# Spatial analysis of pricing behaviour of gasoline stations: the role of contextual factors.

Angela S. Bergantino[*] Claudia Capozza[†] Mario Intini[‡]

**Abstract**

This work aims at empirically exploring the nature of price variation in the retail gasoline market. In doing so, we adopt a different approach compared to the existing research. Besides modelling the spatial dependence in prices, considering local market conditions and station-specific characteristics, we try to understand whether contextual factors shape the price fixing behaviour. To this purpose, we employ variables at sub-municipal level accounting for micro-territorial differences. The analysis is focused on the city of Rome, showing a great deal of heterogeneity across sub-municipal areas. Our results provide evidence of spatial dependence in prices. Further, prices charged by stations in a sub-municipal area decrease as the local competition increases. However, when contextual variables are added to the model, the spatial dependence becomes weaker, until it vanishes, as the real estate value is introduced. This would suggest that gasoline stations' pricing behaviour might be weakly explained by the spatial propagation of prices, but rather that all gasoline stations operating in the same sub-municipal area might adapt their prices to the contextual factors.

[*]Department of Economics, Management and Business Law, University of Bari Aldo Moro, Italy. Email: angelastefania.bergantino@uniba.it
[†]Ionian Department of Law, Economics and Environment, University of Bari Aldo Moro, Italy. Email: claudia.capozza@uniba.it
[‡]Department of Economics, Management and Business Law, University of Bari Aldo Moro, Italy. Email: mario.intini@uniba.it

## 1. Introduction

The purpose of this paper is to explain and describe spatial dependence in observed retail gasoline price in an urban area. Specifically, we will focus on the importance of localization of companies in the area and the relative local spatial competition that explains price variation. The retail gasoline market was analysed by several researchers for the suitability in the investigation of the spatial price competition. A relevant study is written by Houde (2009) who develop a structural spatial model of gasoline retailing for Quebec City, making attention on commuting routes. He developed a spatial model of demand, considering the transportation cost that incurs when a buyer must leave her commuting path to provide gasoline. This means that the commuters can choose between different service stations unlike the single-address users only choose between the stations closest to their home. Since gasoline is a homogeneous product, according to the chemical composition, different stations try to differentiate themselves by providing additional services and according to a spatial differentiation.

It is observed that the price in the gasoline market undergoes daily variations. These variations have prompted researchers and policymakers to investigate whether these disparities are the result of agreements between companies or if certain variables determine price fixing. This change in prices leads us to analyse the gasoline market.

According to the Italian Antitrust Authority, the fuel distribution sector is profoundly different from other European countries. In AGCM annual report (2001), the Authority note an abundance of service stations, with a few presences of unbranded and white pumps category.

Furthermore, on 18 January 2007, the antitrust authority initiated a preliminary investigation of the big branded companies: API, ENI, ERG, ESSO, IP, KUWAIT, SHELL, TAMOIL and TOTAL to establish the existence of violations of Article 81 of the EC Treaty, consisting of restrictions of competition on the Italian fuel markets. Following a statement by the National Association of Craftsmen and Small and Medium Enterprises of Freight Transport (FITA) in which they accused of "uniform price trend" emerged "over the last year" of big brand companies that distribute diesel oil on the national network. The provision hypothesized that these practices could play a role facilitating the collusion of price between oil companies. The first findings seem to have confirmed the nature of facilitating practice of the exchange of information assumed in the order to start.

This work contributes to the empirical analysis of this phenomenon by studying for the largest city of Italy as well as the capital, Rome, what affects the behaviour of these stations. We decided to analyse the Italian market for the profound differences with respect to European countries both in the structure and in the definition of the price, as the international literature could not be suitable for the Italian case. Furthermore, we decided to test our research hypotheses on the city of Rome for its high degree of heterogeneity among the different sub-municipal areas.

No studies have been carried out at this level of analysis previously and this is the first study that measures spatial competition according to contextual variables for Rome.

The literature focused mainly on the study of this phenomenon at the station level or in the study of price propagation. Many researchers have also developed spatial competition models, those who have analysed the structure of the market but almost no one has looked at whether the price varies as the context variables change.

The purpose of our work is to contribute in this literature by emphasizing the role of context variables in price determination. In addition to the spatial analysis of price competition, in this work we take a step forward by deciding to insert contextual variables that can influence the behaviour of companies in determining the prices.

Our results show that there is a spatial dependence between the different gas stations present in the territory of Rome.

The peculiar aspect of this work is the inclusion of context variables at the sub-municipal level that can capture the differences between the various districts of Rome. In fact, our results show that there is a spatial dependence in our reference market but as such it loses its significance when context variables such as real estate value are included in our models.

The rest of the paper is organized as follows. In Section 2 we discuss literature on pricing in the gasoline market, while in Section 3 we describe the empirical setting. In Section 4 we present the empirical design: we illustrate data and variables' construction and the econometric method. In Section 5 we show the results and provide the discussion. Finally, concluding remarks are offered in Section 6.

