

We focus on the case where $\eta > 0$, i.e. a deviation from the collusive price is observed by rivals with a strictly positive probability. If this was not the case, then increasing the share of shoppers ϕ would have no effect on the critical discount factor. With $\eta > 0$, we do not need to consider η further to determine the sign of Equation 15. Instead, we analyse the rest of the expression, which becomes:

$$\begin{aligned} \frac{\partial \pi^d}{\partial \phi}(\pi^c - \pi^*) + \frac{\partial \pi^*}{\partial \phi}(\pi^d - \pi^c) = \\ \upsilon\xi^2\Big(1 - \frac{1}{n}\Big)\Big(\frac{\upsilon}{n} - \frac{p_r(1-\phi)}{n}\Big) + \upsilon\xi^2\Big(\frac{\partial p_r}{\partial \phi}\frac{1-\phi}{n} - \frac{p_r}{n}\Big)\Big(\phi - \frac{\phi}{n}\Big) = \\ \frac{\upsilon\xi^2}{n^2}(n-1)\Big[\upsilon - p_r + \frac{\partial p_r}{\partial \phi}(1-\phi)\phi\Big]\,. \end{aligned} \tag{16}$$

To determine the sign of this expression, we need an expression for the reservation price and its derivative with respect to the share of shoppers ϕ.[41] In equilibrium, Equation 9 becomes:

$$\frac{1}{n-1}\Big(\frac{1-\phi}{n\phi}\Big)^{\frac{1}{n-1}}\int_{\frac{p_r(1-\phi)}{1+(n-1)\phi}}^{p_r}\Big(\frac{p_r}{p} - 1\Big)^{\frac{1}{n-1}}\frac{p_r}{p}dp = \frac{1}{n-1}\Big(\frac{1-\phi}{n\phi}\Big)^{\frac{1}{n-1}}p_r\int_{\frac{1(1-\phi)}{1+(n-1)\phi}}^{1}\Big(\frac{1}{t} - 1\Big)^{\frac{1}{n-1}}\frac{1}{t}dt\,. \tag{17}$$

If $n = 2$, then Equation 18 simplifies to:

$$\frac{1-\phi}{2\phi}p_r\int_{\frac{1-\phi}{1+\phi}}^{1}\Big(\frac{1}{t} - 1\Big)\frac{1}{t}dt = p_r\Big(\frac{1-\phi}{2\phi}ln\Big(\frac{1-\phi}{1+\phi}\Big) + 1\Big) = s\,. \tag{18}$$

The reservation price therefore becomes:

$$p_r = s\Big(\frac{1-\phi}{2\phi}ln\Big(\frac{1-\phi}{1+\phi}\Big) + 1\Big)^{-1}\,, \tag{19}$$

and the derivative of the reservation price with respect to the share of shoppers is:

$$\frac{\partial p_r}{\partial \phi} = s\Big(\frac{1-\phi}{2\phi}ln\Big(\frac{1-\phi}{1+\phi}\Big) + 1\Big)^{-2} \times \Big(\frac{2\phi + (\phi+1)ln(\frac{1-\phi}{1+\phi})}{2\phi^2(\phi+1)}\Big)\,. \tag{20}$$

We can furthermore show that the reservation price decreases in the share of shoppers.

[41] The remainder of the proof closely follows Petrikaite (2016).

The search cost s, the first bracket and the denominator of the second bracket are always positive. Furthermore, we can show that the derivative of $2\phi + (\phi+1)ln(\frac{1-\phi}{1+\phi})$ with respect to ϕ is negative:

$$-\frac{2\phi - (\phi-1)ln(\frac{1-\phi}{1+\phi})}{1-\phi} < 0\,. \tag{21}$$

Therefore, since ϕ is defined on the domain $[0,1]$

$$2\phi + (\phi+1)ln\Big(\frac{1-\phi}{1+\phi}\Big) \leq \lim_{\phi\to 0}\Big(2\phi + (\phi+1)ln\Big(\frac{1-\phi}{1+\phi}\Big)\Big) = 0\,, \tag{22}$$

and the derivative $\frac{\partial p_r}{\partial \phi}$ is always negative.

Next, we plug the expression for $\frac{\partial p_r}{\partial \phi}$ and s into Equation 18, set $n = 2$ and multiply everything by $\frac{4}{\upsilon}$. As a result we obtain the following expression:

$$\begin{gathered} \upsilon - p_r + \Bigg(\frac{\frac{2\phi+(\phi+1)ln(\frac{1-\phi}{1+\phi})}{2\phi^2(\phi+1)}}{\frac{1-\phi}{2\phi}ln(\frac{1-\phi}{1+\phi})+1}\Bigg)(1-\phi)p_r = \\ \upsilon - p_r\frac{4\phi^2}{(1+\phi)((1-\phi)ln(\frac{1-\phi}{1+\phi})+2\phi)}\,. \end{gathered} \tag{23}$$

In line with Proposition 2, we now show that the sign of this expression depends on ϕ. As shown above, $\frac{\partial p_r}{\partial \phi}$ is always negative. Furthermore

$$\frac{\partial}{\partial\phi}\Big(\frac{4\phi^2}{(1+\phi)((1-\phi)ln(\frac{1-\phi}{1+\phi})+2\phi)}\Big) = \frac{8\phi(2\phi+ln(\frac{1-\phi}{1+\phi}))}{(1+\phi)^2((1-\phi)ln(\frac{1-\phi}{1+\phi})+2\phi)^2} < 0\,, \tag{24}$$

where the inequality is obtained from the fact that

$$\frac{\partial}{\partial\phi}\Big(2\phi + ln\Big(\frac{1-\phi}{1+\phi}\Big)\Big) = 2 - \frac{2}{1-\phi^2} < 0 \tag{25}$$

and thus since ϕ is defined on the domain $[0,1]$

$$2\phi + ln\Big(\frac{1-\phi}{1+\phi}\Big) \leq \lim_{\phi\to 0}\Big(2\phi + ln\Big(\frac{1-\phi}{1+\phi}\Big)\Big) = 0\,. \tag{26}$$

