Price dispersion on the French retail gasoline market

Working paper

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Abstract: Using a large panel of daily French diesel prices, this paper finds support for a relation between price dispersion and imperfect consumer information. The volatility in price rankings between pairs of competitors is indeed found to be positively correlated with the distance that separates them, namely a measure of consumer search costs. Furthermore, price dispersion is strongly connected with price levels. Pairs of supermarket competitors, which operate at relatively low markups, exhibit less dispersion than pairs of independent or oil company gas stations. At the market level, a higher diesel cost is associated with lower dispersion, and a higher number of nearby competitors is associated with increased dispersion for high markup gas stations. These results suggest that supermarkets compete for a well informed and thus highly price sensitive demand, while oil company and independent gas stations generally address customers characterized by more loyalty or higher search costs.

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1 Introduction

The understanding of retail gasoline prices has motivated a rich academic literature, marked by concerns of insufficient competition and collusion. The first commonly cited paper of the literature, Bacon (1991), was meant to formally investigate an hypothesis of the British Monopolies and Mergers Commission, according to which gas stations might take advantage of cost fluctuations, adjusting prices downwards at a slower pace than upwards. Using a partial adjustment model with fortnightly UK prices between 1982 and 1989, the paper found support for the "rocket and feather" asymmetry hypothesis. Borenstein et al. (1997), working with weekly US data over a six year period ending in 1992 and an Error Correction Model, also found evidence of such a phenomenon, in particular between city branded terminal prices and retail gasoline prices. Empirical investigations on competition at the gas station-level have somewhat lagged behind, most likely due to data limitations. Hastings (2004), studying a merger in California, found that independent gas stations fostered competition, while an increase in the share of branded gas stations was associated with higher price levels. More closely connected to the "rocket and feather" literature, several papers have investigated price dynamics at the city or gas station level and found evidence of "Edgeworth cycles", namely cycles unrelated to cost variations (Eckert (2002), Eckert (2003), Eckert and Douglas (2004a), Eckert and Douglas (2004b), Noel (2007a), Noel (2007b) and Noel (2008) in Canada, Lewis (2009) and Lewis and Noel (2011) in the US)[1].

The complexity and diversity of observed price patterns have led to question competition intensity and its determinants. Stigler (1961) has initiated a large body of literature by highlighting the link between the "ignorance in the market", namely a lack of consumer information, and price dispersion i.e. the persistence over time of different prices for a homogeneous good. A major theoretical contribution was made by Varian (1980) through the modeling of price dispersion as a result of mixed pricing strategies. According to the paper, price dispersion thereby obtained can be interpreted as "temporal" price dispersion, typically in the form of "sales". This provides a rationale for rank reversals namely the fact that a seller can be cheaper or more expensive than a competitor depending on the time of the observation. The retail gasoline market is an interesting candidate when it comes to studying the impact of consumer search costs on competition. Consumers indeed purchase only one relatively homogeneous product and typically face significant costs to remain informed about prices.

Barron et al. (2004) were the first to investigate price dispersion in the retail gasoline market, using a data set of nearly 3000 gas station prices within four US areas on a single day, in 1997. The non observation of price dynamics implies a limited ability to control for the impact of station-specific characteristics on prices, and the necessity to consider both static and dynamic theoretical

[1] Cf. Eckert (2013) for a survey on Edgeworth cycles in retail gasoline markets

explanations of price dispersion[2]. Under monopolistic competition, price dispersion related to heterogeneity in seller demand or cost should decrease when seller density increases, and so should the average price. Under a search-theoretic approach, the average price can either decrease or increase[3], but seller density and price dispersion should be negatively correlated. This effect can yet be mitigated or reinforced depending whether seller density influences search costs. In particular, Varian (1980) finds that a higher proportion of informed customer can lead to an increase or decrease in the variance of prices, depending on the model's parameters. Barron et al. (2004) measure the density of sellers by the number of gas stations within a 1.5-mile radius around each station. Price dispersion is measured by unexplained variations in prices, namely the squared residuals of the regression of the log of prices on market characteristics, including seller density. An increase in the number of nearby gas stations is found to be associated with a reduction in price dispersion.

Hosken et al. (2008) provide some insights about price dispersion[4] with weekly prices from 272 gas stations around Washington DC between 1997 and 1999. They first regress prices on week time indicators, common to all gas stations, and use the residuals to study the persistence of gas station pricing policies. They then add station fixed-effects to the regression so that residuals reflect deviations from each station's typical price level. Controlling for station fixed-effects accounts for much of the persistence in prices, meaning that a significant amount of dynamic price dispersion is observed once gas station long term pricing policies are taken into account. The data and method employed offer an improvement over Barron et al. (2004) as they shed light on dynamics which require to go beyond models of static price dispersion, but they don't allow to provide an order of magnitude and study variations across markets.

Lewis (2008) reconciles the two previous approaches by using station level fixed-effects to control for differentiation, and investigating the relationship between price dispersion and local market characteristics. Data include price records of 327 gas stations in the San Diego area on each Monday in 2000 and 2001 (91 weeks). The paper finds a negative relationship between seller density and price dispersion, in line Barron et al. (2004), and refine this result by introducing a distinction between high-brand groups, composed by premium branded stations, and low-brand groups, which include discount brand and unbranded stations. The relationship between the density of low-brand sellers and price dispersion is found to be negative, while high-brand sellers have a weakly positive or insignificant impact. Lewis (2008) however observes that a more localized measure of dispersion can lead to find a positive relationship between density and price dispersion, which suggests a

[2] In a theoretical context, price randomization by sellers in a mixed strategy equilibrium is typically interpreted as dynamic price dispersion. Varian (1980), for instance, notes that "It is common to observe retail markets where stores deliberately change their prices over time-that is, where stores have sales". Static price dispersion simply refers to the use of heterogeneous pure price strategies in equilibrium.

[3] It decreases in Carlson and McAfee (1983), in which price dispersion is static, and increases in Varian (1980), which has dynamic price dispersion

[4] They focus on the explanation of gas station mark up levels, the main determinant of which is found to be brand affiliation, and observe many changes in mark up levels on a yearly basis

complex relationship between seller heterogeneity and price dispersion.

Finally, Chandra and Tappata (2011) make two significant contributions to the literature. Working with US daily gas station prices spanning one year and a half, they introduce a formal test regarding the relationship between price dispersion and consumer search, using distance between competing gas stations as a proxy for consumer information, and then use price dispersion measured at the market level to investigate the relationship between price dispersion and market characteristics.

The following paper approaches price dispersion from a gas station, competitor pair and market prospect, offering methodological insights on the pros and cons of each method. A remarkable specificity exhibited by the French market is the presence of significant static price dispersion, with supermarket gas stations setting prices generally 8 to 10 euro cents per liter cheaper than oil company and independent gas stations. Findings support a connection between consumer search and price dispersion. Among pairs of competing stations, price dispersion is indeed found to significantly increase with distance separating gas stations, namely a measure of information imperfection. Price dispersion is higher when competitors are both independent or oil company gas stations than when they are operated by supermarkets. This suggests that supermarkets generally address a well informed, thus more price sensitive demand, justifying the lower observed markups. At the market level, price dispersion is found to increase with the number of competitors and decrease with price.