## 2. Literature review

In this section, we offer a review of past empirical evidence on pricing behaviour in the gasoline market. The survey is organised to cover the research streams strictly connected to the objective of our work: i) local market competition; ii) spatial dependence in price; iii) contextual factors.[1]

In the literature, great attention has been devoted to the role of local competition among gasoline stations in determining retail prices. Across studies, the degree of competition has been

[1] See Eckert (2011) for an extensive review of empirical studies of pricing in gasoline retail sector.

measured by different indicators. Clemenz and Gugler (2006) explore the relationship between station density (i.e. the number of gasoline stations per square kilometres) and the average price charged by all gasoline stations within a district in the Austrian retail gasoline market. Intuitively, more densely populated markets with many gasoline sellers are likely to be associated with a more competitive market structure. The authors, indeed, find a negative association between station density and the average price. Consistently, Van Meerbeek (2003), focusing on Belgian gasoline stations, shows that, as long as the number of competitors in a given municipality increases, the gasoline prices in that municipality decrease. On the contrary, Pennerstorfer (2009) finds a positive relationship between density - measured by the number of stations per inhabitants at district-level - and prices of gasoline stations in Austria: a lower demand per station is found to increase the prices. On the same line, Pennerstorfer and Weiss (2013), by the means of a "quasi experiment", show that the spatial clustering of stations, by reducing the degree of competition among gasoline stations, increase the equilibrium prices.

Barron et al. (2004) and Hosken et al. (2008) consider two alternative measures of localized competition, namely the number of stations located within 1.5 miles from the observed station and the distance between the observed station and the next closest station.[2] Both works consider some US market areas. Barron et al. (2004) provide evidence of a negative relationship between seller density and average price across markets: stations competing with a greater number of sellers within 1.5 miles are found to set, on average, lower prices.[3] On the contrary, the distance to the next closest station does not seem to influence the average price. Focusing on the Washington DC suburb, Hosken et al. (2008) offer new results. When considering all the gasoline stations in the empirical analysis, they find that both measures of localised competition do not affect the station's mark-up.[4] However, when one of the station systematically charging lower gasoline prices (i.e. Crown) is excluded from the analysis, then the greater the distance to the closest gasoline station, the higher the station's mark-up, although the size of this relationship remains very small. Overall, this would suggest that pricing behaviour is not homogenous across stations.

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[2] From the survey administrated by Ning et al (2003) to managers of petrol retailing, it turns out that 83% of the stations set the price by looking the adjacent stations, whereas only the 17% fix it regardless of the other stations. Furthermore, more than 60% of the stations do not look at only one station, but at more stations located nearby. Lastly, given the lower prices of supermarket stations, many competing stations take the latter as a reference to fix their prices.

[3] Results appear to be consistent across all four geographic areas considered (Phoenix, Tucson, San Diego and San Francisco).

[4] The station's mark-up is defined as the retail price minus branded rack price and taxes (see page 1427).

Some contributions also consider local concentration indexes, such as the Concentration Ratio ($CR_n$) and Herfindahl- Hirschman Index (HHI), as a proxy of competition intensity. Sen (2003) and Eckert and West (2004) shows that, in the Canadian market, the local market concentration is significantly associated with higher retail price. Recently, Kihm et al. (2016), exploring the German retail gasoline market, find that a higher HHI, measured over 5 km radius from the observed station, increases the ability of that station to set higher prices. Instead, Clemenz and Gugler (2006) find that market concentration, measured by the $CR_1$, $CR_4$ and HHI, does not significantly affect average price.

All in all, the majority of the papers surveyed underline a negative relationship between local competition intensity and prices, although opposite results are sometimes present. Therefore, we can expect, from our estimates, that gasoline prices are likely to decrease as long as local competition increases.

In the last decades, there has been a growth of research on the spatial dependence of prices across gasoline stations. The spatial proximity is a crucial point to be explored because it is expected to influence the strategic interaction between companies in the gasoline market. Ning and Haining (2003), including a spatial structure in modelling gasoline stations' pricing behaviour, show a positive relationship between the observed station's price and the average price of stations in the same local cluster. Particularly, Pennerstorfer (2009) and Pennerstorfer and Weiss (2013) find that prices of gasoline stations are spatially correlated. In other terms, the price of the closest neighbour has an influence on a station's pricing behaviour. Further, Hogg et al. (2012), focusing on the South-Eastern Queensland market, prove that neighbouring stations tend to experience unobserved shocks in a very similar way, thus providing evidence of spatial propagation of prices and confirming the intuition that gasoline tend to be homogenous product across stations.

Interestingly, Firgo et al. (2015) focusing on the Austrian market, demonstrate that both spatial proximity and centrality of stations significantly contribute in explaining the spatial correlation of prices. In other words, a given gasoline station's price is more strongly related to prices of central competitors than prices of remote rivals. Finally, Alderighi et al. (2015) find a weak but significant spatial dependence in the Italian market. They show that diesel price is much more reactive than gasoline price to competitors' prices. This might be explained by the heterogeneity of consumers' price sensitiveness across gasoline types.[5]

[5] These results are interpreted by the authors as the evidence that diesel-powered cars' owners are more price sensitive than unleaded-gasoline cars' owners because the former sustain higher fixed cost (for instance, car purchase costs) that should be compensated by lower car management costs, such as the lower price of diesel.

Overall, the spatial dependence of prices in the gasoline market has been largely proved. Hence, we expect that a similar finding might arise from our study.

As mentioned in the introductory section, the main novelty of our study is to explore the role of contextual factors in the gasoline market, in addition to the local competition and the spatial propagation of prices. So far, there is very little evidence on whether and how contextual factors shape the pricing behaviour of gasoline stations.

The contextual variable mostly considered is the population. Clemenz and Gugler (2006), Pennerstorfer (2009) and Kihm et al. (2016), using the population density in thousands of people per square km, highlight a positive relation with the price dependent variable. Differently, Pennerstorfer and Weiss (2013), using the population density together with the share of tourists, show a negative relationship of both variables with gasoline prices.