We can therefore conclude that Equation 23 increases in ϕ. By replacing p_r by its value,

we can analyse how the second part of Equation 23 behaves in the limits of ϕ:

$$\lim_{\phi \to 0} \Big(p_r \frac{4\phi^2}{(1+\phi)((1-\phi) ln(\frac{1-\phi}{1+\phi}) + 2\phi)} \Big) = \infty \tag{27}$$

$$\lim_{\phi \to 1} \Big(p_r \frac{4\phi^2}{(1+\phi)((1-\phi) ln(\frac{1-\phi}{1+\phi}) + 2\phi)} \Big) = s \,. \tag{28}$$

Since we assume that the search cost $s \leq p_r$, this means that

$$s \leq \int_{\underline{p}(\upsilon)}^{\upsilon} (\upsilon - p) dG(p) \,. \tag{29}$$

Analogous to the steps to obtain Equation 18, for $n = 2$ this inequality simplifies to

$$s \leq \Big(\frac{1-\phi}{2\phi} ln\Big(\frac{1-\phi}{\phi+1} \Big) + 1 \Big) < \upsilon \,. \tag{30}$$

Since $s < \upsilon$, the derivative of the critical discount factor with respect to the share of shoppers ϕ is negative for values of $\phi \leq \bar{\phi}$ and positive for values of $\phi > \bar{\phi}$.

□

Proof of Proposition 3. The effect of a change in α on the profitability of engaging in collusive behaviour can be decomposed in the following way:

$$\frac{d\underline{\delta}}{d\alpha} = \frac{\partial \underline{\delta}}{\partial \eta} \frac{\partial \eta}{\partial \alpha} + \frac{\partial \underline{\delta}}{\partial \phi} \frac{\partial \phi}{\partial \alpha} \,. \tag{31}$$

Since a change in α increases the critical discount factor if, and only if, $\frac{d\underline{\delta}}{d\alpha} > 0$, it follows that a marginal increase in α is pro-competitive if, and only if:

$$\frac{e_{\eta,\alpha}}{e_{\phi,\alpha}} < - \frac{\frac{\partial \underline{\delta}}{\partial \phi}}{\frac{\partial \underline{\delta}}{\partial \eta}} \frac{\phi}{\eta} \,. \tag{32}$$

ϕ, η, $e_{\eta,\alpha}$ and $e_{\phi,\alpha}$ are always positive and $\frac{\partial \underline{\delta}}{\partial \eta}$ is always negative.

If $\frac{\partial \underline{\delta}}{\partial \phi} < 0$, then increasing α is anti-competitive. We showed in the proof of Proposition 2 that this is the case for $\phi \leq \bar{\phi}$.

For an increase in common information α to be pro-competitive, it is necessary that $\frac{\partial \underline{\delta}}{\partial \phi} > 0$, which is the case for $\phi \leq \bar{\phi}$. Finally, the elasticity of ϕ with respect to α must be sufficiently large compared to the elasticity of η with respect to α.

□

Table 5: Share of stations in percent by brand

	Pre-MTU	Post-MTU
Aral	20.1	18.1
Shell	14.2	14.2
Esso	5.7	5.4
Total	7.0	4.7
Jet	5.0	4.6
Orlen	4.7	4.2
Agip	2.0	3.1
Hem	3.0	2.8
OMV	2.6	2.3
Non-integrated	35.8	40.6

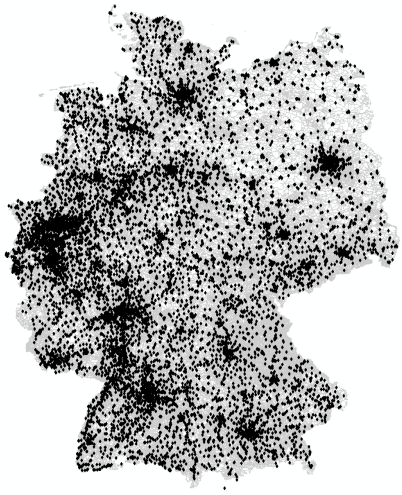
Notes: The "Pre-MTU" column shows the share of petrol stations by brand in the sample for Germany before the introduction of the MTU. The "Post-MTU" column shows the share of petrol stations by brand in the sample for Germany after the introduction of the MTU. We consider all petrol station that have at least one price entry in the sample before or after the MTU introduction, respectively.

B Data

B.1 Retail Margins and Petrol Station Characteristics

Figure 3 shows the distribution of petrol stations in Germany over our sample period. As expected, petrol stations are spread across the country and clustered around urban areas.