2 The French retail gasoline market

Diesel consumption currently accounts for c. 80% of retail gasoline sales in France. The share of diesel in total gasoline consumption has kept increasing over the last decades, largely as a result of a lower tax. Meanwhile, the size of the French retailer network has decreased at a steady pace, from c. 40,000 gas stations in 1980 to c. 12,000 currently. Unlike most other European countries, the French market is characterized by a strong competitive pressure generated from gas stations operated by supermarket chains. They currently represent c. 50% of sales in retail gasoline.

According to the French Union of Petroleum Industries (UFIP), there were 11,662 gas stations operating in France (of which 4,947 operated by supermarket chains) in 2012 and 11,476 in 2013 (4,979 for supermarkets). Regarding volumes, it was reported that 1,506 gas stations sold less than 500m^3 in 2012 (1,433 in 2013), with the median gas station selling between 1,000 and 3,000m^3 (same for 2013). As of May 20, 2014, the price comparison website Zagaz listed 12,832 gas stations, but no price had been recorded for long for many of them. This figure can thus be considered as an upper bound of the actual number of gas stations.

Gas stations are essentially either owned and operated by a chain or with a "location-gerance" contract according to which the manager receives a commission on gasoline sold (e.g. Total SA, the largest gas station operator, has reported that only 200 gas stations set prices independently among the c. 2,300 gas stations of its "Total" chain). Industry margins are widely acknowledged to have decreased significantly over the last decade, as a result of competition by supermarket chains and increasingly stringent environmental regulations. This has led some oil companies to exit the market (Shell and BP) or to reduce significantly the size of their network (Esso, Total).

Key cost components are the cost of wholesale gasoline, including delivery fees, gas station operating expenses, and taxes. Taxes included a fix part called TICPE, which slightly varies between regions, and the classical Value-Added Tax (19.6% over the period studied, which bear on cost and TICPE).

At an aggregate level, two kinds of consumers can be distinguished: businesses and individual customers. Businesses are typically offered card programs which allow them to monitor employees' consumptions and obtain rebates. An important implication is that the price of the gas station is irrelevant (or only partly relevant) to a significant number of transactions in the market. Individual consumers pay the posted price, and can get information from a variety of sources: at gas stations, on their gps, mobile phone applications (e.g. Zagaz, Carbeo, Essence Free) and on a computer or mobile phone browser (Prix-Carburants.gouv.fr).

Since 2007, French gasoline retailers are required by law to keep prices updated on the governmental price comparison website prix-carburants.gouv.fr. Small gas stations[5] are exempted from this obligation hence c.10,000 gas stations are observed out of an estimated total number of 12,000 retailers[6]. Significant limitations of the governmental comparison website include the fact that users have never been provided a way to report errors such as wrong or out of date prices or wrong gas station locations, and that price comparison functionalities have always remained relatively poor: e.g. one cannot view prices for a given highway, nor the rivals of a given gas station on a map. As a consequence, the creation of this website may have actually been detrimental to consumer information, as it diverted drivers from other comparison websites such as Zagaz at a time when they crucially needed to grow their user base.

The period studied in the paper is marked by two significant events of different natures. The first is the creation by the largest gas station operator in the country, Total, of a discount brand with a view to recapture market shares lost to supermarket gas stations. This creation was achieved through the rebranding of c. 600 gas stations between 2011 and 2014, accompanied for about half of them by a c. 10 euro cents per liter decrease in prices. More details about this change are provided in the next section. The second event is of political nature. On August 29, 2012, following an election promise made by Francois Hollande, the government announced that a 6 euro cents per liter decrease in prices would be achieved through a 3 euro cent per liter tax cut and an equivalent

[5]Stations having sold over 500m^3 gas the previous year

[6]A 2012 governmental report on the French retail gasoline market notes that "nobody knows precisely the number of gas stations operating in the markets". Two other comparison websites, carbeo.com and zagaz.com, were created in 2005 and 2006, relying on user provided information. Zagaz has stuck to its "crowdsourcing" philosophy until 2014, while Carbeo started purchasing licences from the government in 2009. In 2012, the governmental body in charge of town and country planning worked with Zagaz data to study the French retail gas station network.

"effort" by gas station operators. The impacts of both events on results are evaluated though various robustness checks which are detailed in the following sections.

3 Data

Prices and brand changes were collected from the governmental comparison website on a daily basis between September 4, 2011 and December 4, 2014, hence a period of about 3 years. Figure 1 provides an overview of the evolution of Brent and French average diesel prices excluding taxes. Discontinuities in diesel price series correspond to short periods of missing price records related to technical data acquisition issues. Over the considered period, prices of 10,180 gas stations (after duplicate reconciliations) were recorded, of which 437 were located on highways, 124 on the island of Corsica, and 402 were found to have insufficient or suspicious price data. The analysis was thus performed with a total number of 9,217 gas stations.

