Empirical investigation of retail gasoline prices

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Abstract

This paper explores the nature of price variation in the retail gasoline sector with a novel approach. An empirical model is proposed that *jointly* analyses: i) the *spatial interaction* between stations in price setting; ii) the *direct* and the *indirect* effect of *local competition* on prices; iii) the role of *territorial factors*, generally neglected in the studies on gasoline prices. For all these purposes, variables at sub-municipal level are constructed. The results of the empirical model, tested on the city of Rome, confirm the spatial price interaction across stations. Moreover, evidence of *direct* and *indirect* effects of local competition on prices is found: the competitive forces acting in the gasoline sector are not bounded within a local market but they spill over across local markets. Micro-territorial variables turn out to have a sizeable influence on prices, particularly the real estate value. When these variables are added to the model, the strength of spatial interaction weakens. This suggests that including micro-territorial variables in the empirical specification strongly contributes to explain the variation of gasoline prices and to accurately detect the spatial dependence.

Keywords: gasoline prices; spatial interaction; local competition; territorial factors.

1. Introduction

The study of gasoline prices has always been central in the research agenda of industrial economists for several reasons. Firstly, consumers use to spend a substantial share of their income on gasoline (Pennerstorfer and Weiss, 2013), therefore price coordination and collusive behaviours by fuel companies can seriously harm them. Moreover, according to its chemical composition, gasoline can be considered as a quite homogeneous product. Despite this, gasoline prices are found to vary significantly across stations. This can be easily observed because prices are transparent and readily available to all, because each station shows them on totems. In many papers, price differences are motivated by the degree of local competition that, in the gasoline sector, is determined not only by the number of competitors within a local area, but also by the geographical distribution of stations in the nearby. Consumers usually buy the gasoline at stations near to their place of residence (Van Meerbeeck, 2003) because of transportation cost they incur when

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switching between stations. It follows that competition in the gasoline sector is highly localized, and fuel stations recognize as competitors only the closer stations.

We contribute to this research stream by proposing an empirical approach aiming at deepening the knowledge about the determinants of retail gasoline prices by shedding light factors that received little attention so far.

First, we focus on the competitive behaviour of fuel stations. The highly localised nature of competition leads to an oligopolistic interdependence in price setting between closer stations. To model this aspect, we adopt the spatial econometric method that allow us to detect the spatial price interaction, namely whether the price charged by the observed station is influenced by the spatially weighted average price of nearby competitors.

Moreover, we explore both the *direct* and *indirect* impact of local competition on retail gasoline prices. To test for the *direct* impact of local competition, we construct several indexes of market structure at sub-municipal level. Particularly, we consider the presence of low-cost stations, to assess whether they exert a downward pressure on competitors' prices. To test for the *indirect* impact of local competition, we introduce in our analysis the spatially weighted average measures of local competition. In this way, we can examine whether the price charged by a given station is affected by the competition intensity faced by neighbouring competitors.

While the *direct* impact of local competition on retail gasoline prices is widely documented (see, among the others, Van Meerbeek, 2003; Barron et al., 2004; Eckert and West, 2004; Clemenz and Gugler, 2006; Kihm et al., 2016), to the best of our knowledge, the *indirect* effect of local competition remains largely unexplored. This issue should not be overlooked because it can contribute to explain the competitive dynamics in the gasoline sector, thus allowing policy makers to evaluate the effectiveness of measures aimed at restoring competition.

Besides looking at the competitive behaviour of gasoline stations, we also explore the impact of *territorial factors* on prices, generally neglected in the studies on the gasoline sector or, at most, deemed as mere control variables. We presume that a greater demand for fuel, a stronger intensity of economic activity and a higher willingness to pay of residents at the local level can be seized by fuel companies and exploited to charge higher prices.

Our research questions are tested using data on prices charged by fuel stations in the city of Rome (Italy), collected from the detailed data source «Osservatorio Prezzi Carburanti» of the Italian Ministry of the Economic Development. Station-level data are also matched with territorial data.

The rest of the paper is organized as follows. In Section 2 we discuss the related literature on retail gasoline prices, while in Section 3 we illustrate the econometric method. In Section 4 we present the empirical design: we describe the research context and the data and variables' construction. 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 review the existing empirical papers on retail gasoline prices. The survey is organised to discuss the research streams strictly connected to our work: i) competition; ii) spatial dependence; iii) territorial factors.[1]

In the literature, attention has been mainly devoted to the relationship between competition intensity and retail prices. Across studies, the degree of competition has been 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 (calculated as 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 sellers' 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.

Some contributions also consider the concentration measures, 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

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

[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).

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.

Finally, other papers try to explore the effect of unbranded stations' presence on price competition in the local markets where they provide the fuel. As discussed in Van Meerbeeck (2003) the presence of unbranded stations might force competitors to charge lower prices (i.e. competition effect). However, if the gasoline supplied by unbranded stations is perceived as inferior in quality with respect to the gasoline supplied by branded stations, then a greater presence of unbranded stations might reduce the price competition (i.e. composition effect). Van Meerbeeck (2003) shows that the presence of independent stations in the nearby leads competitors to charge lower prices. Similarly, Hastings (2004) finds that a gasoline station charges lower prices when it faces competition from an unbranded station. Clemenz and Gugler (2006) highlight that gasoline prices decrease as long as the share of independent stations increases in the observed local market. Differently, Pennerstorfer (2009) provides evidence in favour of the composition effect because branded stations surrounded by unbranded stations turn out to charge higher prices, although the increase appear to be small in size.