Finally, Alderighi and Baudino (2015) accounts for the daily variation in the number of workers employed in economic activities near to the observed gas station. They find a positive association between this variable and prices because a positive shift in demand of fuel, induced by an increase of workers in the neighbourhood, leads to a rise in the price charged.

## 3. Empirical setting

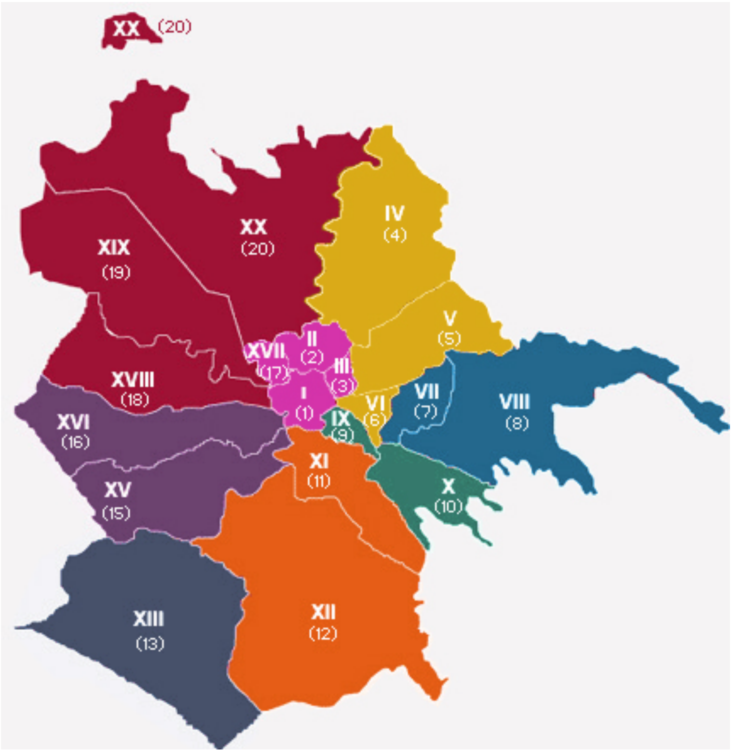
In Italy, the gasoline sector consists of vertically integrated companies controlling the market from production to sales in service stations. Most of branded stations are company owned and only a few stations operate as independent dealer. There are eight major companies that dominate the market: Eni, Esso, Q8, Api, Tamoil, Erg, Shell, and Total. They hold altogether the 95% of market share. Due to the heterogenous morphology of the territory, the Italian gasoline sector is typically characterized by a capillary diffusion of service stations, despite some areas are still not adequately covered. Unlike European countries, such as Germany and UK, the presence of white pump stations is very limited (around 10%) compared to the European average of almost 50% (see Alderighi and Baudino, 2015).

The retail price is defined by the stations as follows. The gasoline stations' owner (or manager) can set a price ranging from a minimum to a maximum. The minimum price corresponds to the price payed by the gasoline station to the main company. The maximum price is established by the main company that, moreover, provide a suggestion for the retail price to the stations' owner (see Andreoli-Versbach, 2011).

Retail prices are function of two components: the industrial component (cost of crude oil extractions and transportations) and the fiscal component (excise and a value added tax applied to both industrial and fiscal component). Data from the Italian Ministry of Economic Development show an average industrial component of 0.532 € per litre in 2015, in line with the Euro-area average of 0.524 € per litre. The fiscal component is of 1,006 € per litre in 2015, which is higher than the Euro-area average, estimated at 0.883 € per litre. Similarly, for diesel fuel the price in Italy is of 1.409 € per litre, including the tax component of 0.871 €, which remains above the Euro-area average of € 0.706 per litre.[6]

Our empirical analysis focuses on the gasoline market in the city of Rome adopting a highly disaggregated approach to define the spatial boundaries within which gasoline companies might compete. Figure 1 shows the fifteen *municipalities* of Rome representing the administrative subdivisions of the territory.

Figure 1. Municipalities of Rome




Source: Comune di Roma.

Each municipality can be further disaggregated by using the *toponymic subdivision* of the territory. Overall, there are: 22 wards that make up the historic centre, all included within the Aurelian Walls; 35 districts surrounding the historic centre outside the Aurelian Walls; 6

6 *La Situazione Energetica Nazionale nel 2015, 2016*. Direzione Generale per la Sicurezza dell'approvvigionamento e le Infrastrutture Energetiche, Ministero Dello Sviluppo Economico.

suburbs, namely territories beyond the district, and 53 sparsely populated areas called the Agro Romano. The list of municipalities together with their toponymic subdivision is provided in the appendix.

## 4. Empirical design

### 4.1 Data and variables' construction

This study combines station-level data and territorial-level data stemming from different databases. Station-level data within the boundary of the city of Rome in 2016 are collected from the «Osservatorio Prezzi Carburanti» of the Italian Ministry of the Economic Development. As required by Law 99/2009, starting from September 2013, it is mandatory for the fuel distribution systems' operators of the entire road network to inform the Ministry of Economic Development about the prices charged for all types of fuels and for all forms of sale, with priority for self-service mode, if active during the entire opening hours. The mandatory frequency of communications by gasoline stations is weekly, to be carried out within the eighth day from the last communication, even when no price variation occurs. The database provides comprehensive information for each fuel distribution plants, including the brand name, the kind of fuel distributed, the provision mode, the location address and the geolocation.