Figure 1: Daily Brent and French diesel retail prices

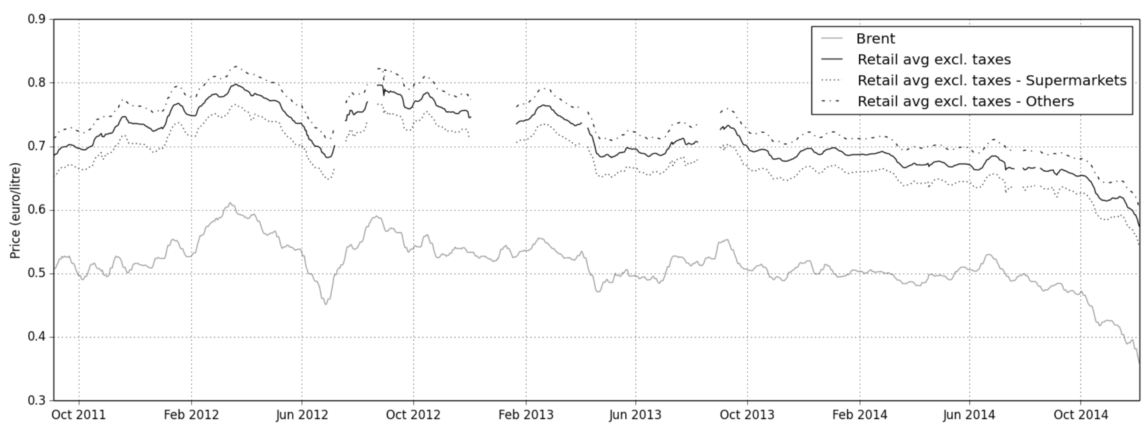


Table 1 provides an overview of gas station prices by chain on the 2014 December, 04, the last day of the studied period. Except for two discount chains operated by oil companies (thereafter simply referred to as discount gas stations), supermarket gas stations are found to set prices significantly lower than these of oil company and independent gas stations, by an average 10 euro cents per liter. Among supermarket gas stations, chain affiliation typically conveys additional information regarding price levels. For instance, the average gas station operated by a Carrefour store (hypermarket), has a diesel price of 1.15 euros per liter vs. 1.18 for a "Carrefour market" (large supermarket) and 1.20 for a Carrefour contact (small supermarkets, often located in city centers). The average difference with a Total gas station thus varies depending on exact chain affiliation within the Carrefour group. Within most chains, the third quartile does not exceed the first quartile by more than 3%. A noteworthy change in gas station affiliations over the period is the creation by Total S.A. of a new chain, Total Access, with a view to expand its discount offer. As a consequence, the previous discount chain of Total S.A., Elf, disappears and is replaced by Total Access. The new discount chain also includes c. 300 former Total stations for which the rebranding is accompanied by a significant change in pricing policy. The impact of this operation is studied in a companion paper, Chamayou and Le Saout (2016), which shows that despite the large price cuts implemented generated triggered very few and limited reactions from nearby competitors.

Table 2 provides an overview of gas station characteristics and pricing behaviors depending on whether they are operated by a supermarket, an oil company or independent network, or are discount gas sations. Since price observations are not available for all gas stations on each day (gas station maintenance, stations which are not required by law to keep prices posted, inconsistent observations), there is an average of 7,895 prices observed per day. The daily probability for a gas station to change its price is 18%, which translates on slightly less than a change per week, and an average of 1,500 price changes per day over France. Supermarket gas stations change prices on a more frequent basis than oil company and independent gas stations, but less frequently than discount gas sations. The order is reversed for the magnitude of price changes. Supermarkets tend to have less nearby competitors than oil and independent gas stations (2.5 vs. 3.8 within 3 km on average), and than discount gas stations (5.2). Their closest rival is generally further (2.6 km vs. respectively 2.0 km and 1.1 km).

The location of gas stations is also correlated with heterogeneity in market characteristics and price setting behaviors. Gas stations within and around Paris tend to change prices for frequently, with smaller variations, and are closer to their closest rival than average. Chamayou and Le Saout (2016) contains regressions of gas station prices on local market socio-demographic characteristics and competition intensity, as well as gas station characteristics, such as the presence of a shop or the opening hours. Results are consistent with Hosken et al. (2008) which find that chain affiliation is a very strong price predictor, while competition variables tend to return insignificant estimates. All these observations have been verified to be robust to the considered day or period. On the French market, this follows from the fact than many supermarkets are located close to oil and independent gas stations, and thus are considered to share the very shame local market characteristics. For instance, more than half non supermarket gas stations are located within 1.4 km from a gas station operated by a supermarket. They are thus typically located in the same municipality or group of municipalities.

A crucial issue when it comes to studying competition between gas stations is the definition of catchment areas. It has been traditionally addresses in the literature by considering circles of various radiuses, usually as the crow flies, around gas stations. Barron et al. (2004) use a radius of 1.5 miles (2.4 km) to study dispersion within four urban areas in California and Arizona. The average number of rivals varies from 8.3 to 10.6 depending on the area, while the distance to the

Table 1: Overview of gas station prices by chain on 2014/12/04 (last day)

			Prices (euro cents)		
Type	Chain	Count	Mean (Std)	Q75/Q25	Q90/Q10
Oil & Independent					
Oil	Total	1 281	1.27 (0.03)	1.03	1.07
Oil	Elan (Total)	233	1.32 (0.04)	1.05	1.08
Oil	Agip	116	1.25 (0.03)	1.02	1.06
Oil	BP	262	1.26 (0.04)	1.03	1.07
Oil	Esso	144	1.27 (0.05)	1.05	1.11
Independent	Avia	375	1.27 (0.05)	1.03	1.07
Independent	Dyneff	55	1.26 (0.04)	1.05	1.07
Independent	Other	360	1.24 (0.06)	1.07	1.12
Total - Oil and Independent		2 826	1.27 (0.04)	1.04	1.08
Oil discount					
Oil discount	Total access	621	1.16 (0.02)	1.02	1.04
Oil discount	Esso express	318	1.16 (0.02)	1.02	1.04
Total - Oil Discount		939	1.16 (0.02)	1.02	1.04
Supermarkets					
Large	Carrefour	200	1.15 (0.02)	1.02	1.05
Large	Auchan	118	1.16 (0.03)	1.02	1.05
Large	Cora	111	1.18 (0.04)	1.04	1.08
Large	Geant Casino	97	1.16 (0.02)	1.03	1.04
Large and medium	Intermarche	1 389	1.17 (0.03)	1.03	1.06
Large and medium	Systeme U	770	1.16 (0.03)	1.03	1.06
Large and medium	Leclerc	585	1.15 (0.02)	1.03	1.06
Medium and small	Carrefour market	716	1.18 (0.03)	1.03	1.05
Small	Carrefour contact	233	1.20 (0.03)	1.03	1.05
Small	Simply (Auchan)	222	1.20 (0.03)	1.04	1.07
Small	Casino	200	1.21 (0.03)	1.03	1.06
Small	Intermarche contact	112	1.20 (0.03)	1.04	1.07
Other	Other	209	1.20 (0.04)	1.05	1.08
Total - Supermarkets		4 962	1.17 (0.03)	1.04	1.07
Total - All		8 727	1.20 (0.06)	1.07	1.12

Sub-classification of type for supermarkets is meant to reflect what consumers can infer from chain name (as provided on the price comparison website).

Gas stations are considered independent when they are neither operated by a supermarket nor part of a chain operated by an oil company. BP and Esso (including Esso Express) gas stations have an intermediary status: they have been sold to third-party companies with a supply agreement and the right to exploit the brand name.