Figure 3: Distribution of Petrol Stations Across Germany



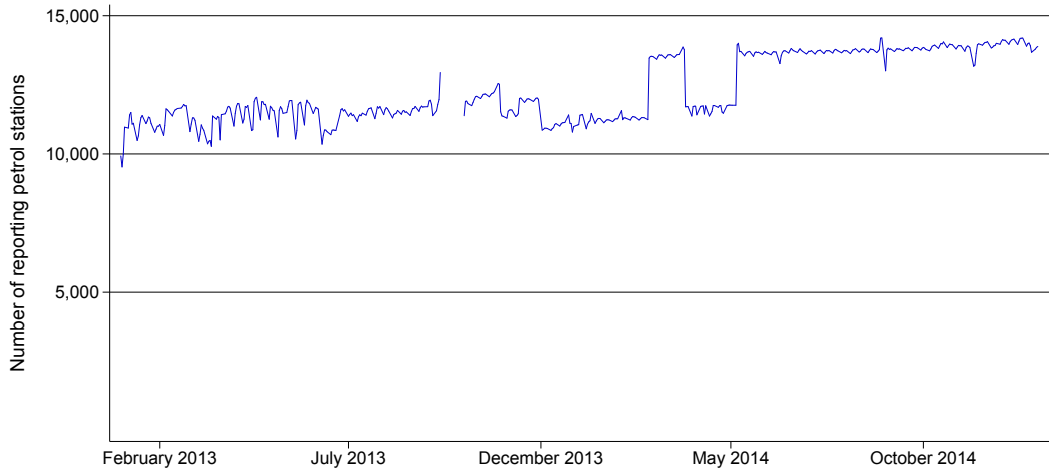
Note: The Figure shows the geographic distribution of petrol stations in Germany.

5 shows the share of the vertically integrated firms, as well as the share of non-integrated firms before and after the MTU introduction.

Figure 4 shows the daily number of petrol stations for which the price panel contains a

price entry at 5 pm. There is no structural break in the daily number of petrol stations for which there is an entry in the price panel before and after the MTU introduction. For most days in the pre-MTU period, we have prices for approximately 12,000 petrol stations in our panel. This number stays approximately the same after the introduction of the MTU and only increases to around 13,500 at the end of February 2014, when reporting issues of Total and Esso stop.[42] At any point in time over the observation period, our panel therefore includes prices for most of the approximately 14,700 petrol stations in Germany.

Figure 4: Number of petrol stations with positive price reports at 5pm



Notes: The Figure shows the average daily number of petrol stations with a positive price report at 5 pm in Germany in our sample.

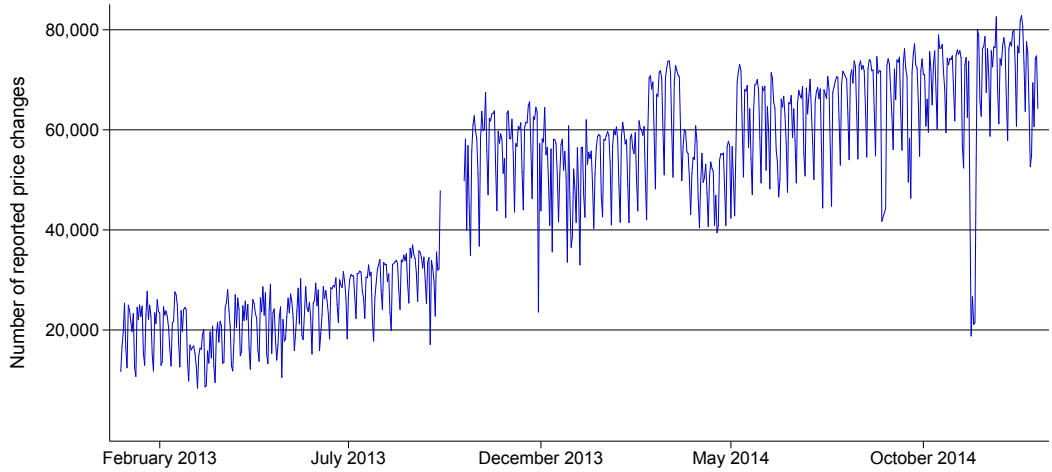
Figure 5 shows that there are fewer price changes per day in our data prior to the MTU introduction than after the MTU was introduced. This is because whereas after the introduction of the MTU we should observe the universe of price changes in Germany, before the introduction of the MTU we only observe the subset of prices that was reported by users to the app.

Figure 6 shows the number of notifications of price changes over the day, before and after the introduction of the MTU. Whereas before the introduction of the MTU there is a notification every time a user of the map notifies a price, after the MTU there is a notification every time that there is a price change.

Figure 8 shows the hourly fuelling patterns as reported in a representative survey among drivers commissioned by the German Federal Ministry of Economic Affairs. As discussed before, the majority of drivers buy fuel between 5 pm and 7 pm, whereas only very few drivers buy petrol in the morning.

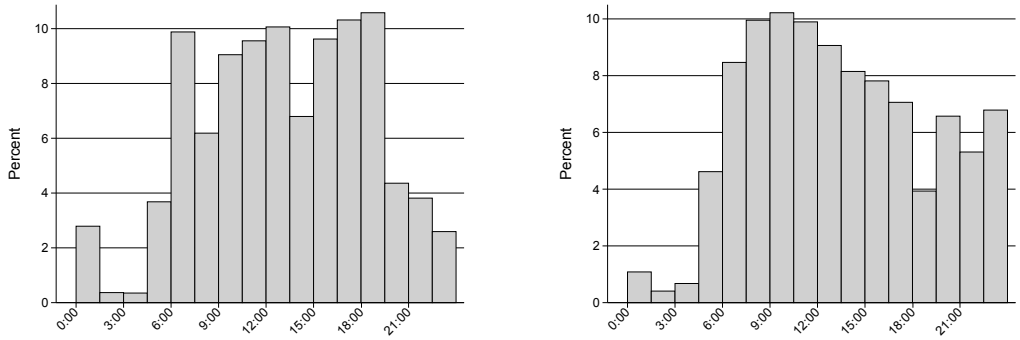
[42]Total and Esso report normally in October 2013. Esso reports only a very limited amount of prices between November 2013 and mid-February 2014. Total only reports a very limited amount of prices between December 2013 and mid-February 2014. Both experienced reporting issues in April 2014, after which they returned to full reporting.