All in all, the majority of the papers surveyed underline a negative relationship between the intensity of market competition and retail gasoline prices, although opposite results are sometimes present. However, they only consider the *direct* effect of local competition on prices, disregarding the *indirect* effect.

In the last decades, there has been a growing research interest in the spatial dependence of gasoline prices, given the highly localized nature of stations' interaction. Previous papers try to assess whether the price of the observed station is influenced by prices of neighbour stations (i.e. spatial autocorrelation of prices) and whether unobserved shocks affect the prices of stations in the same neighbourhood in a similar fashion (i.e. spatial error correlation).

Ning and Haining (2003), using survey data of gasoline stations in Sheffield (UK), find evidence of unobserved shocks affecting prices of neighbour stations. Moreover, they measure spatial price competition by several variables: the price at the nearest-neighbour station irrespective of location; the price at the nearest-neighbour station on the same road; the median price of stations in the same local cluster, and the lowest price charged by stations in the radius of 2.5 km. All variables, except for the former, have a positive impact on the observed station's price. Although by these variables the authors do not explicitly model the spatial autocorrelation, their results suggest that some spatial autocorrelation in prices is present.

Pennerstorfer (2009) explores spatial dependence in gasoline prices by defining a spatial autocorrelation model where also some explanatory variables are spatially weighted. He finds a strong spatial autocorrelation in prices charged by gasoline stations, whereas almost all the spatially weighted covariates turn to be not statistically significant. In a complementary fashion, Pennerstorfer and Weiss (2013), by allowing for spatial autoregressive process is the residuals, show a relevant cross-sectional dependence of gasoline prices.

Further, Hogg et al. (2012), on the South-Eastern Queensland market, carry out a comprehensive spatial econometric analysis on gasoline prices by testing different models. First, they found that gasoline stations are likely to experience unobserved shocks in a very similar fashion, supporting the view that firms in the gasoline market tend to be homogenous. Moreover, they show a spatial autocorrelation in prices together with significant impacts of spatially weighted covariates.

Interestingly, Firgo et al. (2015) focusing on the Austrian gasoline market, explore spatial autocorrelation by considering both the centrality of the stations and the spatial proximity between stations. Their results reveal that gasoline prices are more strongly related to prices of central competitors than to prices of remote rivals. Alderighi and Baudino (2015) simultaneously model spatial autocorrelation in prices and unobserved common shocks. Using data on gasoline stations in Cuneo (IT), they find evidence of spatial price transmission, but the propagation effect appears to be not very strong. Additionally, they show that diesel prices are much more reactive than gasoline prices to respective competitors' prices. This might be explained by the heterogeneity of consumers' price sensitiveness across gasoline types.[5] Finally, Eleftheriou et al. (2018) employ the asymmetric spatial error-correction model to further explore price adjustment mechanisms. Using data of stations located in Hudson County, New Jersey (USA), they provide robust evidence of spatial spillover across prices. Their results emphasize the importance of modelling spatial dependence in the retail gasoline market.

So far, there is a minor evidence on whether and how territorial variables shape the prices of gasoline stations. Previous works mostly consider the population as a proxy of gasoline demand. More specifically, Clemenz and Gugler (2006), Pennerstorfer (2009), Firgo et al. (2015) and Kihm et al. (2016) find a positive relation between the population density (i.e. thousands of people per square km) and the price dependent variable. Pennerstorfer and Weiss (2013) include in the analysis, besides the population density, also the share of tourists. The former appears to have a negative relationship with gasoline prices, thus implying that stations located in remote areas (low level of population density) are significantly more expensive. The latter has a negative but not always significant impact on gasoline prices. Alderighi and Baudino (2015) use the number of workers employed in economic activities near to the observed station to measure gasoline demand. 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. Finally, Firgo et al. (2015) also consider the rate of commuters and the land price. Both appear to be positively related to gasoline prices.

The novelty of our study is to propose an empirical model where the three issues – the spatial price interaction, the influence of competition and territorial factors – are treated in a unified framework. Particularly, we distinguish the *direct* and the *indirect* effect of competition on prices, and we place emphasis on territorial factors by introducing elements not considered before.

[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.

3. Econometric method

We implement a spatial econometric analysis to investigate the determinants of gasoline prices (Anselin, 1988). First, to model the spatial price interaction between stations, we specify the *Spatial Autoregressive Model* (SAR):

$$\mathbf{p} = \iota_N \alpha + \rho \mathbf{W}\mathbf{p} + \beta \mathbf{CI} + \gamma \mathbf{T} + \delta \mathbf{CV} + \varepsilon \qquad \varepsilon \sim iid\ \mathcal{N}(0, \sigma_\varepsilon^2 \mathrm{I}_N) \quad |\rho| < 1 \tag{1}$$

where **p** is the N × 1 dependent variable vector, namely the prices charged by each gasoline station; **CI** is the N × k matrix of variables measuring the local competition intensity; **T** is the N × k matrix of variables capturing micro-territorial differences; **CV** is the N × k matrix of station-level control variables, and β, γ and δ are the related k × 1 vectors of coefficients. Moreover, **W** is the N × N spatial weights matrix, representing the spatial structure of neighbour influences among the residuals and ρ is the coefficient for the endogenous variable **W**p. It amounts to including the average price of neighbours as an additional variable into the regression, referred as spatially lagged dependent variable. Each generic element of **W** is defined as:

$$w_{ij} = \begin{cases} 1 \text{ if } d_{ij} < \mathrm{D} \\ 0\ otherwise \end{cases} \tag{2}$$

where d_{ij} is the distance between station *i* and station *j* and D is the cut off we set equal to the minimum distance allowing each station to have at list one neighbour. The matrix **W** is row-standardized (i.e. the weights are standardized such that $\sum_j w_{ij} = 1, \forall i$) to ensures that $|\rho| < 1$ (i.e. stability condition) is satisfied.