Using this database, we define the dependent variable *Price*, the average yearly price of each gasoline station *i*. We calculate the average price using the daily prices charged by gasoline stations over the observed year for two kinds of fuels, gasoline and diesel, and for the two provision modes, self-mode and the served mode.[7]

Moreover, we define the following explanatory variables. We construct two proxies of localized competition. First, the *HHI*, i.e. $\sum_{j=1}^{J} s_{i,j}^2$, where $s$ is the market share of station $i$ in the toponymic area $j$, calculated as the number of same-brand stations within a toponymic area over the total number of stations in that area.

To control for differences in prices due to the kind of road where the plant is located we define the following dichotomous variables: *Motorway*, equal to 1 if the gasoline station is located on a motorway, 0 otherwise; *Trunk road*, equal to 1 if the gasoline station is located on a trunk road, 0 otherwise; and, *Other road*, equal to 1 if the gasoline station is located on other roads, 0 otherwise. As mentioned before, for each station we have the variables *Latitude* and *Longitude* identifying the geolocation.

[7]Besides gasoline and diesel, data on LPG and methane prices are also available.

Station-level data are matched with data at the territorial-level. Consistently with surveyed papers, we define the variable *Population 20 to 69*, the number of inhabitants aged between 20 and 69 which are supposed to have a greater transport demand, therefore we expect a positive coefficient for this variable. Moreover, we define the variable *Commercial activities,* the number of active commercial businesses, to capture the intensity of the economic activities in the neighbourhood and, likely, a greater demand for fuel. Hence, a positive coefficient for this variable is expected. The data used to construct the variables above are provided by ISTAT at municipality-level for the reference year 2012. Finally, to seize the richness of the territory, and the overall willingness to pay of inhabitants for all kind of products, we define the variable *Real estate value*, namely the value of buildings per square meter in euro, for which we expect a positive coefficient. For this variable data are provided by the Revenue Agency at the toponymic-level. The Agency reports the minimum and maximum value of properties per semester. We calculate the average value of civil dwellings for the year 2016.

In Table 1 we summarize the definitions and the data sources for the variables in the empirical analysis.

**Table 1**. Variables' definition and data sources.

| Variable | Description | Level | Source |
|---|---|---|---|
| *Price* | Average yearly price for two kinds of fuels (gasoline and diesel) and two provision modes (self and served), fixed by station *i* in area *j*. | Station | Osservatorio Prezzi Carburanti, Italian Ministry of the Economic Development. |
| *HHI* | $\sum_{k=1}^{K} s_{i,k}^2$ where *s* is the market share of station *i* in area *j* (computed using the number of same-brand stations within an area). | Toponymic | Osservatorio Prezzi Carburanti, Italian Ministry of the Economic Development. |
| *Road type* | | Station | Osservatorio Prezzi Carburanti, Italian Ministry of the Economic Development. |
| Motorway | Equal to 1 if the gasoline station is located on a motorway, 0 otherwise. | | |
| Trunk road | Equal to 1 if the gasoline station is located on a trunk road, 0 otherwise. | | |
| Other road | Equal to 1 if the gasoline station is located on other roads, 0 otherwise. | | |
| *Latitude* | Latitude of station *i.* | Station | Osservatorio Prezzi Carburanti, Italian Ministry of the Economic Development. |
| *Longitude* | Longitude of station *i.* | Station | Osservatorio Prezzi Carburanti, Italian Ministry of the Economic Development. |
| *Population 20 to 69* | Number of inhabitants aged between 20 and 69. | Municipality | National Institute for Statistics (ISTAT). |
| *Commercial activities* | Number of active commercial businesses. | Municipality | National Institute for Statistics (ISTAT). |

| | | | |
|---|---|---|---|
| *Real estate value* | Average yearly value of civil dwellings per square meter in euro. | Toponymic | Revenue Agency (Agenzia delle Entrate – OMI). |

In Table 2 and in Table 3 we provide the descriptive statistics and the correlation matrix, respectively.

### 4.2 Econometric method

In this work, we adopt the spatial econometric approach to model the pricing behaviour of gasoline stations. We start by defining the *baseline* model taking the following form:

$$P_{ij} = \alpha + \lambda WP_{ij} + \beta X_{ij} + u_{ij} \qquad |\lambda| < 1 \qquad (1)$$

$$u_{ij} = \rho W u_{ij} + \varepsilon_{ij} \qquad |\rho| < 1 \qquad (2)$$

where $i$ indexes the gasoline station and $j$ the territorial area. Moreover, $P$ is the N×1 vector of observations on the dependent variable and $X$ is the N×k matrix of observations on the independent variables. The spatial weights matrix $W$ is N×N matrix that parameterizes the distance between neighborhoods in which each generic element is defined as:

$$w_{ij} \begin{cases} 1 \text{ if } j \in \mathrm{N}(i) \\ 0 \ otherwise \end{cases} \qquad (3)$$

where N($i$) represent the set of neighbours of different location $j$. In this work, we adopt the concept of neighbouring according to the maximum distance between stations. The spatial weights matrix $W$ is row-standardized. Moreover, $u$ are spatially correlated residuals and $\varepsilon$ are independent and identically distributed residuals. Finally, the scalars $\lambda$ and $\rho$ measure, respectively, the dependence of $P_{ij}$ on nearby $P$ and the spatial correlation in the errors. The restrictions on parameters λ and ρ hold if W is row standardized.

To test for the spatial correlation among observations, we use the Moran's I test with the null hypothesis of zero-correlation between regression residuals. A positive spatial autocorrelation is observed when observations that are close to the others are more similar than more distant ones (Arbia, 2014).