Figure 5: Number of daily price changes



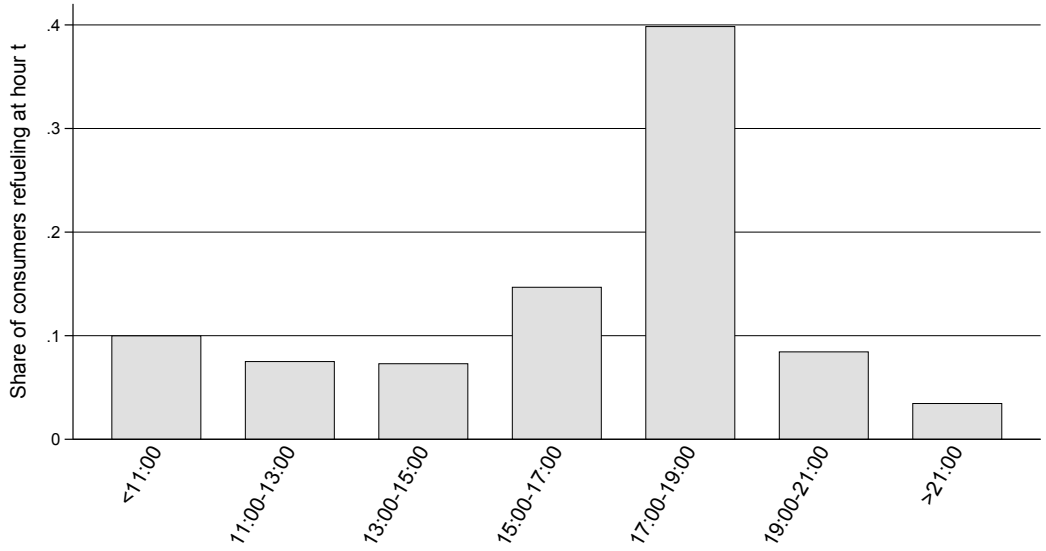
Notes: The Figure shows the average daily number of price changes in Germany in our data. In the pre-MTU period consecutive reports of the same price are not considered a price change.

Figure 6: Notification patterns over the day



Notes: Panel (a) shows the share of price notifications in our data set for every hour of the day for the pre-MTU period. Panel (b) shows the share of price notifications in our data set for every hour of the day for the post-MTU period. Pre-MTU, each price report by users notifying a price change to the information service provider is a price notification. Post-MTU, each price change notified by petrol stations to the MTU is a price notification.

Figure 8: Daily fuelling patterns

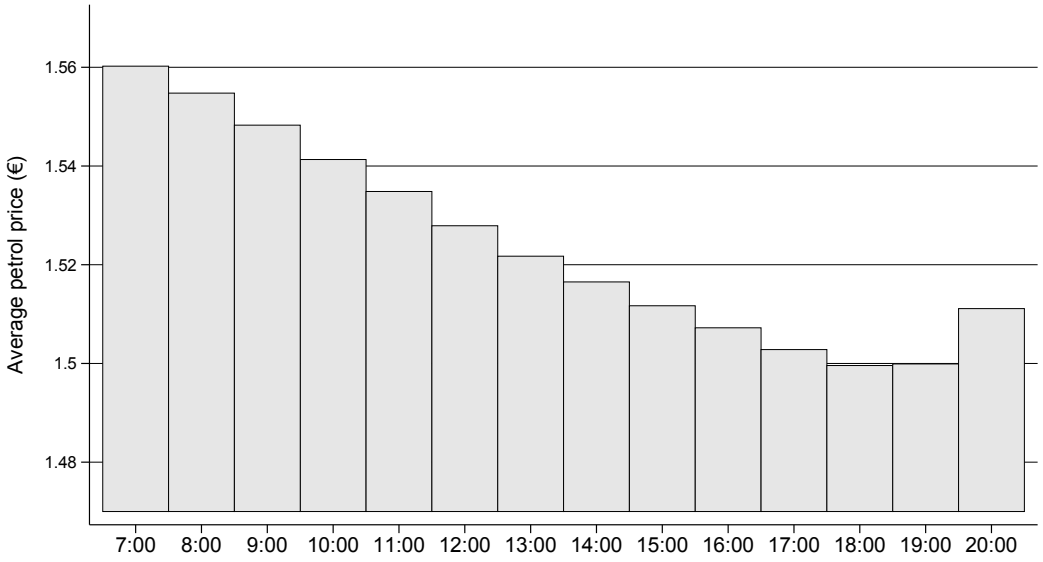


Notes: The Figure shows the average fuelling patterns by German motorists over the day. Data is based on a representative survey among drivers commissioned by the German Federal Ministry of Economic Affairs.

The fuelling patterns are also consistent with price patterns reported in Figure 9. Whereas prices are highest in the morning, they fall during the day until the early evening and start rising again at around 8 pm.

