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Locational choice and price competition: some empirical results for the austrian retail gasoline market

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Abstract Using data from the Austrian retail gasoline market we find that a higher station density reduces average prices. Market (i.e. ownership) concentration does not significantly affect average price, however is negatively related to the density of stations. Estimation of the pricing and entry equations as simultaneous equations does not alter our conclusions, and suggests causality running from station density to price. We argue that the spatial dimension of markets allows the identification of market conduct, which is particularly relevant for competition policy.

Keywords Spatial competition · Retail gasoline · Pricing regressions

JEL Classification L1 · L13 · L81

1 Introduction

The purpose of the paper is twofold: Firstly, we want to test empirically for the Austrian gasoline market two hypotheses derived from models of spatial competition concerned with the relationships between population density, density of outlets, and prices. Secondly, we want to show how these results can be used to determine whether there is price competition or collusion in a market in which the location of suppliers plays an important role.

The second purpose is particularly interesting in view of the fact that the European Commission has recently widened the concept of dominance by including joint or collective dominance in merger and antitrust analysis. To judge whether firms compete with each other or whether they collude, competition authorities need to have an appropriate notion of "competition". That is, to decide whether firms behave anti-competitively, they need to have a benchmark model

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against which to compare actual market conduct. The textbook model of perfect competition where price equals marginal cost in equilibrium is particularly inappropriate for markets characterized by large fixed or sunk entry and exit costs, as e.g. in the retail gasoline market.

We argue that the spatial dimension of markets allows one to identify possible dominance by a firm or group of firms. The retail gasoline market *is* characterized by a strong spatial dimension a feature which can be used to identify (anti-) competitive behavior. In particular, provided there is competition between stations, the nearer they are next to each other, on average, the lower should be the equilibrium price they can charge. The alternative (collusion) hypothesis would be *no* or even a *positive* relation between station density and price. No systematic relation between station density and price is expected if stations collude in price setting so that they effectively eliminate competition between them. A positive relation between station density and price might even result from facilitated collusion if stations are nearer to each other (e.g. if detection lags of deviant behavior are shorter), and/or if higher station density enables station operators to collectively better siphon off the additional consumer surplus that is generated by lower consumer transport costs. Thus, if one explicitly recognizes the spatial dimension of markets, identification of market conduct is possible.[1] Moreover, directly utilizing the spatial dimension of markets to identify market conduct obviates the need to use market concentration–price relations, which suffer from problems of reverse causality and endogeneity.

Building on the seminal paper of Hotelling (1929) a large number of theoretical models of spatial competition have been analyzed.[2] Though the papers differ considerably with respect to their scope and purpose it seems fair to say that the following two questions are among the core issues of spatial economics: (i) What determines the equilibrium pattern of locations of firms? (ii) What are the properties of the equilibrium prices if there is spatial competition between firms? Not surprisingly, different models come up with different results, depending on their main focus, but at times also on rather subtle differences in their assumptions. However, the following two hypotheses are supported by, or at least compatible with the vast majority of theoretical models:

Hypothesis 1 With free entry retail shops tend to be more densely located in areas with a higher population density.

Hypothesis 2 With spatial competition, equilibrium prices tend to be lower the higher the density of seller locations is.

Hypothesis 2 has an obvious consequence for Hypothesis 1: With spatial competition the increase in the density of shops must be less than proportional to the increase in population density since a higher station density reduces the equilibrium price.

[1] Guidelines to identify market conduct are particularly relevant given the strict theoretical and data requirements for detecting collusive behavior in other models of competition (see Phlips 1995).

[2] For surveys see e.g. Anderson et al. (1992); Beath and Katsoulacos (1991); Beckmann and Thisse (1986); Martin (1993); Tirole (1988).

As far as hypothesis 1 is concerned two remarks should be made: Firstly, a positive correlation between station density and population density is also compatible with collusive behaviour. A pure monopolist would also increase the number of outlets if the number of consumers increases, though she would run fewer outlets and increase their number by less than would be observed in a competitive market. Our data do not, however, allow for discrimination between competition and a lack of it with respect to the choice of locations. Secondly, other oligopoly models are also compatible with the observation that the number of firms is increasing in the number of consumers, e.g. the Cournot model. In a Bertrand model or in a pure monopoly with a homogenous good, however, such a relationship would not exist. Considering that petrol is almost homogenous at the least such an observation would underline the importance of the spatial aspect in the retail market for petrol.