The second model we specify is the spatial geo-additive model (see Basile, 2014):

$$y_i = x_i^* \beta^* + \rho \sum_{J=1}^{n} w_{ij} y_j + f_1(x_{1J}) + f_2(x_{2j}) + \dots + h(no_i, e_i) + \varepsilon_i$$

With $\varepsilon_i \sim \text{iid } N(0, \sigma_\varepsilon^2) \quad i = 1, \dots, n$

Where:

$w_{ij}$ = element of a spatial weight matrix $W_n$

$\sum_{J=1}^{n} w_{ij} y_j$ is the spatial lag of the dependent variable

$\rho$ is the spatial spillover parameter

$h(no_i, e_i)$ is a smooth spatial trend surface,

i.e. a smooth interaction between latitude and longitude.

As observed by Basile, it allows us "to control for unobserved heterogeneity, which is a primary task when dealing with spatial data. When the term $h(no_i, e_i)$ is interacted with one of the explanatory variables, it allows us to estimate spatially varying coefficients."

The general Spatial autoregressive with additional autoregressive error (SARAR) structure considers five cases:

-β=0 and λ or ρ=0 called as Pure spatial autoregressive model;

-λ=ρ=0 called Lagged Independent variable model;

-λ=0, ρ≠0 called Spatial Error Model (SEM);

-λ≠0, ρ=0 called Spatial Lag Model (SLM or SAR);

-λ≠0, ρ≠0 represent the SARAR model.

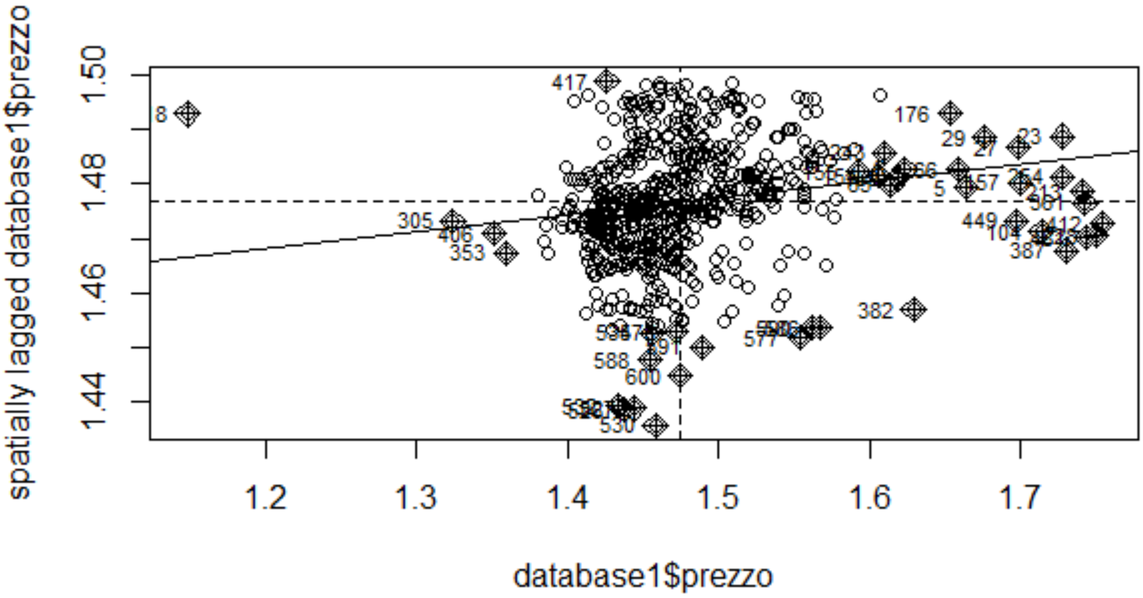
We test our data using Spatial Lag model and Spatial Error Model. Considering the Lagrange Multiplier test, with our data fits better (significant at 1%) the SAR model.

In this model, theory suggest using Maximum likelihood estimator or Two-Stage Least Squares. We use a Maximum Likelihood estimator in all estimates.

## 5. Results and discussion

The empirical results of our analysis are collected in Table 4-5.

Our analysis focuses on the data related to gasoline and diesel fuel provided in self-mode. Our data, as stated in the previous paragraph, are expressed through georeferencing. This allows us to calculate the W matrix based on the Euclidean distance that exists between the different distributors, where everyone has at least one neighbour. The distance taken into consideration is expressed in km. The weighted distance matrix identified is standardized. This process is particularly useful in this type of analysis to remove dependence on extraneous scale factors. After defining the weight distance matrix, the next step is to test the spatial autocorrelation among OLS regression residuals. The most common text is the Moran Test which provides for the null hypothesis the uncorrelation among regression residuals. As studied by Arbia (2014), the negative aspect of this test is precisely that of not providing an alternative hypothesis. This




test takes the form of correlation between residual regression and their spatially lagged values.

Fig.4 Moran test of Gasoline self-mode-plants in Rome

| ***Moran's I test under randomisation*** | | |
|---|---|---|
| Moran I statistic standard deviate = 5.1743, alternative hypothesis: greater | p-value = 1.144e-07 | |
| | sample estimates: | |
| Moran I statistic | Expectation | Variance |
| 3,66E+04 | -1,62E+03 | 5,45E+01 |
| | | |

Tab. 1 Moran'I Test

The Moran's I test (Tab.1) and the plot (Fig.4) reveal the presence of a significant positive and highly spatial autocorrelation among the regression residuals. For this reason, we know that the hypothesis of no spatial autocorrelation in the disturbances is violated. That motivates further analysis. For this we apply two different models to our analysis: the spatial lag model and the standard error model. As said before, we test these models with a maximum likelihood approach and we prefer the SAR model. We test the SAR model both for general spatial model (model number 1) and geo-additive spatial model (model number 2).