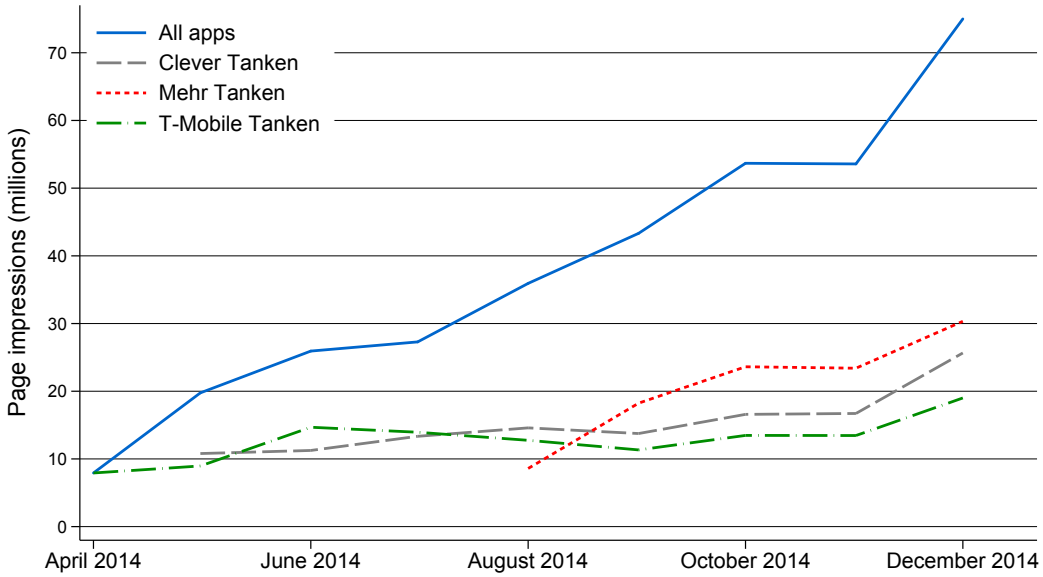
Figure 10 shows the evolution of monthly page impressions for three mobile price comparison applications for which data is available in 2014. Although these three mobile applications are only a fraction of the German mobile petrol price comparison market, they together have more than 70 million page impressions in December 2014. This shows that mobile price comparison applications were widely used by the end of 2014.

Figure 9: Daily price patterns



Notes: The Figure shows the average petrol price for every hour between 7 am and 20 pm in Germany between 2013 and 2014.

Figure 10: Monthly page impressions

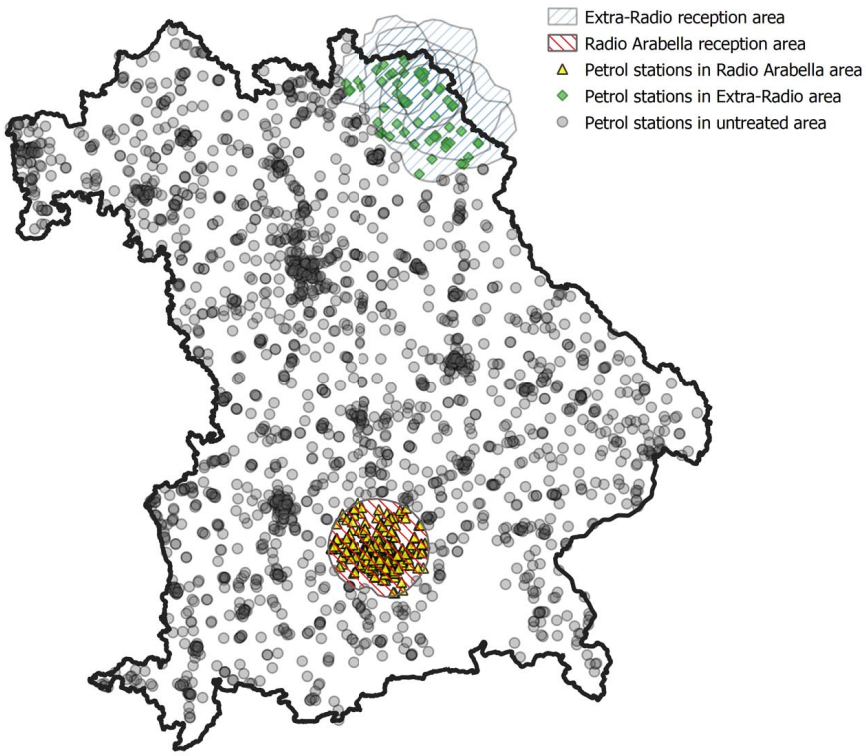


Notes: The Figure shows the evolution of monthly page impressions for three popular mobile price comparison applications. Each line begins when data for the particular app becomes available and ends at the end of our sample period, in December 2014.

B.2 Local Radio Reports of Petrol Prices

There are 381 radio stations in Germany broadcasting via short-wave out of which 83 are active in Bavaria. Among these, we identified 60 radio stations that could potentially broadcast petrol prices, which we contacted. For all of these stations, we know that there were four local radio stations that broadcasted local petrol prices (e.g. the three lowest price petrol stations in their reception area) more than once a day at some point after the MTU introduction in 2013 and 2014 and know the exact period of time of these broadcasts. We discard two of the radio stations because they already broadcasted the lowest petrol prices amongst those called in by their listeners before the MTU was introduced. The two remaining radio stations are *Radio Arabella*, which started its broadcast on 25 April 2014 and *Extra-Radio*, which started its broadcasts on 2 February 2014. We merge this information with data on the geographic availability of radio stations which we received from *fmlist.org*. Figure 11 shows the reception area of *Radio Arabella*. For each petrol station we can therefore say whether, on a particular day, it is within the reception area of a radio station broadcasting prices or not.

Figure 11: Radio reception areas and petrol stations in Bavaria



B.3 Consumer Search and Information

The commuter data from the German Federal Employment Agency includes information on how many workers live in one municipality and work in another municipality for all municipality pairs for which there are more than 3 commuters as at the 30^{th} June 2013. There were 11,197 municipalities in Germany in 2013. These are the smallest administrative unit in Germany, with a median size of $19km^2$. The centroid of a municipality is therefore a particularly good approximation of the home and work address outside of the largest cities.[43] In the following, we detail our methodology of how to compute the share of perfectly informed potential customers of a petrol station. This description broadly follows the methodology introduced by Pennerstorfer et al. (2017).

To identify whether a particular commuter drives by a petrol station, we calculate the shortest path via the road network between the centroid of the home and work municipalities using the *osrmtime* package for Stata, introduced by Huber and Rust (2016). We only keep commutes that are less than 200 km, since commutes above this threshold are unlikely to be daily commuters.

In a next step, we identify the set of petrol stations that could potentially lie on a commuter route. This step is essential in order to make the problem computationally tractable as we have $111,520$ centroid combinations with positive commuter streams and around $14,700$ petrol stations.