The retail gasoline market appears to be particularly apt for testing predictions of spatial economics for the following reasons.[3] (i) Gasoline can be considered as an almost perfectly homogenous good with respect to its physical and chemical properties. (ii) As a consequence, gasoline stations are engaged in direct competition almost entirely only with their immediate neighbors, which agrees with most models of spatial competition.[4] (iii) Gasoline stations cause substantial entry and exit costs, and frequently used two stage models with the choice of location in the first stage and (price) competition in the second stage capture quite well some of the crucial features of the retail gasoline market. (iv) Last, but not least, relevant data are available, particularly because prices are quite transparent and well documented.

In spite of this, to the best of our knowledge this is the first empirical test of the two above mentioned hypotheses resulting from models of spatial competition for the retail gasoline market. There exists, however, a fair number of empirical studies of the gasoline market, though their focus is different from that of this paper. Several authors have addressed the question whether recent game theoretic models are compatible with observed price movements in gasoline markets, most notably M. Slade (1987, 1992); Castania and Johnson (1993) or Borenstein and Shepard (1996). Spatial competition, however, is not a main concern in these papers. Borenstein's (1991) focus is on the determinants of margin differences between leaded and unleaded gasoline. Others have used data from gasoline markets to assess the impact of policy measures or of certain contractual arrangements on gasoline prices (Anderson and Johnson 1999; Johnson and Romeo 2000; Shepard 1993). An interesting line of research concerns the choice of contract between gas stations and their suppliers (Slade 1996; 1998). Finally, the demand for gasoline

[3] A more detailed description of the structure of a retail gasoline market can be found in von Weizsäcker (2002).

[4] For a recent test of the spatial dimension of competition, see Pinkse et al. (2001). They conclude that competition in the *wholesale* gasoline market is highly localized. It appears that competition in the *retail* gasoline market is even more likely to be localized.

has been estimated by several authors (Schmalensee and Stoker 1999; Baltagi and Griffin 1997). Considine (2001) analyses an upstream market, petroleum refining.[5]

We show that both of the above hypotheses are very well supported by the data. Using the 121 political districts of Austria as regional units we find that population density explains more than 95% of the cross-district variation in the density of gasoline stations. As far as the relationship between prices and the density of gas stations is concerned we find in all specifications that the coefficient has the predicted negative sign and is significant at the 5% level or better. Market (ownership) concentration does not have a clear-cut relation to price. Moreover, we do not obtain different results when we estimate a simultaneous equations system, nor when we choose different regional units.

The plan of the paper is as follows. In the next section we give a brief outline of the theoretical rationale for the two hypotheses we are going to test. In Section 3 we describe the data basis, and in Section 4 we present our empirical results. Section 5 concludes.

2 Theoretical background

Probably the most well known model of spatial competition is the circle model of Salop (1979).[6] This model has been modified in a number of ways. Capozza and Van Order (1980) have made the distinction between immobile and portable firms, and Eaton and Wooders (1985) have analysed equilibria in models where relocation is prohibitively costly. The analysis becomes rather involved, and in particular the equilibrium cannot be expected to be unique (if one exists at all), or to require zero profits. In what follows therefore we focus on a description of those aspects of the Salop (1979) model, which are relevant for our purpose (see the Appendix for more details).

A crucial feature of pure spatial competition is that each consumer buys at that shop where total costs, consisting of price (times quantity) plus any transport costs she has to incur are smallest. Consequently, each shop has a “local monopoly” whose geographical size depends on the prices charged by the nearest competitors and the transport costs consumers have to incur at different shops in a given area. The latter depend to a large extent on the distances between different shops, but also on the quality of the roads, the availability of public transport, etc.