Moreover, we extend the SAR model by including the spatial lag of competition intensity:

$$\mathbf{p} = \iota_N \alpha + \rho \mathbf{W}\mathbf{p} + \beta \mathbf{CI} + \theta \mathbf{WCI} + \gamma \mathbf{T} + \delta \mathbf{CV} + \varepsilon \qquad \varepsilon \sim iid\ \mathcal{N}(0, \sigma_\varepsilon^2 \mathrm{I}_N) \quad |\rho| < 1 \tag{3}$$

where **WCI** is the N × k matrix of spatially-lagged variables for competition and θ is the related k × 1 vectors of coefficients. While β measures the impact of a change in the competition intensity on the price of the observed station (i.e. *direct* effect), θ measures the degree to which the price of a given station is influenced by a change in the weighted average competition intensity faced by neighbouring observations (i.e. *indirect* effect). In this sense, spatial dependence can be seen as the source of indirect effect (Le Sage and Pace, 2009).

The regression coefficients are obtained using Maximum Likelihood Estimator (MLE). Before performing the estimations, we employ the Moran's I statistics for spatial autocorrelation to regression residuals. A positive spatial autocorrelation would be observed when nearby stations show similar prices, whereas a negative spatial autocorrelation would be observed when nearby stations shows very dissimilar prices (Moran 1948, 1950).

Additionally, we consider further statistics obtained from MLE to check the robustness of model specifications: the Wald test is a significance test on the spatial autoregressive parameters in the spatial lag (1) and in the spatial error (3) model, while the Likelihood

Ratio (LR) test statistics compares the spatial models with the model with no spatial effects.

4. Empirical design

4.1 Research context

The Italian gasoline sector consists of vertically integrated companies that control the market from production to sales in service stations. Most of branded stations are company owned and only a few operate as independent dealers. There are major companies holding altogether the 95% of market share: Agip Eni, Api-Ip, Esso, Q8, Shell, Tamoil and Total Erg.[6] 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 compared to the European average (see Alderighi and Baudino, 2015).

The retail price is defined by 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 paid by the gasoline station to the main company. The maximum price is established by the main company that provides also an indication to the stations' owner on the retail price to be charged (see Andreoli-Versbach, 2011).[7]

Our analysis focuses on Rome city because it shows a good degree of heterogeneity in the territorial characteristics that appears to be suitable for testing our research idea. We define gasoline market areas, within Rome city, at the very local level, by adopting the toponymic subdivision (see Figure 1) to detect, with accuracy, the existence of spatial patterns of prices.

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 *suburbs*, namely territories beyond the district, and 53 sparsely populated *zones*, the so-called the Agro Romano.

[6] The company Total Erg results from the merger of two companies, Total and Erg, happened in 2010.

[7] Retail prices has 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, 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 (see *La Situazione Energetica Nazionale nel 2015, 2016*, Direzione Generale per la Sicurezza dell'approvvigionamento e le Infrastrutture Energetiche, Ministero Dello Sviluppo Economico).

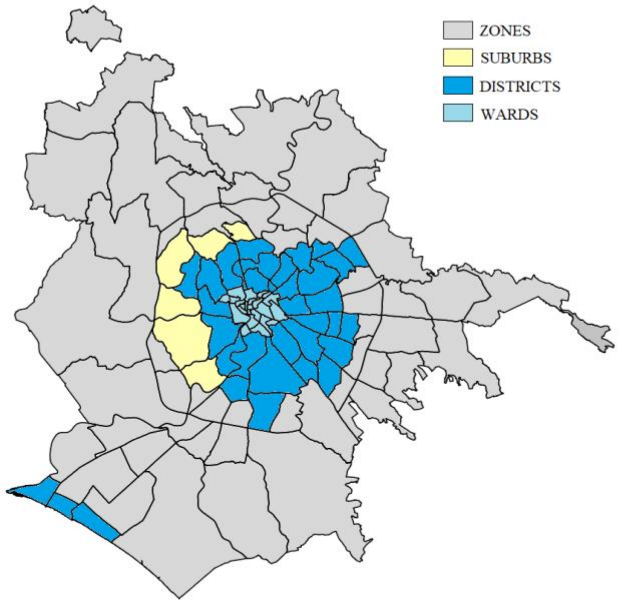

Figure 1. Toponymic subdivisions of Rome city.
Source: Authors' own.

Moreover, Figure 2 shows the fifteen *municipalities* of Rome representing the administrative subdivisions of the territory, corresponding to a more aggregate level compared to toponymic areas.