Firstly, using the coordinates of the two centroids of a commuting route, we identify the most Western and most Eastern longitude, as well as the most Southern and most Northern latitude of the centroids. Then, we push these boundaries 55 km further out and draw a rectangle that contains both centroids. Using the coordinates of the petrol stations, we identify which petrol stations lie within the rectangle of a particular commuter route and could thus potentially be on the commuter route.

The set of potential petrol stations within the rectangle of a commuting route can still be large. In a second step, we therefore want to reduce this set by identifying the set of stations that are closer to the linear distance line between the two centroids than the difference between the shortest path via the road network and the linear distance, plus an additional buffer of 2 km. This leaves us with a subset of petrol stations within the rectangle, which could potentially lie on the commuting route.

Finally, for the subset of stations that could potentially lie on the commuting route, we

[43] Large cities, such as Berlin or Munich, are treated as only one municipality. Municipality centroids are therefore particularly good proxy for the residence of commuters outside of these large cities.

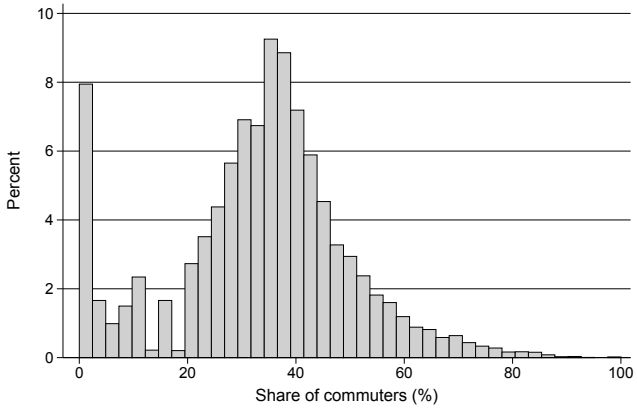
calculate the driving distance from the origin municipality to a petrol station and from the petrol station to the destination municipality. If the sum of these two routes is less than 250 m longer than the shortest driving distance between origin and destination municipality, we consider this petrol station to be on the commuting route. We then consider that the number of commuters on this commuting route therefore all drive past the respective petrol station.

We assume that out-of-municipality commuters are perfectly informed about station prices in their home and work municipalities, as well as stations outside of these municipalities, that are on their daily way to work. The number of informed consumers of a petrol station i, denoted by I_i, are hence all out-of-municipality commuters residing or working in the municipality of the station, as well as all driving past the station on their daily commute. The number of uninformed consumers, U_i, is proxied by employed individuals who do not commute outside their municipality. The share of ex ante informed consumers among potential customers of a petrol station is thus:

$$\zeta_i = \frac{I_i}{I_i + U_i} \,. \tag{33}$$

Figure 12 shows the distribution of the ex ante share of informed consumers among potential customers of a petrol station. The majority of petrol stations have a share of ex ante informed consumers of between 20 percent and 60 percent.

Figure 12: Distribution of Ex Ante Informed Consumer Share Across Stations



Notes: The Figure shows the distribution of petrol stations by the ex ante share of informed consumers. This is measured as the share of out-of-municipality commuters on 30 June 2013 as a share of all potential customers of a petrol station.

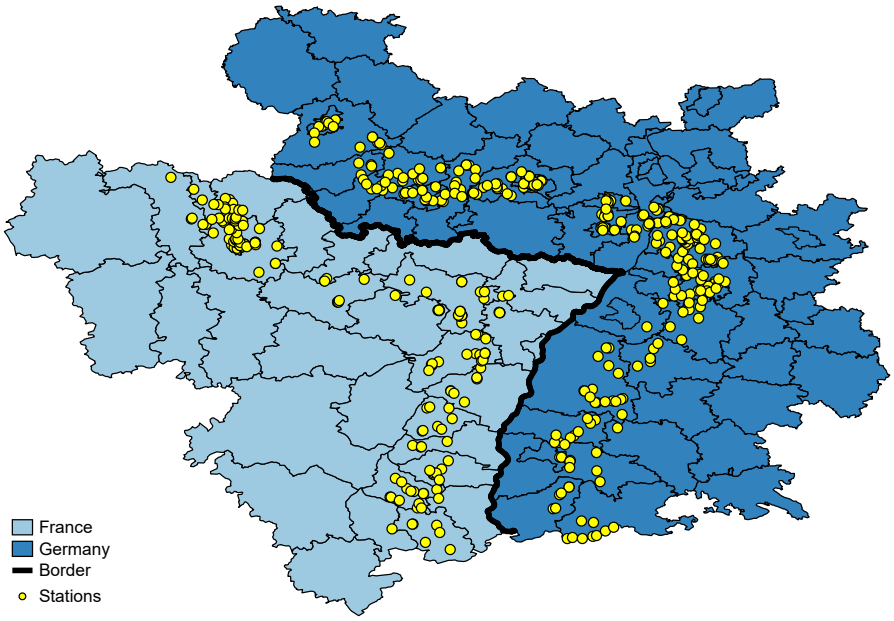
C Additional Empirical Analysis

In this Section we provide further empirical evidence on the average effect of the MTU on retail margins in Germany. They show that our results in Section 5 are robust to alternative specifications.

C.1 Donut Regression

Figure 13 shows the identification strategy for the Donut-DiD regression analysis graphically. Petrol stations that are less than 20 km away from the Franco-German border are not considered, because these could be in direct competition to each other and so spillovers of the treatment effect could occur. Petrol stations more than 40 km away from the border could be subject to very different market conditions and are thus also not considered. Each point in Figure 13 thus represents a petrol station, either in France or in Germany, which is 20 to 40 km away from the border.