Table 2: Station-level summary statistics

	Oil & Ind	Oil discount	Supermarkets	All
Nb stations				
All periods	3 177	985	5 055	9 217
Nb daily observations	2 632 (134)	863 (9)	4 400 (55)	7 896 (122)
Price and Markup (euro / litre)				
Price after tax	1.42 (0.04)	1.31 (0.02)	1.33 (0.02)	1.36 (0.05)
Price excl. Tax	0.75 (0.03)	0.66 (0.02)	0.68 (0.02)	0.70 (0.04)
Markup over wholesale cost	0.15 (0.03)	0.07 (0.01)	0.08 (0.01)	0.10 (0.04)
Price changes (euro cent / litre)				
Daily price change probability	0.11 (0.05)	0.29 (0.07)	0.18 (0.10)	0.17 (0.10)
Avg. price increase	1.49 (0.50)	0.74 (0.20)	1.29 (0.45)	1.30 (0.50)
Avg. price decrease	1.67 (0.63)	0.79 (0.22)	1.48 (0.58)	1.47 (0.62)
Rivals				
Nb within 1 km	0.77 (0.94)	0.94 (0.98)	0.55 (0.82)	0.67 (0.89)
Nb within 3 km	3.76 (4.05)	5.18 (3.68)	2.51 (2.92)	3.23 (3.54)
Nb within 5 km	7.92 (9.59)	11.01 (8.77)	4.89 (6.23)	6.59 (8.09)
Distance to closest	1.95 (2.67)	1.08 (1.03)	2.64 (3.18)	2.23 (2.89)

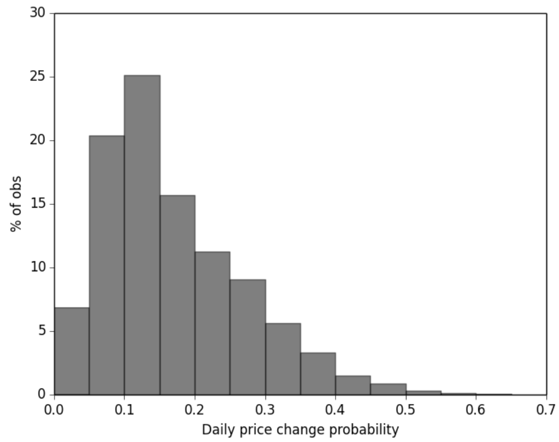
Price statistics are obtained by i) computing the average for each station over time ii) taking the average over stations. Costs of transportation and distribution are to be subtracted from the markup, leading to a net margin generally estimated at c. 1 euro cent per liter.

closest rival respectively fluctuates from 0.3 to 0.5 miles (0.5 to 0.8 km). Chandra and Tappata (2011) analyses price dispersion across Californa, Florida, New Jersey and Texas using distances of 1 and 2 miles (respectively 1.6 and 3.2 km). Depending on the state, the average number of rivals varies from 4.3 to 4.6 with 1 mile and from 13.5 to 14.2 with 2 miles. Houde (2008), uses travel times of 0.5, 1 and 1.5 minutes to study a merger in Quebec city. In the Netherlands, Bruzikas and Soetevent (2015) use distances of 2 and 5 km to study the impact of conversions of manned to unmanned gas stations on prices. Pennerstorfer et al. (2015), in Austria, combine a driving distance of 2 miles and commuting patterns to build markets.

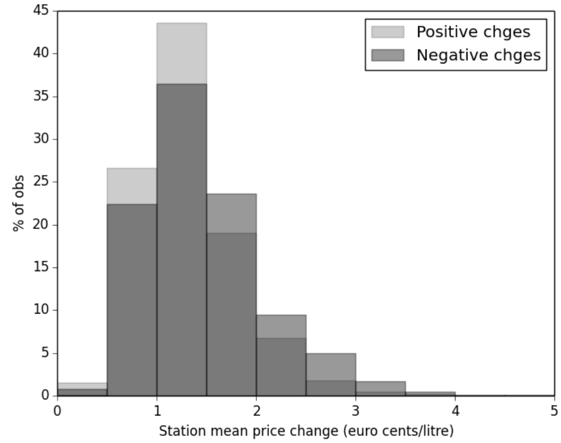
Though driving distances, or travel times, can be seen as an improvement over distance as the crow flies, their merits must yet be relativised. On small distances, taking into account the often observed imprecision in retailer location, and given the difficulty of taking congestions and local driving habits into account, they should not be expected to change results in a major way. Estimations in the paper are based on a distance as the crow flies of 3 km and robustness checks are performed with 1 or 5 km depending on the nature of the analysis.

Investigations on price change distributions at the gas station level lead to rule out the presence of Edgeworth cycles on the French retail gasoline markets. Price increases and decreases are indeed observed in similar proportions and with similar values, while Edgeworth cycles generally imply (relatively) scarce large price increases and numerous small price decreases. Gautier and Le Saout

Figure 2: Histograms of station price changes



(a) Station daily price change probabilities



(b) Station average price variations

(2015), using the same data source, analyse the dynamics of retail gasoline prices in France between 2007 and 2009 with a time-varying menu cost model. They find that wholesale cost variations are fully transmitted to prices in about 10 days, with no significant upwards or downwards asymmetry.

4 Price dispersion from a competitor pair prospect

In order to test the relevance of the link between price dispersion and consumer search, Chandra and Tappata (2011) examine pairs of competing gas stations, arguing that distance between sellers is a good proxy for consumer information. Indeed, when gas stations are located very close to each other, a higher share of consumers is likely to perfectly observe prices than when gas stations are separated by a higher distance. If the share of uninformed consumers is negligible, sellers can be expected to compete a la Betrand (or Hotelling) and prices should essentially match cost fluctuations. On the other hand, if information is imperfect, dynamic dispersion can be expected to arise following the intuition exposed in Varian (1980). Chandra and Tappata (2011) measure temporal price dispersion between two stations as the probability that the gas station which is in general cheaper (in terms of day count) turns out to be more expensive. Formally, considering the prices p_{it} and p_{jt} of two stations i and j over T_{ij} days, such that $p_{it} \geq p_{jt}$ is observed most of the time, the rank reversals statistic writes:

$$r_{ij} = \frac{1}{T_{ij}} \sum_{t=1}^{T_{ij}} \mathbb{1}_{p_{jt} > p_{it}}$$

Alternatively, in order to check the robustness of results to the influence of persistent price differences between gas stations, they use standard deviation of price differences to account for pair prices dispersion:

$$\sigma_{ij} = \sqrt{\frac{1}{T_{ij}} \sum_{t=1}^{T_{ij}} [s_{ijt} - \bar{s}_{ij}]^2}$$

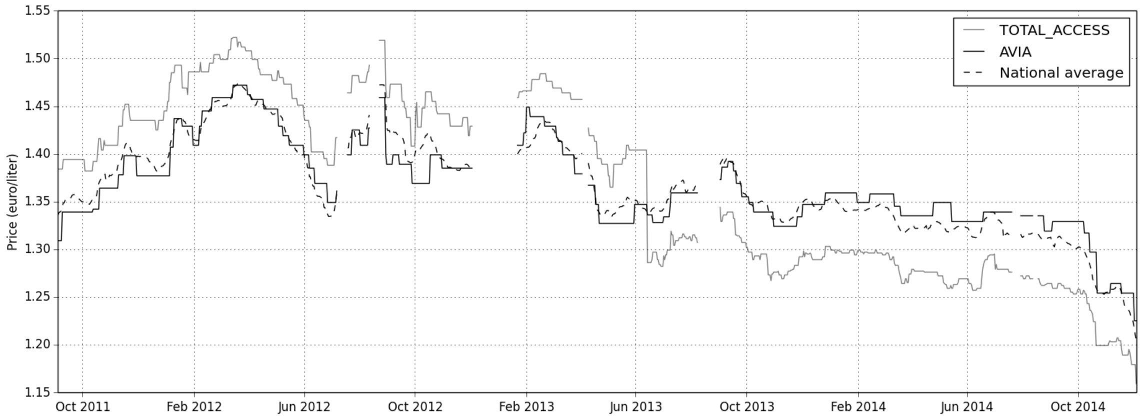
The treatment of persistent differences in average prices is a sensitive issue in the empirical analysis of dispersion. It has been frequently addressed in the literature by working with price residuals i.e. after controlling for seller (and occasionally time) fixed effects. However, beyond the practical errors inherent to the statistical treatment, this approach is only valid to the extent that static price dispersion mirrors heterogeneity in offered utility, common to all consumers. In the case of French gasoline retailers, the relatively low predictive power of observed seller characteristics does not offer strong support for this hypothesis. High price gas stations could be focusing on loyal or time-constrained consumers, while low price gas stations would address a more price sensitive demand. As a consequence, the analysis focuses on pairs of gas stations which are found to operate at similar price levels over the studied period. Practically, this implies that virtually all observations can be classified either as low price (supermarket and oil company discount gas stations) or high price (other oil company gas stations and independent).