In our case, since we are referring to a small sub-municipal area, it is certainly reasonable to speculate that the gasoline price change smoothly through space. For this reason, we can test if a spatial lag model achieves a better fit to our data while removing the remaining correlation.

Only for the second model, following the approach of Basile et al. (2014), we define the variable *Latitude* and *Longitude* of each station, together with their interaction. This interaction is a smooth spatial trend surface between northing and easting. It allows us to control for unobserved spatial heterogeneity.

We have made the estimates inserting the variable real estate values in addition to the other context variables for both models.

Starting from the model with only the station level variables, we estimated several models, inserting the context variables one by one, to evaluate their significance, and finally we estimated the full model, with all the variables, both Spatial lag and Spatial Error.

Specifically, we estimated 5 different spatial regressions for both models. The first regression considers only the variables at the service station level. The second regression adds to the station level variables also the number of residents aged between 20 and 69 years. This variable represents the potential consumer demand in the Roman gasoline market. The third model takes into consideration, in addition to the station level variables, the number of commercial businesses active in the various municipalities. The fourth regression considers the variables collected from "Agenzia delle Entrate". Specifically, we included the real estate value. The last model considers all the station' level variables and the contextual variables.

In the spatial lag model (tab. 2 and tab.3), z-value show that contextual variables like commercial activities (the logarithm of the number of commercial activities active in the various toponymic areas of Rome), and real estate value are highly significant.

The stations level variables: latitude, longitude, the interactions between them (for the second model) the HHI index variable, and the "station's type category" are all significant in the full model (model number 5). Station type variables that indicate whether the service station is on

the highway assuming the plant type name system_1, or on trunk road or on other roads are significant. As we expected, the sign of the prices of plants that are not located on motorways have a negative sign compared to the latter in all estimates.
The fundamental difference between the two models used is carried out when we insert the variables in model 4 and 5. Using the general spatial model (method n.1) the lambda maintains its significance also in model 4 and model 5. If, on the other hand, we use a geo-additive model, the significance of the lambda is lost completely if the real-estate value variable is inserted into the model. This means that the model we use, which inserts the coordinates as regressors, is the best model to use. With the geo-additive model we can capture unobserved heterogeneity obtaining more accurate estimates.
For the second model, lambda in gasoline market (tab.2) takes a value between 0,25 and 0,48. Both likelihood Ratio Test and the Wald Test show that the parameter Lambda is highly significant except in the model 4 and in the full model where real estate value is in the estimates.
We find same results for diesel market where variable Lambda (tab.3) takes a value between 0,33 and 0,54. Both likelihood Ratio Test and the Wald Test show that the parameter Lambda is highly significant except in the model 4 and in the full model where real estate value is in the estimates.
In general, the strong explanatory power of the variable relating to real estate value has emerged. Only when this variable is present in the models, the coefficient of the price tag laced in space is not significant. This would suggest that prices seem to be correlated with each other in space, but this correlation is not due to spatial propagation of prices, but rather is determined by the fact that stations operating in neighbourhoods with higher real estate values tend to practice higher prices.
Very similar results are found in the Spatial Error Model (tab. 4). In this model, the variables assume the same significance and the same sign as the Spatial Lag model, with the exception that when the real estate value variable is considered in the full model (model n.5), Rho variable is not significant for both statistical tests.

| Spatial Lag Model Gasoline (self-mode) | | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| HHI | 4.7218e-06***<br>(1.4329e-06) | 4.8991e-06 ***<br>(1.4457e-06) | 3.7827e-06***<br>(1.4324e-06) | 3.9017e-06***<br>(1.4167e-06) | 3.8331e-06***<br>(1.4514e-06) |
| Latitude | 4.7218e-06***<br>(1.4329e-06) | -8.6296e+00<br>(5.3582e+00) | -1.1489e+01***<br>(5.3901e+00) | -1.2356e+01**<br>(5.4063e+00) | -1.3550e+01**<br>(0.0130495) |
| Longitude | -8.3286e+00<br>(5.3321e+00) | -2.9103e+01<br>(1.8033e+01) | -3.8777e+01**<br>(1.8143e+01) | -4.1577e+01**<br>(1.8200e+01) | -4.5660e+01**<br>(1.8378e+01) |
| Latitude*Longitude | 6.7096e-01<br>(4.2853e-01) | 6.9548e-01<br>(4.3069e-01) | 9.2607e-01***<br>(4.3329e-01) | 9.9402e-01**<br>(4.3467e-01) | 1.0912e+00**<br>(4.3894e-01) |
| *Station type* (omitted cathegory: highway) | | | | | |
| Trunk road | -4.4183e-02**<br>(1.9143e-02) | -4.3367e-02**<br>(1.9156e-02) | -4.7546e-02<br>(1.8913e-02) | -4.5516e-02**<br>(1.8773e-02) | -4.7672e-02**<br>(1.8784e-02) |
| Other road | -4.2974e-02***<br>(1.3631e-02) | -4.3645e-02***<br>(1.3626e-02) | -4.9856e-02***<br>(1.3597e-02) | -5.1157e-02***<br>(1.3551e-02) | -5.4628e-02***<br>(1.3591e-02) |
| Lagged price (**Lambda**) | **0.47742 **** | **0.50154**** | **0.41678**** | **0.24527** | **0.25151** |
| Brand dummies | YES | YES | YES | YES | YES |
| *Contextual variables* | | | | | |
| Population 20 to 69 | | 5.4391e-03<br>(6.4452e-03) | | | 9.4490e-04<br>(6.7987e-03) |
| Commercial activities | | | 2.3649e-02***<br>(5.8273e-03) | | 1.6529e-02**<br>(6.5484e-03) |
| Real Estate Value | | | | 1.5819e-05***<br>(3.1821e-06) | 4.0491e-02***<br>(1.1691e-02) |
| LR test value | 5.5412 | 6.0591 | 4.0683 | 1.2211 | 1.2422 |
| Wald statistic | 9.6254 | 11.168 | 6.4406 | 1.8189 | 1.8738 |