Figure 13: Petrol stations 20 to 40 km from the Franco-German border



Notes: The thick, solid line represents the Franco-German border. Each point on the right of the border represents a petrol station in Germany, which is 20 to 40 km away from the border. Each point on the left side of the border represents a petrol station in France, which is 20 to 40 km away from the border. These are the petrol stations considered in our baseline Donut-DiD regression analysis.

In Table 6, we re-estimate the Donut-DiD regression for the analysis period 12 April 2013 until 30 September 2014 using different distances to the Franco-German border. We find that the results are robust to changing the distances and the average effect of the MTU introduction is always around 1 Eurocent.

Table 6: Alternative Donuts

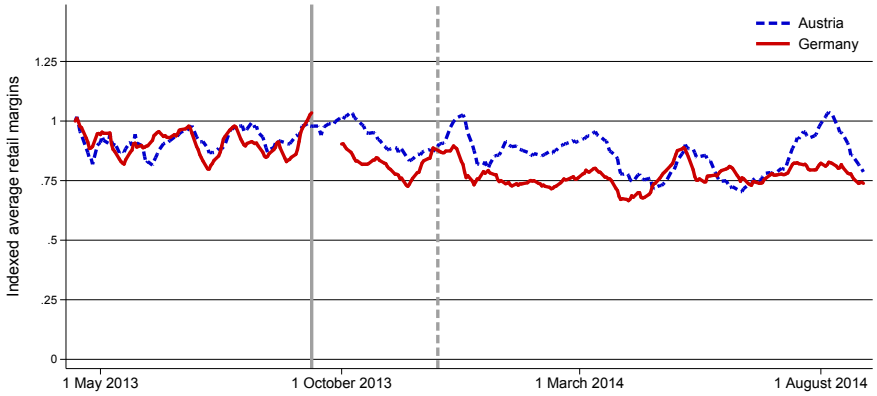
	(1)	(2)	(3)	(4)	(5)	(6)
MTU Introduction	-1.25***	-1.18***	-1.00***	-0.94***	-0.95***	-1.03***
	(0.13)	(0.18)	(0.18)	(0.15)	(0.11)	(0.09)
Date Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Station Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	206,140	111,319	166,595	234,831	416,647	551,184
Adjusted R^2	0.336	0.302	0.305	0.297	0.317	0.327
Mean Retail Margin	10.41	10.42	10.16	9.78	9.04	8.85

Notes: The test phase of the MTU (12 September 2013 until 30 November 2013) is dropped in all specifications. The analysis period is the 12 April 2013 until 30 September 2014 in all specifications. Column (1) uses only data for stations 10 to 40 km away from the Franco-German border. Column (2) uses only data for stations 20 to 40 km away from the Franco-German border. Column (3) uses only data for stations 20 to 50 km away from the Franco-German border. Column (4) uses only data for stations 20 to 60 km away from the Franco-German border. Column (5) uses only data for stations 20 to 80 km away from the Franco-German border. Column (6) uses only data for stations 20 to 100 km away from the Franco-German border.
Standard errors are in parentheses.
Standard errors clustered at petrol station level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

C.2 Austria as a Control Group

To test the robustness of our estimates of the average effect of the MTU on retail margins in Germany, we use an alternative specification where we compare the indexed evolution of retail margins in Germany and Austria. Since we only have daily average prices and retail margins at the country level for Austria, we aggregate the German data to the same level and analyse the evolution of margins descriptively. We begin by estimating a daily average price for Germany, by taking the simple average of prices at each petrol station at 9 am, 12 pm and 5 pm and then averaging across petrol stations. Each observation is hence the daily simple average retail margin in the respective country. Since for Germany we overweigh times that are less treated by the MTU, we underestimate the magnitude of the treatment effect. Figure 14 shows the development of retail margins in Germany and Austria between April 2013 and August 2014. Although retail margins follow a common trend before the introduction of the MTU and are sometimes higher in Austria, sometimes higher in Germany, shortly after the increase in transparency in Germany, we observe a divergence in margins between the two groups and retail margins in Germany fall compared to Austria.

Figure 14: Control: Austria



C.3 Local Monopolists as a Control Group

Driving to another petrol station is costly and hence retail petrol markets are usually segmented geographically. In the following, we define local markets as driving distance catchment areas around a focal station.[44] We assume that stations that do not face competition from another station in their catchment area act as local monopolists. Like in the analysis of Albæk et al. (1997) for the cement industry, these local monopolists are unaffected by increasing transparency and can therefore serve as a control group.

In Table 7, we report the results of an estimation strategy in which we analyse the effect of the MTU on retail margins of petrol stations in Germany. We compare petrol stations in Germany, which have at least one competing petrol station in their catchment area to petrol stations that are local monopolists. Only petrol stations that are of a different brand are considered as competitors. Whereas we consider local monopolists as untreated by the introduction of the MTU, because consumers have no alternative in the vicinity and can thus not act upon the new information, stations that have a competitor in their market are considered treated. In Column (1), we define a local monopolist as not having any other station within a 1 km radius. We find a treatment effect of 0.1 Eurocent, however, according to this definition 64% of petrol stations in Germany are local monopolists. We thus consider broader markets in Columns (1) and (2). In Column (2), we define local monopolists as not having a competing station within a 3 km radius. We drop all petrol stations with a competitor within a 3 km radius, but without a competitor within a 1 km radius from the control group, as these are local monopolists according to the market definition in Column (1). We find a treatment effect of 0.2 Eurocent per litre using 3 km catchment areas. In Column (3), we repeat this analysis for 5 km catchment

[44]The empirical literature analysing price dispersion in retail petrol markets considers different geographic market definitions. For example, Chandra and Tappata (2011) consider a 1 mile as well as a 2 miles radius, while Barron et al. (2004), Hosken et al. (2008) and Lewis (2008) consider a radius of 1.5 miles.