French data provide several examples of high rank reversal unrelated to consumer lack of information. The conversion by Total S.A. of about c. 300 Total gas stations to its discount brand, Total Access, generates many such observations. Indeed, the conversion is generally accompanied by a decrease in prices of c. 10 euro cents per liter, which has been found to trigger very moderate adjustments by competitors (Chamayou and Le Saout (2016)). A converted Total gas station can thus often be observed to be consistently more expensive than its competitor(s) at the beginning of the period, and then cheaper once the conversion has occurred. Figure 3 provides an example for which rank is measured to be reversed 47% of the time.

More generally, such an issue may arise whenever a shock affects a gas station differently from the way it affects its closest competitors, so that relative competitive advantages change over time. In order to reduce the potential influence of this issue, gas stations which are found to implement a significant change in pricing policy over the period are excluded, and various constraints are imposed on the maximum length of rank reversals or their number to check the robustness of results.

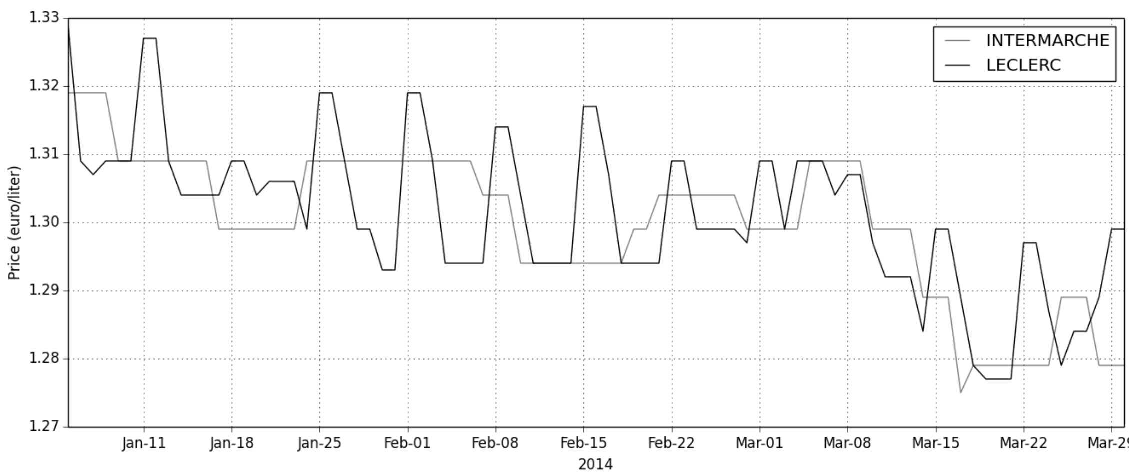
Descriptive statistics performed at the gas station level have also shown that a few gas stations appeared to implement dynamic price discrimination. In order to detect such practices, the number and regularity of successive inverse price changes were measured for each gas station. The most commonly observed pattern is a surge in prices during weekends. Such a pricing policy, whenever it is implemented unilaterally by a gas station in one market, can generate rank reversals which

Figure 3: Example of "spurious" rank reversals: Total Access conversion



are unrelated to the use of mixed strategies. Figure 4 provides an illustration of this phenomenon. Since only a handful of gas stations are concerned, dynamic price discrimination does not have a significant impact on the present analysis.

Figure 4: Example of "spurious" rank reversals: deterministic price variations



Rank reversals and standard deviation are computed for all pairs of competing gas stations in France with an upper distance limit (as the crow flies) of 3 km (figures are provided for a limit of 5km in appendix). This yields a database describing price competition between 11,754 pairs of rival gas stations (respectively 23,824 pairs with 5km).

Table 3: Overview of pairs (distance $\leq$ 3 km)

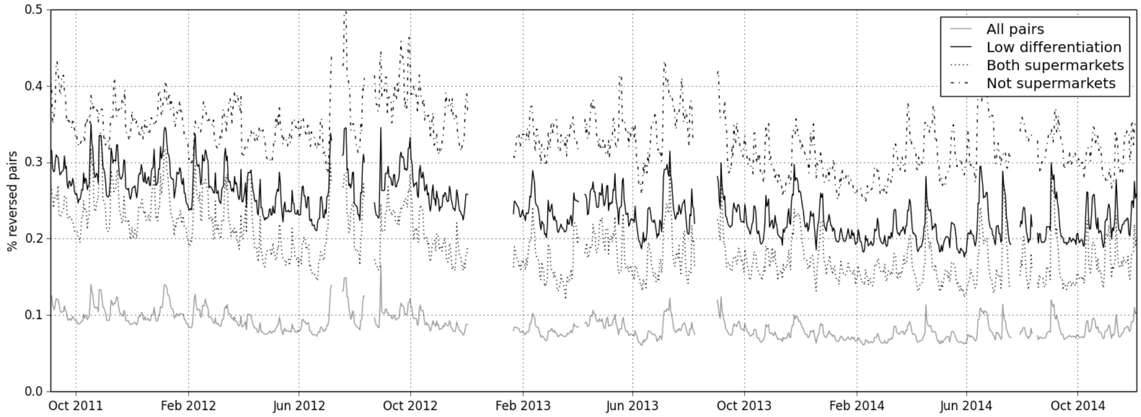
	Nb pairs	Rank reversals (%)	Same price (%)	Price spread Mean	Price spread Std
No price spread restriction					
All types	11 754	7.1 (10.8)	7.8 (17.0)	5.3 (4.3)	1.6 (0.6)
- Oil & Ind	1 679	10.5 (12.0)	3.9 (9.0)	3.2 (2.6)	1.9 (0.6)
- Supermarkets & Discounters	3 706	15.4 (11.3)	21.7 (23.6)	1.0 (1.0)	1.3 (0.5)
- Supermarkets	2 232	12.9 (10.3)	27.3 (27.6)	1.0 (1.1)	1.3 (0.5)
- Discounters	157	28.2 (9.5)	13.6 (6.5)	0.4 (0.4)	1.1 (0.3)
- Supermarkets vs. discounters	1 317	18.1 (11.4)	13.1 (11.7)	1.0 (0.9)	1.3 (0.5)
Price spread $\leq$ 1 cent per liter					
All types	1 928	20.3 (11.8)	27.4 (24.6)	0.4 (0.3)	1.1 (0.4)
- Oil & Ind	297	29.0 (10.5)	12.1 (17.0)	0.5 (0.3)	1.6 (0.4)
- Supermarkets & Discounters	1 423	19.0 (11.5)	30.2 (24.9)	0.4 (0.3)	1.1 (0.4)
- Supermarkets	1 404	15.9 (10.8)	40.0 (17.3)	0.3 (0.3)	1.1 (0.4)
- Discounters	140	30.0 (8.2)	14.4 (6.4)	0.3 (0.2)	1.0 (0.3)
- Supermarkets vs. discounters	879	22.2 (10.9)	17.1 (11.9)	0.5 (0.3)	1.1 (0.3)