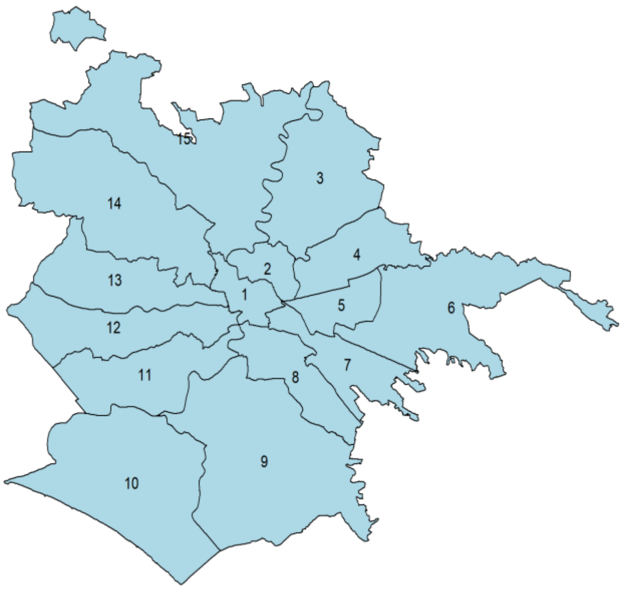

Figure 2. Municipality of Rome city.
Source: Authors' own.

The list of municipalities and toponymic subdivisions is provided in the Appendix (see Table A1).

According to the data collected from the «Osservatorio Prezzi Carburanti» of the Italian Ministry of the Economic Development, in the city of Rome there are 617 self-service stations providing gasoline and diesel fuel. In Table 1, we show the market shares of active oil companies constructed using the number of stations from the same company. The companies with greater market shares are Agip Eni, Api Ip, Q8 and Total Erg. These figures reflect the market shares held by companies at national-level, as previously mentioned.

Table 1. Market shares of oil companies in the city of Rome.

Brand	*Stations (n)*	*Percentage (%)*
Agip Eni	147	23.82
Api Ip	142	23.01
Q8	84	13.61
Total Erg	78	12.64
Esso	54	8.75
White Pumps	43	6.97
Tamoil	31	5.02
Repsol	10	1.62
Retitalia	7	1.13
Blu Fuel	6	0.97
Enerpetroli	6	0.97
7sette	2	0.32
Edra Oil	2	0.32
MyOil	2	0.32
Auchan	1	0.16
Carrefour	1	0.16
Shell	1	0.16
Total	617	100

4.2 Data and variables' construction

We combine station-level data and territorial-level data stemming from different sources. 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, such as the kind of fuel distributed, the provision mode, the location address, the geolocation and the brand name. In our sample, there are 20 different gasoline brand.

Using this database, we define the dependent variable *Price*, the average yearly price per litre of each fuel station *i*. We calculate the average price per litre using the daily self-service prices charged by stations over the observed year for two kinds of fuels, *gasoline* and *diesel*.

Regarding explanatory variables, we construct several measures for competition intensity at the local level:

- *Brand market share*, the market share of gasoline brand *i* in the toponymic subdivision *j*, calculated as the number of same-brand stations within a toponymic subdivision over the total number of stations in that area;
- *CR*3, equal to $\sum_{j=1}^{3} Brand\ market\ share_{i,j}$;
- *HHI*, equal to $\sum_{j=1}^{J} Brand\ market\ share_{i,j}^{2}$;
- *N Stations*, the number of gasoline stations in the toponymic subdivision *j*
- *N Low-cost stations*, the number of low-cost stations in the toponymic subdivision *j*.[8]

To control for differences in prices due to the road where the station 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. Additionally, *Brand dummies* are introduced to control for differences in prices depending on the stations' brand.

Station-level data are matched with data at the territorial-level. In line with surveyed papers, as first proxy of transport demand, we consider the variable *Population 20 to 69*, that we define as the logarithm of the number of inhabitants aged between 20 and 69. We expect a positive coefficient for this variable. Moreover, we define the variable *Commercial activities,* the logarithm of 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 these two variables 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, we define the variable *Real estate value*, the logarithm of the value of buildings per square meter in euro, for which we expect a positive coefficient. This variable is constructed using data from 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.

After data cleaning, due to missing values on some station-level and toponymic-level variables, we end up with a final dataset comprising 601 valid observations. In Table 2 we summarize the definitions and the data sources for the variables in the empirical analysis, while in Table 3 we provide some descriptive statistics.

[8] *Low-cost stations* are Auchan, Pompe Bianche and Carrefour.

Table 2. Variables' definition and data sources.

Variable	*Description*	*Level*	*Source*
Price	Average yearly self-service price per litre for two kinds of fuels (gasoline and diesel) of station *i*.	Station	Osservatorio Prezzi Carburanti, Italian Ministry of the Economic Development.
Brand market share	Market share of gasoline brand *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).	Toponymic	Osservatorio Prezzi Carburanti, Italian Ministry of the Economic Development.
CR_3	Equal to $\sum_{j=1}^{3} Brand\ market\ share_{i,j}$	Toponymic	Osservatorio Prezzi Carburanti, Italian Ministry of the Economic Development.
HHI	Equal to $\sum_{j=1}^{J} Brand\ market\ share_{i,j}^{2}$.	Toponymic	Osservatorio Prezzi Carburanti, Italian Ministry of the Economic Development.
N Stations	Number of gasoline stations in the toponymic area *j*.	Toponymic	Osservatorio Prezzi Carburanti, Italian Ministry of the Economic Development.
N Low-cost stations	Number of low-cost gasoline stations in the toponymic area *j*.	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.		
Population 20 to 69	Logarithm of the number of inhabitants aged between 20 and 69.	Municipality	National Institute for Statistics (ISTAT).
Commercial activities	Logarithm of the number of active commercial businesses.	Municipality	National Institute for Statistics (ISTAT).
Real estate value	Logarithm of the average yearly value of civil dwellings per square meter in euro.	Toponymic	Revenue Agency (Agenzia delle Entrate – OMI).