Table 7: Estimating the Impact of the MTU using Local Monopolies

	(1)	(2)	(3)
MTU Introduction	-0.08***	-0.18***	-0.23***
	(0.03)	(0.03)	(0.04)
Date Fixed Effects	*Yes*	*Yes*	*Yes*
Station Fixed Effects	*Yes*	*Yes*	*Yes*
Observations	3,964,609	2,417,378	1,978,679
Share local monopolists	64.2%	42.2%	29.4%
Adjusted R^2	0.310	0.306	0.309
Mean Retail Margin	6.85	6.91	6.88

Notes: The test phase of the MTU (12 September 2013 until 30 November 2013) is dropped in all specifications. The analysis period is the 12 April 2013 until 30 September 2014 in all specifications. Column (1) compares petrol stations without competition within a 1 km radius to all other petrol stations. Column (2) compares petrol stations without competition within a 3 km radius to petrol stations with competition within a 1 km radius. Column (3) compares petrol stations without competition within a 5 km radius to petrol stations with competition within a 1 km radius. Only petrol stations that are of another brand are treated as competitors. Standard errors are in parentheses.
Standard errors clustered at petrol station level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

area and find a similar treatment effect to Column (2). Overall, our results are consistent with Lemus and Luco (2019), who find that mandatory price disclosure reduced the time to reach a new equilibrium for oligopoly markets, but not for local monopolies.

Overall, the average effect of the MTU that we find using this specification is consistent with our estimates for the average effect of the MTU using France as a control group. We are likely to underestimate the treatment effect using the local monopolist identification strategy, since consumers in monopoly markets are likely also partially treated by the MTU. It therefore makes sense that the magnitude of the effect that we find using local monopolists is smaller than when comparing retail margins in Germany and France.

C.4 Sub-group analysis

In Table 8 we estimate the effect of the MTU on different sub-groups of petrol stations in Germany. Each sub-group is compared to all petrol stations in France between 12 April 2013 and 30 September 2014. In Column (1), we estimate the effect of the MTU on Aral stations, which is the largest brand in Germany. We find that retail margins for Aral decreased by 0.33 Eurocent. In Column (2), we repeat the analysis for Shell, which is the second largest brand and often the most expensive. We find that retail margins decreased by 2.1 Eurocent. In Columns

Table 8: The Effect of the MTU on Retail Margins by Sub-group

	(1)	(2)	(3)	(4)	(5)
MTU Introduction	-0.33***	-2.10***	-0.93***	-0.83***	-0.90***
	(0.03)	(0.04)	(0.02)	(0.03)	(0.02)
Date Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Station Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	2,999,649	2,827,722	4,647,714	3,826,649	5,697,926
Adjusted R^2	0.423	0.495	0.347	0.369	0.332
Mean Retail Margin	15.46	15.95	12.45	13.22	11.29

Notes: The test phase of the MTU (12 September 2013 until 30 November 2013) is dropped in all specifications. The analysis period is the 12 April 2013 until 30 September 2014 in all specifications. The control group in each specification are all petrol stations in France. Column (1) only uses Aral petrol stations in Germany. Column (2) only uses Shell petrol stations in Germany. Column (3) only uses integrated petrol stations in Germany. Column (4) only uses non-integrated petrol stations in Germany. Column (5) only uses petrol stations present for at least 100 days in our sample between 12 April 2013 and 12 September 2013 in Germany.
Standard errors are in parentheses.
Standard errors clustered at petrol station level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

(3) and (4), we estimate the effect of the MTU on integrated brands and non-integrated brands separately. We find that the effect of the MTU is stronger on petrol stations of integrated brands than of non-integrated brands. Finally, in Column (5) we estimate the effect of the MTU only keeping petrol stations in Germany which are present in the sample for at least 100 days between 12 April 2013 and 12 September 2013. We find that the MTU decreased retail margins by 0.90 Eurocent for this sub-group compared to 0.89 Eurocent for all German stations in our sample found in Table 2. The average treatment effect in our main estimation results is thus not driven by differences in the sample composition before and after the MTU introduction.

C.5 Dropping September 2013

To show that the estimated average treatment effect of the MTU is not driven by the margin increase in Germany in the first half of September 2013, we re-estimate all specifications presented in Table 2 dropping September 2013. The results are presented in Table 9 and show that the average treatment effect of the MTU is robust to dropping September 2013.

Table 9: Average Effect of the MTU Dropping September 2013

	(1)	(2)	(3)	(4)	(5)	(6)
MTU Introduction	-0.17***	-0.67***	-1.41***	-0.55***	-0.95***	-1.65***
	(0.02)	(0.02)	(0.03)	(0.17)	(0.18)	(0.23)
Date Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Station Fixed Effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	4,712,213	6,050,273	7,404,444	83,657	108,371	133,613
Adjusted R^2	0.367	0.326	0.303	0.351	0.308	0.298
Mean Retail Margin	10.97	10.88	11.14	10.47	10.39	10.69

Notes: The test phase of the MTU (12 September 2013 until 30 November 2013) and the margin increase in September 2013 are dropped in all specifications. Column (1) uses data for all stations in Germany and France until 30 June 2014. Column (2) uses data for all stations in Germany and France until 30 September 2014. Column (3) uses data for all stations in Germany and France until 31 December 2014. Column (4) uses only data for stations 20 to 40 km away from the Franco-German border only until 30 June 2014. Column (5) uses only data for stations 20 to 40 km away from the Franco-German border until 30 September 2014. Column (6) uses only data for stations 20 to 40 km away from the Franco-German border until 31 December 2014.
Standard errors are in parentheses.
Standard errors clustered at petrol station level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$