Except for the first column, all figures are averages of statistics computed at the pair level (standard errors in parentheses). As regards the price spread, the average accounts for the existence of persistent price differences (0 if both gas stations are equally expensive over the long term), and the standard deviation measures dispersion around the long term price difference (0 if both gas stations always set the same price).

Figure 5 displays the percentage of pairs of gas stations whose price rank is reversed on each day of the period studied. Among pairs of gas stations built with a maximum distance of 3km, the percentage of reversed pairs fluctuates between 5.4% and 15.3% (mean 8.1%). The "No differentiation" series results from a focus on pairs which exhibit an average price difference below 2c/l. Among these pairs, the minimum percentage of reversed pairs fluctuates between 13.8% and 29.3% (mean 19.5%). From a consumer viewpoint, this translates in one chance in five to pay the highest price upon patronizing among two competitors of similar price level the one which is cheaper most of the time.

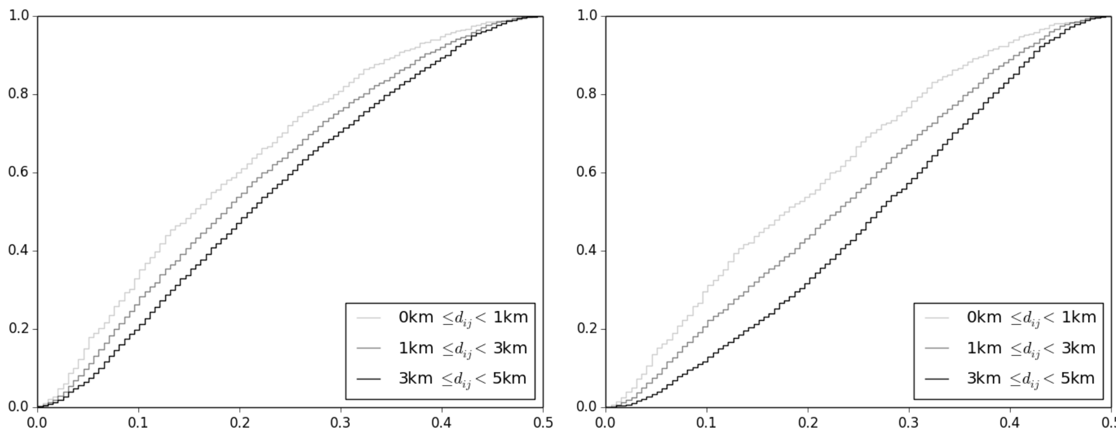
A clear ranking of empirical distribution functions of rank reversals can be observed among pairs of gas stations depending on distances (Figure 6). This is consistent with the idea that nearby gas stations compete in a (virtually) complete information setting, in which there is no reason to expect rank reversals. Conversely, distance can create an information issue for other pairs, preventing the existence of an equilibrium in pure strategy.

Figure 5: Percentage of rank reversals among pairs



Series represent for each day the percentage of pairs observed where the usual price order is not respected (reversed rank). No differentiation implies that pairs exhibit an average price difference below 1c/l.

Figure 6: Empirical distribution functions of rank reversals (raw prices)



(a) Pair average price spread $\leq$ 2 cent/litre (b) Pair average price spread $\leq$ 1 cent/litre

A formal test, proposed by Chandra and Tappata (2011), consists in regressing measures of price dispersion on a dummy variable which identifies competitor pairs for which a low separating distance implies low search costs. Denoting r_{ij} the rank reversals between gas stations i and j, $\mathbb{1}\text{Corner}_{ij}$ an indicator for whether the stations are at the same corner, and X_{ij} other control variables, the regression writes:

$$P_{it} = \beta_0 + \beta_1 \mathbb{1}\text{Corner}_{ij} + X_{ij} + \epsilon_{ij} \tag{1}$$

Results (Table 4) support the hypothesis that limited consumer information is linked to price dispersion. Among supermarkets, competitors are often found to set the very same price, which, given the relatively low prices and absence of evidence of collusion, suggests fierce price competition. Daily price records allow to uncover a number of situations in which one gas station appears to act as a leader.

Table 4: Regressions of pair price dispersion

	Dependent Variable	OLS	Quantile regressions 25%	50%	75%	90%
All pairs	r_{ij}	-2.28***	-1.70***	-3.60***	-2.70***	-2.10***
(N = 2 928)		(0.25)	(0.32)	(0.42)	(0.39)	(0.39)
	σ_{ij}	-0.04**	-0.05***	-0.03	-0.02	-0.01
		(0.02)	(0.02)	(0.02)	(0.03)	(0.04)
Oil & Ind	r_{ij}	-3.29**	-3.80**	-3.00*	-1.90	-0.50
(N = 297)		(1.34)	(1.82)	(1.74)	(1.84)	(1.84)
	σ_{ij}	-0.22***	-0.25***	-0.21***	-0.17*	-0.1
		(0.05)	(0.06)	(0.06)	(0.09)	(0.12)
Supermarkets	r_{ij}	-2.12***	-1.40**	-2.50***	-2.30	-1.90
(N = 1 404)		(0.68)	(0.60)	(0.91)	(1.41)	(1.60)
	σ_{ij}	-0.01	-0.02	-0.01	0.04	-0.02
		(0.02)	(0.03)	(0.03)	(0.04)	(0.05)
Discounters	r_{ij}	-2.29	-2.80	-1.10	-3.10**	-2.80***
(N = 140)		(1.69)	(2.96)	(2.44)	(2.15)	(2.23)
	σ_{ij}	-0.28***	-0.19***	-0.24***	-0.38***	-0.52***
		(0.06)	(0.07)	(0.08)	(0.08)	(0.10)
Supermarkets vs. Discounters	r_{ij}	-2.70***	-3.40**	-2.80**	-2.60**	-4.30***
(N = 879)		(0.91)	(1.49)	(1.34)	(1.32)	(1.31)
	σ_{ij}	-0.02	-0.05*	-0.03	-0.00	0.02
		(0.03)	(0.03)	(0.03)	(0.04)	(0.07)