Table 3. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Gasoline Price	601	14.742	0.0595	1.148	1.750
Diesel Price	599	12.843	0.0630	1.137	1.557
Brand market share	601	28.536	19.696	3.57	100
CR_3	601	88.852	13.021	60	100
HHI	601	2,853.596	1,676.876	1,377.78	10,000
N Station	601	1.1156	6.4092	1	28
N Low cost station	601	1.0150	1.5389	0	6
Big Brand station	601	9.4143	5.0662	0	20
Motorway	601	0.03	0.1706	0	1
Trunk roads	601	0.03	0.1706	0	1
Other roads	601	0.9401	0.2375	0	1
Population 20 to 69	601	95,379.55	31,841.54	30,611	155,289
Commercial activities	601	4,336.854	2,106.971	1,699	12,936
Real estate value	601	3,085.014	784.7428	1,633.333	7,25

5. Results and discussion

The presentation of results is organized as follows. The estimation results of SAR model with as dependent variables the *gasoline* prices and the *diesel* prices are collected in Table 4*a* and Table 4*b*, respectively. The estimation results of SAR model with the inclusion of spatially-lagged competition variables are reported in Table 5.[9]

The Moran's I test statistics reported at the bottom of each table, allows to strongly reject the null of zero-correlation among observations, it shows a positive relationship between prices and spatially-lagged prices, which implies a positive spatial autocorrelation. In other words, nearby gasoline and diesel stations tend to apply similar prices. Moreover, the LR test statistics confirms that the spatial model is preferred over the model with no spatial effects. Overall, the suitability of spatial regression analysis is strongly supported.

The variables measuring the competition at the local level are introduced one at a time in the model because they are built using the same data (i.e. number of stations). Moreover, we estimate regressions with and without the territorial variables to assess their contribution in explaining price variation across stations. Overall, estimated coefficients are robust across regressions with *gasoline* and *diesel* prices.

The coefficients of *Brand market share, CR_3* and *HHI* are all positive and highly significant across regressions for both types of fuel prices, thus suggesting that the higher the market share and the concentration within a toponymic area, the higher the prices charged by stations. Consistently, the coefficient of *N Stations* is negative and highly significant: the greater the number of stations within a toponymic area, the lower the price charged by competitors. Regarding the presence of low-cost stations, we provide evidence in favour of the competition effect because the coefficient of *N Low-cost stations* is negative and highly significant. Our findings, in line with previous research (Van Meerbeek, 2003; Barron et al., 2004; Eckert and West, 2004; Clemenz and Gugler, 2006;

[9] Estimations are performed with R software, *spdep* package developed by Bivand (2018).

Kihm et al., 2016), allow us to claim that a greater competition at the local level is clearly associated with lower prices, whatever measure of competition is used.

Concerning station-level controls, the coefficients of *Trunk road* and *Other road* are negative and significant. This implies that stations located on these types of roads charge lower prices compared to stations located on *Motorway* (the omitted category).

Turning to territorial variables, the coefficient of *Population 20 to 69* is not statistically different from zero, while the coefficient of *Commercial activities* is positive and significant across regressions. In the city of Rome, or more generally in large cities, the number of people moving to a district because of its attractiveness (commercial activities, schools and other facilities) might be very different from the number of actual residents. Therefore, the number of potential fuel consumers can be better proxied by the presence of economic activities in the observed municipality rather than by the mere number of residents. Moreover, the coefficient of *Real estate value* is positive and highly significant across regressions, meaning that the greater the richness of the local area, the higher the prices charged by stations. Interestingly, this variable appears to have the greatest effect on prices compared to the other territorial factors.

Coming to the coefficient ρ for the endogenous variable $\mathbf{W}$p, it appears to be positive and highly significant across regressions, thus confirming the existence of spatial price interaction among competing stations. However, it is worth noting that the size of ρ is lower in regressions where the territorial variables are included.[10]

The results of the SAR model with spatially-lagged competition variables confirm the results already obtained with the baseline SAR model. In the specific, the coefficients of the spatially-lagged CR_3, *N Stations* and *N Low-cost stations* are significant and have the same sign of the corresponding variable. The prices charged are *directly* affected by the competition faced by the observed stations, but they are also *indirectly* affected by the average (spatially weighted) competition faced by neighbouring stations. In other words, an increase in local competition has a negative effect on the price charged by a given station, which is transmitted to prices charged by competitors in the neighbours. Interestingly, the curbing effect on prices by low-cost stations' presence appears to be very strong: it is not limited to competitors in the same local market but, instead, affects competitors in nearby local markets.

With the introduction of spatially-lagged competition variables, the significance level and the size of the coefficient ρ for the endogenous variable $\mathbf{W}$p notably reduce, meaning the spatial interaction is also explained by the spatial dependence of competition variables.

All in all, our results highlight the relevance of introducing the spatially-lagged competition variables and territorial variables in the empirical specification to better capture the spatial structure of gasoline prices, which is explained, not only by the spatial autocorrelation, but also by the spatial dependence of competition variables. For the same reason, the inclusion of territorial variables seems relevant for capturing micro-territorial differences.

We have also performed the estimations using the average yearly full-service prices per litre for *gasoline* and *diesel* as dependent variables, instead of self-service prices.[11] In this case, price variation turns to be explained mostly by brand-specific dummies. There is no

[10] The authors have performed regressions by adding one at a time the territorial variables. It turns out the size of ρ shrinks the most as the variable Real estate value is introduced. These estimations are available from the authors upon request.