Tab.2 Spatial Lag Model

| **Spatial Lag Model Diesel (self-mode)** | | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| HHI | 4.5620e-06***<br>(1.5435e-06) | 4.6447e-06 **<br>(1.5584e-06 ) | 3.7827e-06**<br>(1.5487e-06) | 3.6689e-06**<br>(1.5294e-06) | 3.5977e-06**<br>(1.5684e-06) |
| Latitude | -8.8844e+00<br>(5.6362e+00) | -9.0314e+00<br>(5.6779e+00) | -1.1887e+01**<br>(5.6995e+00) | -1.2818e+01**<br>(5.6986e+00) | -1.3830e+01**<br>(5.7680e+00) |
| Longitude | -2.9968e+01<br>(1.8968e+01) | -3.0466e+01<br>(1.9110e+01) | -4.0122e+01**<br>(1.9185e+01) | -4.3149e+01**<br>(1.9185e+01) | -4.6608e+01**<br>(1.9421e+01) |
| Latitude*Longitude | 7.1607e-01<br>(4.5299e-01) | 7.2804e-01<br>(4.5641e-01) | 9.5830e-01***<br>(4.5817e-01) | 1.0316e+00**<br>(4.5819e-01) | 1.1139e+00**<br>(4.6385e-01) |
| *Station type* (omitted cathegory: highway) | | | | | |
| Trunk road | -3.9977e-02**<br>(2.0241e-02) | -3.9594e-02**<br>(2.0272e-02) | -4.3091e-02**<br>(2.0064e-02) | -4.1467e-02**<br>(1.9875e-02) | -4.3766e-02***<br>(1.9927e-02) |
| Other road | -3.6992e-02**<br>(1.4422e-02) | -3.7285e-02 **<br>(1.4426e-02) | -4.3498e-02 **<br>(1.4434e-02) | -4.5834e-02***<br>(1.4355e-02) | -4.8749e-02***<br>(1.4426e-02) |
| Lagged price (**Lambda**) | **0.53308**** | **0.54238**** | **0.48744**** | **0.33388** | **0.33041** |
| Brand dummies | YES | YES | YES | YES | YES |
| *Contextual variables* | | | | | |
| Population 20 to 69 | | 2.5178e-03<br>(6.8231e-03) | | | -1.2953e-03<br>(7.2140e-03) |
| Commercial activities | | | 2.1842e-02 ***<br>(6.2071e-03) | | 1.5036e-02**<br>(6.9673e-03) |
| Real Estate Value | | | | 1.6296e-05***<br>(3.3837e-06) | 4.2824e-02***<br>(1.2438e-02) |
| LR test value | 7.7817 | 7.9066 | 6.3049 | 2.5857 | 2,4434 |
| Wald statistic | 13.58 | 14.349 | 10.201 | 3.8956 | 3.6741 |

Tab.3 Spatial Lag Model (diesel)

| Spatial Error Model Gasoline (self-mode) | | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| HHI | 4.6865e-06*** (1.4302e-06) | 4.8376e-06*** (1.4359e-06) | 3.6471e-06** (1.4396e-06) | 3.5977e-06** (1.4171e-06) | 3.6681e-06** (1.4433e-06) |
| Latitude | -1.2213e+01 (8.0962e+00) | -1.2540e+01 (8.4376e+00) | -1.6059e+01** (7.0175e+00) | -1.3941e+01** (6.8078e+00) | -1.5487e+01** (6.7937e+00) |
| Longitude | -4.1244e+01 (2.7202e+01) | -4.2360e+01 (2.8347e+01) | -5.4234e+01** (2.3588e+01) | -4.6972e+01** (2.2882e+01) | -5.2234e+01** (2.2839e+01) |
| Latitude*Longitude | 9.8544e-01 (6.4958e-01) | 1.0123e+00 (6.7695e-01) | 1.2954e+00** (5.6328e-01) | 1.1230e+00** (5.4645e-01) | 1.2485e+00** (5.4541e-01) |
| *Station type* (omitted cathegory: highway) | | | | | |
| Trunk road | -4.2017e-02** (1.9122e-02) | -4.1519e-02** (1.9106e-02) | -4.5519e-02** (1.8952e-02) | -4.5297e-02** (1.8762e-02) | -4.7268e-02** (1.8760e-02) |
| Other road | -4.5195e-02*** (1.3579e-02) | -4.5933e-02*** (1.3560e-02) | -4.9447e-02** (1.3546e-02) | -5.2323e-02*** (1.3449e-02) | -5.5483e-02*** (1.3484e-02) |
| **Rho** | **0.5144**** | **0.54632***** | **0.39051**** | **0.37419*** | **0.36604** |
| Brand dummies | YES | YES | YES | YES | YES |
| *Contextual variables* | | | | | |
| Population 20 to 69 | | 6.7414e-03 (6.9044e-03) | | | 3.2681e-03 (7.0590e-03) |
| Commercial activities | | | 2.2941e-02*** (5.9221e-03) | | 1.4373e-02** (6.5592e-03) |
| Real Estate Value | | | | 1.7788e-05*** (3.4236e-06) | 4.9627e-02*** (4.6314e-06) |
| LR test value | 6. 2731 | 7. 0169 | 3.0424 | 3.0491 | 2.505 |
| Wald statistic | 11. 477 | 14.089 | 5. 0124 | 4.4594 | 4.202 |