Pairs involving supermarkets and discounters typically display large percentages of similar prices over time. Observations of strong price alinement raise the question of convergence to equilibrium and potential collusion. In order to capture the potential existence of leadership in price dynamics, for all pairs, we count the number of times each seller matches its competitors' price (formally the number of time seller i matches seller j's price writes $\#\{p_{it} = p_{jt}$ with $p_{it-1} \neq p_{jt-1}$ and $p_{jt} = p_{jt-1}\}$). The hypothesis that each gas station is equally likely to match its competitor price is tested through a binomial test of the equality of the two figures (i.e. seller i matches j and the converse). Whenever the equality hypothesis is rejected, the gas station which displays the higher figure is considered as a leader, and the other as a follower. It must me noted that with daily price records, competitors are often observed to simultaneously adopt the same price on a given day. Such observations are not taken into account in the previously mentioned test, with an importance consequence. The hypothesis of equality of likelihood to adopt the other's price can indeed be accepted either because gas stations actually never set the same prices, or because they always do so at the same time. In order to distinguish these two cases, we adopt a threshold regarding the percentage of days on which both gas stations set the same price. Below this threshold, pairs of competitors are assumed to either be significantly differentiated and/or to be best described by a competition model which does not yield a symmetric price equilibrium. Above this threshold, competitors are expected to either be engaged in relatively tough price competition, or to coordinate on prices.

Information can then be aggregated for each gas station in order to distinguish which have at least one competitor with similar prices, and among those to see whether some appear to rather act as leaders or followers. A gas station is labeled as a relative leader (follower) when it is found to lead (follow) in at least one observation. Further, all gas stations which belong to a pair in which no leader can be identified are labelled as uncertain. Importantly, these three labels are not mutually exclusive: a gas station can be found to act as a leader in one pair, a follower in another, and to neither leader nor follower in a third. An obvious shortcoming of this approach is that when a gas station A systematically matches the prices of a competitor B to the extent that no leader can be identified, if a seller C loosely follows B, both A and B will be labelled as relative leaders in their comparison with C. Finally, an absolute leader (follower) is then a seller which belongs to the set of relative leaders, but not to the sets of relative followers (leaders) and uncertain. Gas station which are only part of pairs for which no leader can identified are labelled as absolutely uncertain.

5 Market price dispersion

The following section extends the analysis to markets, investigating how variations in cost and competition intensity impact market price dispersion. The first approach consists in adapting the method employed by Chandra and Tappata (2011) to obtain comparable results. The richness of the data is then used to evaluate how gas station price distributions are affected by the intensity of competition.

The first approach in terms of market definition consists in considering each gas station successively as the center of a market delimited by a circle of a given radius. Price dispersion is then measured on each day as the range and the empirical standard deviation in prices. This allows to observe how price dispersion varies with cost variations over time (similar across all markets) and the intensity of competition (number of competitors within each market). Results on the latter must yet be analyzed with caution. First, it is clear that the number of gas stations within an area reflects demand and thus may not provide an accurate measure of the competitiveness of the market. Second, the empirical range and standard deviation are not unbiased estimators of the true range and standard deviation. Their downward bias is all the more pronounced as the size of the sample is small, such as in the gas of gas station local markets. In order to address these issues, dispersion is measured directly for each gas station, and regressed on its number of competitors.

As noted by Chandra and Tappata (2011), considering each gas station as the center of a market leads to attribute a lot of weight to markets which have a high gas station density. A simple algorithm is used to obtain non overlapping markets. For each gas station, the set of competitors (within 3 or 5 km) is compared to set of competitors from the competitors. If the latter is found to be included in the former, a market is identified. The final list of non overlapping market only includes markets which are obtained both with a 3 and 5 km distance.

Two treatments of differentiation are contemplated. In a first approach, all gas stations are considered to compete in the same market. Price dispersion is computed with price residuals in order to account for gas station specific characteristics. A scenario involving market segmentation is then investigated. Oil and independent gas stations compete in a "high price" market, while supermarket and discounter gas stations form a "low price" market. The analysis is then run both with raw prices and price residuals.

Table 5 reports descriptive statistics of price dispersion at the market level. All measures of price dispersion can be seen to drop significantly when residual prices are used and under the market segmentation scenario. For instance, under the simple 3 km radius market definition, gains from search, are estimated to be 1.25 euro cents per liter with residual prices while they were 3.93 euro cents per liter with raw prices. Under segmentation, dispersion is higher within "high price" gas station markets (2.90 vs. 0.97 euro cents per liter gains from search with raw prices). The variations observed between dispersion measures computed with raw and residual prices confirm than "high price" gas stations tend to be more differentiated than "low price" gas stations.

Table 5: Market-level summary statistics

	3km all		3km low price		3km high price		Non-overlapping	
Nb sellers	5.99	(3.36)	3.81	(1.13)	5.66	(3.41)	4.36	(2.06)
Nb sellers observed	5.74	(3.22)	3.70	(1.13)	5.32	(3.20)	4.18	(2.04)
Raw prices (euro cents per liter)								
Range	9.70	(4.54)	2.24	(1.97)	6.04	(3.82)	8.61	(4.61)
Standard deviation	3.80	(1.71)	0.92	(0.80)	2.21	(1.23)	3.65	(1.96)
Gain from search	3.93	(2.27)	0.97	(0.88)	2.90	(1.74)	3.39	(2.07)
Residual prices (euro cents per liter)								
Range	2.50	(1.75)	1.60	(1.37)	2.91	(1.86)	2.01	(1.55)
Standard deviation	0.88	(0.57)	0.64	(0.55)	1.01	(0.61)	0.79	(0.59)
Gain from search	1.25	(0.95)	0.80	(0.72)	1.39	(1.01)	1.01	(0.84)
Nb markets	5,501		1,604		883		604	
Nb obs	5,852,850		1,709,055		918,581		641,314	

The results of regressions of measured price dispersion on the number of firms and cost are reported in Table 6. Formally, with $PriceDispersion_{tj}$ a mesure of price dispersion on market j at date t, MC_t a measure of the marginal cost (wholesale diesel) on date t, N_j the number of gas stations on market j, and $\mathbb{1}\text{HighPrice}_j$ an indicator for whether the market is composed by high price gas stations (Oil and independent as opposed to Supermarkets and discounters), the regression writes:

$$\text{PriceDispersion}_{jt} = \beta_0 + \beta_1 MC_t + \beta_2 N_j + \mathbb{1}\text{HighPrice}_j + \epsilon_{jt} \tag{2}$$

Considering the government intervention between August 2012 and January 2013, estimation outputs are provided for the period starting February 1, 2013 (628 days) and their robustness is checked over the period ending on July 1, 2012 (302 days). They are consistent with results obtained by Chandra and Tappata (2011): dispersion is found to increase with the number of firms and decrease with cost (cf. Table 5).