[11] Results are available from the authors.

evidence of spatial price interaction between stations and, moreover, neither competition variables nor territorial variables are found to affect prices consistently. This could be because consumers purchasing the full-service gasoline are typically less price sensitive and, thus, less willing to drive around to find out the cheapest station. This implies that for these consumers, stations might set prices following their brand strategies, regardless of the competitive environment and any other factors.

Table 4a: SAR model. Dependent variable: Average yearly *gasoline* price.

	Brand Market Share	*CR_3*	*HHI*	*N Stations*	*N Low-cost stations*	*Brand Market Share*	*CR_3*	*HHI*	*N Stations*	*N Low-cost stations*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
W Price (ρ)	0.62594***	0.58699***	0.62045***	0.58608***	0.5913***	0.52359***	0.45924***	0.5261***	0.49939**	0.49958***
Competition	0.00037**	0.00050**	0.00049**	-0.00164***	-0.00629***	0.00030**	0.00074***	0.00041**	-0.00185***	-0.00733***
	(0.00012)	(0.00019)	(0.0001)	(0.00037)	(0.00158)	(0.00013)	(0.00019)	(0.00014)	(0.00040)	(0.00161)
Road Type*										
Trunk Road	-0.04472**	-0.04230**	-0.0458**	-0.04129**	-0.03979**	-0.05012**	-0.04803**	-0.05068**	-0.04448**	-0.04441**
	(0.01916)	(0.01916)	(0.01911)	(0.01899)	(0.01904)	(0.01886)	(0.018722)	(0.01882)	(0.01864)	(0.01865)
Other Roads	-0.04662***	-0.04476***	-0.04526***	-0.03993***	-0.04594***	-0.05857***	-0.05748***	-0.05732***	-0.05192**	-0.05929***
	(0.01364)	(0.01369)	(0.01361)	(0.01363)	(0.01356)	(0.01361)	(0.01351)	(0.01360)	(0.01354)	(0.01343)
Brand dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Territorial Variables										
Population 20 to 69						-0.00298	0.00252	-0.00182	0.00610	0.00355
						(0.00621)	(0.00649)	(0.00624)	(0.00656)	(0.00641)
Commercial Activities						0.01771**	0.01867**	0.016890**	0.01078*	0.01765**
						(0.00627)	(0.00616)	(0.00628)	(0.00644)	(0.00613)
Real estate value						0.03489**	0.04411***	0.03470461**	0.04620***	0.04088
						(0.01104)	(0.01102)	(0.01101)	(0.01096)	(0.01081)
LR test Value	16.292	13.649	15.993	13.945	14.189	9.7472	7.2276	9.8811	8.8807	8.8815
AIC	-1708	-1707.1	1711.7	-1719.2	-1715.5	-1728.1	-1737.2	-1730.7	-1743.7	-1743
Wald Statistics	25.415	20.772	24.81	23.028	22.179	13.987	9.4718	14.112	11.831	11.871
Moran's I test	0.03532 ***	0.03532 ***	0.03532 ***	0.03532 ***	0.03532 ***	0.03532 ***	0.03532 ***	0.03532 ***	0.03532 ***	0.03532 ***
Observations	601	601	601	601	601	601	601	601	601	601

*Omitted category: motorway.

*** p<0.01, ** p<0.05, * p<0.11

Table 4b: SAR model. Dependent variable: Average yearly *diesel* price.

	Brand Market Share	*CR$_3$*	*HHI*	*N Stations*	*N Low-cost stations*	*Brand Market Share*	*CR$_3$*	*HHI*	*N Stations*	*N Low-cost stations*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
W Price (ρ)	0.6736***	0.64103***	0.66704***	0.64036***	0.64924***	0.56987***	0.5145***	0.56957***	0.54489***	0.54771***
Competition	0.00036** (0.00014)	0.00055** (0.00018)	0.00048*** (0.00015)	-0.0017*** (0.00041)	-0.00622*** (0.00185)	0.00028** (0.00014)	0.00074*** (0.00018)	0.00038** (0.00015)	-0.00190*** (0.00043)	-0.00730*** (0.00191)
Road Type*										
Trunk Road	-0.04049** (0.02025)	-0.03827* (0.02019)	-0.04156** (0.02021)	-0.03721* (0.02007)	-0.03574* (0.02017)	-0.04620** (0.01999)	-0.04439** (0.01980)	-0.04673** (0.01996)	-0.04061** (0.01978)	-0.04089** (0.01984)
Other Roads	-0.04074** (0.014424)	-0.03824** (0.01444)	-0.03934** (0.01440)	-0.03387** (0.01442)	-0.04038** (0.0143726)	-0.05242*** (0.01444)	-0.05087*** (0.01429)	-0.05115*** (0.014435)	-0.04550*** (0.014372)	-0.05345 (0.01429)
Brand dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Territorial Variables										
Population 20 to 69						-0.00552 (0.00659)	-0.00021 (0.00677)	-0.00448 (0.00662)	0.00382 (0.00697)	0.00041 (0.00683)
Commercial Activities						0.01624** (0.00668)	0.01748** (0.00654)	0.01549** (0.00669)	0.00908 (0.00685)	0.01678** (0.00654)
Real Estate Value						0.03705 (0.01175)	0.04638*** (0.01165)	0.03680*** (0.01173)	0.00908*** (0.00686)	0.04301*** (0.01160)
LR test Value	21.15	18.44	20.671	18.703	19.211	12.929	10.225	12.941	11.805	11.893
AIC	-1634.5	-1637	-1637.6	-1645.4	-1638.9	-1651.4	-1663.2	-1653.5	-1666.3	-1662.1
Wald Statistics	34.463	29.366	33.288	31.872	30.929	18.937	13.388	18.776	15.863	16.222
Moran's I test	0.04477***	0.04477***	0.04477***	0.04477***	0.04477***	0.04477***	0.04477***	0.04477***	0.04477***	0.04477***
Observations	599	599	599	599	599	599	599	599	599	599

*Omitted category: motorway.