Tab.4 Spatial Error Model (gasoline)

| Spatial Lag Model Gasoline (no geo-additive) | | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| HHI | 5.7173e-01 *** (1.8790e-01) | 5.0586e-06 *** (1.4331e-06) | 4.2125e-06** (1.4133e-06) | 4.1879e-06*** (1.4050e-06) | 4.0665e-06 *** (1.4295e-06) |
| *Station type* (omitted cathegory: highway) | | | | | |
| Trunk road | -4.5824e-02* (1.9115e-02 ) | -4.5242e-02* (1.9140e-02 ) | -4.9884e-02** (1.8914e-02 ) | -4.7512e-02* ( 1.8801e-02) | -5.0683e-02** (1.8826e-02 ) |
| Other road | -4.5267e-02*** (1.3613e-02 ) | -4.5771e-02*** (1.3615e-02 ) | -5.2678e-02*** (1.3597e-02 ) | -5.3493e-02*** (1.3550e-02 ) | -5.7323e-02*** (1.3599e-02) |
| Lagged price (**Lambda**) | **0.62045 ***** | **0.63942**** | **0.62086***** | **0.51126***** | **0.5261***** |
| Brand dummies | YES | YES | YES | YES | YES |
| *Contextual variables* | | | | | |
| Population 20 to 69 | | 3.4090e-03 (6.0357e-03) | | | -1.8291e-03 (6.2373e-03) |
| Commercial activities | | | 2.1885e-02*** (5.7589e-03) | | 1.6890e-02** (6.2806e-03) |
| Real Estate Value | | | | 1.3973e-05*** (3.1115e-06) | 3.4705e-02*** (1.1017e-02) |
| LR test value | 24.81 | 15.978 | 16.251 | 10.041 | 9,8811 |
| Wald statistic | 9.6254 | 27.776 | 24.307 | 13.955 | 14.112 |

Tab.5 Spatial Lag Model Gasoline (no geo-additive)

| Spatial Lag Model Diesel (no geo-additive) | | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| HHI | 4.8126e-06*** (1.5235e-06) | 4.8219e-06 ** (1.5401e-06 ) | 4.1300e-06** (1.5224e-06) | 3.9722e-06** (1.5123e-06) | 3.8300e-06** (1.5397e-06) |
| *Station type* (omitted cathegory: highway) | | | | | |
| Trunk road | -4.1570e-02** (2.0214e-02 ) | -4.1520e-02** (2.0255e-02) | -4.5311e-02** (2.0062e-02) | -4.3316e-02** (1.9905e-02) | -4.6735e-02*** (1.9969e-02 ) |
| Other road | -3.9342e-02** (1.4406e-02) | -3.9382e-02 ** (1.4415e-02) | -4.6196e-02 ** (1.4434e-02) | -4.8030e-02*** (1.4359e-02 ) | -5.1150e-02 *** (1.4435e-02 ) |
| Lagged price (**Lambda**) | **0.66704***** | **0.66834**** | **0.67046***** | **0.56905***** | **0.33041***** |
| Brand dummies | YES | YES | YES | YES | YES |
| *Contextual variables* | | | | | |
| Population 20 to 69 | | 2.8160e-04 (6.3966e-03) | | | -4.4825e-03 (6.6267e-03 ) |
| Commercial activities | | | 2.0079e-02 *** (6.1312e-03) | | 1.5494e-02** (6.6898e-03) |
| Real Estate Value | | | | 1.4404e-05*** (3.3066e-06) | 3.6801e-02*** (1.1727e-02) |
| LR test value | 20.671 | 19.392 | 21.167 | 13.909 | 12.941,0000 |
| Wald statistic | 33.288 | 33.4 | 33.539 | 20.056 | 18.776 |

Tab.6 Spatial Lag Model Diesel (no geo-additive)

## 6. Conclusions

Fuel prices are often the focus of consumers who daily choose their service distributor based on their needs and characteristics. In this paper, we analysed the fuel market of Rome, a city with a high presence of service stations, where consumers are very different from each other in terms of income, preferences and location.

In this work, we found evidence of a spatial competition among different companies in the territory of Rome. As it is well known, in Italy, the fuel sector has notable differences compared to the other European countries. Investigating the Italian sector and a large city like Rome, using a series of variables not previously used in literature, represents the peculiarity of this work.

The most important aspect concerns the use of context variables as regressors to explain this price behavior among the various service stations. With the use of these variables, it is easier to investigate the pricing behavior of the various service stations. The Rho and Lambda indicators used to monitor spatial competition are significant and show how this type of competition exists in this area.

But, variable related to real estate value plays a very important role in our analysis. When this is included in our estimates, the rho coefficient is no longer significant. This would suggest that prices seem to be correlated with each other in space, but this correlation is not due to spatial propagation of prices, but rather is determined by the fact that stations operating in neighbourhoods with higher property values tend to practice higher prices. This very important result testifies to the peculiarities of our study in inserting context variables of such great importance. A significant lambda is found if all variables were considered.

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