Table 6: Regressions of market dispersion

Markets	3 km radius				No-overlap	
Prices	Raw prices		Residuals		Residuals	
Dispersion stat.	Range	Std	Range	Std	Range	Std
Cost	-0.031^{**}	-0.014^{**}	-0.038^{**}	-0.015^{**}	-0.042^{**}	-0.016^{**}
	[3.86]	[4.76]	[4.95]	[5.04]	[4.73]	[4.68]
Nb firms	0.560^{**}	0.093^{**}	0.265^{**}	0.046^{**}	0.208^{**}	0.033^{**}
	[15.41]	[9.40]	[26.19]	[15.75]	[13.56]	[7.08]
High price	2.703^{**}	1.109^{**}	0.619^{**}	0.258^{**}		
	[26.53]	[26.78]	[17.87]	[18.63]		
Constant	1.854^{**}	1.386^{**}	2.670^{**}	1.294^{**}	3.370^{**}	1.535^{**}
	[3.71]	[7.56]	[6.04]	[7.48]	[6.49]	[7.44]
R2	0.42	0.31	0.26	0.12	0.09	0.02
N	1,074,894		1,074,894		261,687	

6 Price dispersion from a gas station prospect

Given the richness of price data, price dispersion can also be measured at the gas station level, using each residual price distribution. Measures of price dispersion thereby obtained are reported in Table 7.

Table 7: Gas station residual price distributions

	Low price		High price	
Nb stations	5,603		3,044	
Std	1.10	(0.33)	1.26	(0.47)
Kurtosis	2.51	(3.92)	0.80	(2.30)
Skewness	-0.38	(0.91)	0.13	(0.66)
Range	7.52	(2.16)	7.12	(2.25)
Trimmed range 5%	4.27	(1.36)	4.83	(1.80)
Trimmed range 10%	3.42	(1.11)	4.02	(1.54)

Price distributions of low price gas station tend exhibit smaller standard deviations but fatter tails than these of high price gas stations. They are often left-skewed which reflects the use of occasional promotions, often implemented at the chain level. Conversely, no systematic skew is observed for high price gas stations.

Table 8: Regressions of gas station price residual distributions

	Tr. range	Std	Tr. range	Std
Constant	4.802**	1.243**	4.266	1.106
	[35.45]	[33.58]	[230.88]**	[307.05]**
Low type	−0.507**	−0.138**		
	[4.81]	[5.31]		
Nb competitors	0.021**	0.008**	0.040**	0.012**
	[2.64]	[3.79]	[2.75]	[4.19]
Nb competiors *	−0.039*	−0.014**	−0.064**	−0.020**
Low type	[2.13]	[3.08]	[3.32]	[4.90]
Controls			Region*type	
R2	0.03	0.04	0.07	0.09
N	8,647	8,647	8,647	8,647

Regression results in Table 8 confirm the fact that dispersion is positively associated with the number of competitors for high price gas stations. It is yet not true regarding low price gas stations.

7 Conclusion

This paper expands the methodology of Chandra and Tappata (2011) to measure and analyse price dispersion in the French retail gasoline market, taking into account the presence of significant differentiation and potential segmentation. Rank reversals are generally found to be less frequent for pairs gas stations separated by a short distance i.e. competitors whose prices are easy to compare for consumers. This result supports the hypothesis of a connection between consumer information and price dispersion. Pairs of competitors which operate at low prices exhibit less rank reversals than those which sell at higher prices, and many are actually observed to set the very same price on a regular basis. Conversely, among high price gas stations, all pairs tend to be characterized by significant static and/or dynamic price dispersion.

Due to large persistent differences in gas station price levels, working with raw prices leads to largely overestimate price dispersion potentially related to search costs in France. At the local market level, price dispersion is found to increase with the number of competitors, and decrease with cost (todo: add station level analysis results).

Regarding the fit between Varian (1980) and the data, it is worth noting that an important aspect of the dynamics remains unexplained. In the model, while firms are ex-ante indifferent between all prices in the support of the equilibrium price distribution (also holds in terms of randomization over utilities), indifference obviously disappears once prices are posted on the market. The cheapest firm attracts shoppers but would be better off increasing its price to (almost) match the second cheapest price. Other firms would rather increase their price to consumers' reservation price, or undercut the cheapest firm. In the retail gasoline market, it is thus not clear why sellers would regularly wish to keep prices unchanged for a week or more, as can be observed in the data. A possible explanation may be that firms refrain from changing prices too often for fear of triggering more search by consumers and thus more intense competition. Whether this can be obtained in a fully competitive setting or would require some kind of collusion (possibly at the retail chain level or at the local level) remains an open question.

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A Robustness checks

Table 9: Overview of pairs (distance $\leq$ 5 km)

	Nb pairs	Rank reversals (%)	Same price (%)	Price spread Mean	Price spread Std
No price spread restriction					
All types	23 824	7.1 (11.0)	6.1 (14.5)	5.4 (4.3)	1.7 (0.6)
- Oil & Ind	3 780	9.6 (11.5)	3.0 (7.4)	3.4 (2.6)	1.9 (0.6)
- Supermarkets & Discounters	7 244	16.1 (11.8)	17.4 (21.2)	1.1 (1.1)	1.3 (0.5)
- Supermarkets	4 292	13.7 (10.9)	21.9 (25.3)	1.1 (1.2)	1.4 (0.5)
- Discounters	296	27.5 (10.6)	11.3 (6.4)	0.5 (0.6)	1.2 (0.3)
- Supermarkets vs. discounters	2 656	18.7 (11.9)	10.8 (10.5)	1.0 (0.9)	1.4 (0.5)
Price spread <= 1 cent per liter					
All types	5 257	22.1 (11.9)	23.4 (22.8)	0.4 (0.3)	1.2 (0.4)
- Oil & Ind	530	19.8 (10.0)	10.4 (15.4)	0.6 (0.3)	1.6 (0.4)
- Supermarkets & Discounters	4 365	20.9 (11.8)	25.8 (23.3)	0.4 (0.3)	1.1 (0.4)
- Supermarkets	2 493	17.9 (11.4)	34.3 (26.5)	0.4 (0.3)	1.1 (0.4)
- Discounters	241	30.8 (8.2)	12.6 (6.2)	0.3 (0.3)	1.1 (0.3)
- Supermarkets vs. discounters	1 631	24.0 (11.1)	14.8 (11.0)	0.5 (0.3)	1.1 (0.3)

Except for the first column, all figures are averages of statistics computed at the pair level (standard errors in parentheses). As regards the price spread, the average accounts for the existence of persistent price differences (0 if both gas stations are equally expensive over the long term), and the standard deviation measures dispersion around the long term price difference (0 if both gas stations always set the same price).