*** p<0.01, ** p<0.05, * p<0.11

Table 5: SAR model with spatially lagged variables.

	Dependent variable: Average yearly *gasoline* price.					Dependent variable: Average yearly *diesel* price.				
	Brand Market Share	CR_3	*HHI*	*N Stations*	*N Low-cost stations*	*Brand Market Share*	CR_3	*HHI*	*N Stations*	*N Low-cost stations*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
W Price (ρ)	0.46084***	0.22753	0.44278***	0.34522**	0.36949**	0.50716***	0.29391*	0.48801***	0.39302**	0.39954**
Competition	0.00028** (0.00013)	0.00055** (0.00020)	0.00037** (0.00014)	-0.00149*** (0.00043)	-0.00662*** (0.00164)	0.00026* (0.00014)	0.00056** (0.00020)	0.00035** (0.00015)	-0.001510** (0.00047)	-0.00642*** (0.00195)
W Competition	0.00083 (0.00056)	0.00133*** (0.00055)	0.0010 (0.00061)	-0.00232** (0.00110)	-0.01049** (0.00532)	0.00091 (0.00059)	0.00146** (0.00056)	0.00108 (0.00064)	-0.00264** (0.00120)	-0.01480** (0.00645)
Road Type*										
Trunk Road	-0.05647** (0.01935)	-0.05271** (0.01876)	-0.05770** (0.01930)	-0.05302** (0.01903)	-0.04958** (0.01881)	-0.05289** (0.02047)	-0.05000** (0.01986)	-0.05401** (0.02042)	-0.04994** (0.02017)	-0.04681** (0.01997)
Other Roads	-0.05936*** (0.01362)	-0.05854*** (0.01352)	-0.05826*** (0.01362)	-0.05593*** (0.01372)	-0.06252*** (0.013574)	-0.05329*** (0.014449)	-0.05223*** (0.01430)	-0.05217*** (0.01445)	-0.04986*** (0.014544)	-0.05680*** (0.01438)
Brand dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Territorial Variables										
Population 20 to 69	-0.00117 (0.00642)	-0.05854 (0.01351)	-0.00019 (0.00640)	0.00794 (0.00670)	0.00792 (0.00693)	-0.00355 (0.00680)	0.00308 (0.00698)	-0.00272 (0.00678)	0.00594 (0.00711)	0.00587 (0.00738)
Commercial Activities	0.01867** (0.00629)	0.01703** (0.00618)	0.01806** (0.00630)	0.01157* (0.00643)	0.01647** 0.0061637	0.01726** (0.00670)	0.01626** (0.00654)	0.01673** (0.00671)	0.00988 (0.00685)	0.01543** (0.00656)
Real Estate Value	0.03671*** (0.01107)	0.06026*** (0.01245)	0.03681*** (0.01104)	0.05857*** (0.01226)	0.05141*** (0.01188)	0.03883*** (0.01176)	0.06416*** (0.01320)	0.03881*** (0.01173)	0.06255*** (0.01306)	0.05617*** (0.01271)
LR test Value	6.7105	1.1996	5.9491	3.1851	3.805	9.0507	2.2729	8.0478	4.5888	4.8267
AIC	-1728.1	-1741.2	-1731.2	-1746	-1744.6	-1651.7	-1667.7	-1654.2	-1668.9	-1665
Wald Statistics	9.2927	1.5822	8.2707	4.2039	4.9167	12.65	2.9378	11.212	6.0387	6.1965
Moran's I test	0.03532 ***	0.03532 ***	0.03532 ***	0.03532 ***	0.03532 ***	0.04477***	0.04477***	0.04477***	0.04477***	0.04477***
Observations	601	601	601	601	601	599	599	599	599	599

*Omitted category: motorway.

*** p<0.01, ** p<0.05, * p<0.11

6. Concluding remarks

In this paper, we explore the pricing behaviour of gasoline stations by shedding light on the factors that received little attention in the related literature despite they can play a significant role in affecting fuel prices. We apply the spatial econometric method to test for the spatial autocorrelation of fuel prices and to appreciate whether there is a strategic spatial interaction in price setting among stations. Moreover, we analyse in depth the role of local competition by capturing both its *direct* and *indirect* effect on prices. We suppose that the local competition might have an indirect effect on the price of a given station by influencing the pricing behaviour of stations operating in the neighbours of that station. Finally, we focus on the role of territorial factors in explaining gasoline price variation by considering different elements describing the local environment.

For this research, we employ station-level data and territorial data on the city of Rome to construct competition variables and territorial variables at a very disaggregated level, namely the toponymic subdivision of the city.

Our results are robust across regressions with gasoline and diesel prices as dependent variables. First, fuel stations are found to adopt a strategic behaviour in price setting, given the significant spatial autocorrelation we consistently find across spatial models. We also find evidence of the *direct* and *negative* effect of local competition on fuel prices, as largely documented in the related literature. Remarkably, we also find evidence of the *indirect* and *negative* effect of local competition, on which little is known. The existence of the *indirect* effect entails that the competitive forces acting in the gasoline sector are not bounded within a local market but they spill over across local markets. These findings have important implications for policy-makers because fostering competition within a market has a more pervasive impact on prices than one might expect. Moreover, from the consumer's perspective, the presence of low cost stations appears to be particularly beneficial.

The intensity of business activities and real estate values turn out to be relevant predictors of fuel prices, thus implying that pricing behaviour of fuel stations is moulded on the characteristics of the local environment, presumably exploited to increase fuel sales.

Our analysis, although offering interesting insights, might be specific for the city explored. However, the heterogeneity of local environments linked to the high population density and thriving business activities, make the city of Rome a valid benchmark for other large metropolitan cities in Europe. A development of the research could be testing the empirical framework we have proposed on a larger number of cities, to see whether coherent patterns emerge or, instead, whether fuel stations adopt different pricing behaviors across city with different market conditions and local environments.

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Appendix

Table A. Municipalities and toponymic subdivisions of Rome

Municipality	*Topoymic subdivision*
Municipality I	**Wards**: I – Monti, II – Trevi, III – Colonna, IV – Campo Marzio, V – Ponte, VI – Parione, VII – Regola, VIII – Sant'Eustachio, IX – Pigna, X – Campitelli, XI – Sant'Angelo, XII – Ripa, XIII – Trastevere, XIV – Borgo, XV – Esquilio, XVI – Ludovisi, XVII – Sallustiano, XVIII – Castro Pretoria, XIX – Celio, XX – Testaccio, XXI – San Saba, XXII – Prati. **Districts:** X – Ostiense, XIV – Trionfale, XV – della Vittoria, XX – Ardeatino.
Municipality II	**Wards**: XVIII – Castro Pretorio. **Districts:** I – Flaminio, II – Parioli, III – Pinciano, IV – Salario, V – Nomentano, VI – Tiburtino, XVII – Trieste; XXI – Pietralata.
Municipality III	**Districts:** XVI – Monte Sacro, XXVIII – Monte Sacro Alto. **Zones**: Area I – Val Melaina, Area II – Castel Giubileo, Area III – Marcigliana, Area IV – Casal Boccone, Area V – Tor San Giovanni.
Municipality IV	**Districts:** VI – Tiburtino, XXI – Pietralata, XXII – Collatino, XXIX – Ponte Mammolo, XXX – S. Basilio. **Zones**: Area VI – Settecamini, Area VII – Tor Cervara, Area VIII – Tor Sapienza, Area IX – Acqua Vergine.
Municipality V	**Districts:** VI – Tiburtino, VII – Prenestino Labicano, VIII – Tuscolano, XIX – Prenestino Centocelle, XXII – Collatino, XXIII – Alessandrino, XXIV – Don Bosco. **Zones**: Area VIII – Tor Sapienza, Area XII – Torre Spaccata.
Municipality VI	**Districts:** XXIV – Don Bosco. **Zones**: Area IX – Acqua Vergine, Area X – Lunghezza, Area XI – San Vittorino, Area XII – Torre Spaccata, Area XIII – Torre Angela, Area XIV – Borghesiana, Area XV – Torre Maura, Area XVI – Torrenova, Area XVII – Torre Gaia.
Municipality VII	**Districts:** IX – Appio Latino, X – Ostiense, XX – Ardeatino, XXVI – Appio-Pignatelli. **Zones**: Area XXI – Torricola, Area XXII – Cecchignola, Area XXIII – Castel di Leva.
Municipality VIII	**Districts:** IX – Appio Latino, X – Ostiense, XX – Ardeatino, XXVI – Appio-Pignatelli. **Zones**: Area XXI – Torricola, Area XXII – Cecchignola, Area XXIII – Castel di Leva.
Municipality IX	**Districts:** X – Ostiense, XXXI – Giuliano Dalmata, XXXII – Europa. **Zones**: Area XXII – Cecchignola, Area XXIII – Castel di Leva, Area XXIV – Fonte Ostiense, Area XXV – Vallerano, Area XXVI – Castel di Decima, Area XXVII – Torrino, Area XXVIII – Tor de' Cenci, Area XXIX – Castel Porziano, Area XXXI – Mezzocammino, Area XXXIX – Tor di Valle.
Municipality X	**Districts:** XXXIII – Lido di Ostia Ponente, XXXIV – Lido di Ostia Levante, XXXV – Lido di Castel Fusano. **Zones**: Area XXVIII – Tor de' Cenci, Area XXIX – Castel Porziano, Area XXX – Castel Fusano, Area XXXI – Mezzocammino, Area XXXII – Acilia Nord, Area XXXIII – Acilia Sud, Area XXXIV – Casal Palocco, Area XXXV – Ostia Antica.
Municipality XI	**Districts:** XI – Portuense, XII – Gianicolense. **Suburbs**: VII – Portuense, VIII – Gianicolense. **Zones**: Area XL – Magliana Vecchia, Area XLI – Ponte Galeria, Area XLIV – La Pisana.
Municipality XII	**Districts:** XI – Portuense, XII – Gianicolense. **Suburbs**: VIII – Gianicolense. **Zones**: Area XLIII – Maccarese Nord, Area XLIV – La Pisana, Area XLV – Castel di Guido.
Municipality XIII	**Districts:** XIII – Aurelio, XIV – Trionfale, XXVII – Primavalle. **Suburbs**: IX – Aurelio, X – Trionfale. **Zones**: Area XLV – Castel di Guido; Area XLVIII – Casalotti.