Clearly, the price a shop can charge is increasing in the distance from the nearest competitors and in the transport costs of consumers. The demand such a local monopoly is facing does not only depend on the geographical size of the market, but on the total number of consumers in that area and therefore, for a given area, on the population density, denoted as D. When choosing a location a firm wants to be where many consumers are, but only few competitors. If there are no entry restrictions firms will establish outlets in a region as long as the setup costs are smaller than the expected profits. In a more densely populated region firms can

[5] Bresnahan and Reiss (1990, 1991) focus on how the number of firms in a market relates to market size, and thereby infer how market power relates to the number firms. There are a few empirical studies on spatial aspects of competition for other markets (Asplund and Sandin 1999; Claycombe and Mahan 1993; Fik 1988), whose focus, however, is different from ours. In particular, locational choice is not part of these investigations.

[6] See also chapter 6 of Anderson et al. (1992).

locate closer to each other than in thinly populated regions because demand per square kilometer is greater. However, the number of shops will increase less than proportionally to the population density since the greater proximity of shops will reduce the equilibrium price.

In reality, additional factors may affect the location decisions of firms. Most obviously, it is not just the number of consumers, but also the demand per consumer, which determines the expected profit per shop. The per capita demand, in turn, depends on the per capita income and, as far as the demand for gasoline is concerned, the number of cars per capita, denoted as *V*.

Another complication arises from the fact that the simplifying assumption that each firm has only one location is certainly not true for the retail gasoline market. Unfortunately, there is no straightforward answer to the question of how market (i.e. ownership) concentration will affect the density of shops. It seems safe to say that the number of outlets a pure monopolist without entry threat will run is the lower bound. Conversely, the upper bound for the number of shops is given by the number of locations a monopolist will set up if there is free entry.[7] Beyond that we have no clear prediction concerning the relationship between market concentration and density of gasoline stations.

Finally, it is worth mentioning that even the retail gasoline market does not fully conform to pure spatial competition. Some consumers have a preference for particular brands, and gas stations compete not only via prices, but also by offering special services, running shops, etc. It is hard to tell, however, how effective these additional strategic variables actually are, and as far as our empirical analysis is concerned we do not have reliable data to test their impact.

In addition to the variables already defined above we use the following notation: *C* is some measure of market concentration, *T* are consumer transport costs, and *S* is the density of shops. The above discussion on the determinants of the density of gasoline stations can be summarized by the following equation and partial derivatives

$$\begin{aligned} &S = S(D, V, T, C, \ldots), \\ &\partial S/\partial D > 0;\ \partial^2 S/\partial D^2 < 0;\ \partial S/\partial V > 0;\ \partial^2 S/\partial V^2 < 0;\ \partial S/\partial T > 0;\ \partial S/\partial C = ? \end{aligned} \tag{1}$$

That is, we expect the demand variables *D* and *V* to positively affect station density. Since larger station density implies increased competition and thus lower equilibrium prices, *S* is expected to be increasing in *D* and *V*, though at a decreasing rate. Station density is also increasing in consumer transport costs *T*. The question mark for the partial derivative with respect to market concentration *C* captures the ambiguity of predictions.

Consider next the equilibrium price for given locations of shops. As argued above, with spatial competition prices can be expected to be increasing in the distances between shops and increasing in the transport costs of consumers. In our empirical analysis we use *S*, the density of shops, as a (inverse) proxy for these

[7] A monopolist who wants to prevent entry will set up more outlets than would result from free entry with single location firms since the monopolist can charge a higher than the competitive price as long as no entry occurs, and a higher density of outlets makes her "tougher" if a competitor enters the market.

distances. Furthermore, equilibrium prices are increasing in marginal costs, denoted as *c*.

An interesting question concerns the impact of market concentration on the retail price. We would expect prices to be increasing in the degree of concentration for at least two reasons:

a) If a firm is able to set up a cluster of outlets such that some of her shops have only shops run by herself as nearest "competitors" then these shops are protected from outside competition and can charge a higher price than with pure spatial competition.
b) In highly concentrated markets tacit collusion is more likely to occur than in markets with many competitors.

However, concentration may be endogenously determined and simply proxy for the efficiency of multi-branch firms leading to lower retail prices.[8] Thus, we do not make strong predictions as to the effects of concentration. To sum up, the price equation and partial derivatives can be written as

$$\begin{aligned} &P = P(S, T, c, C, \ldots) \\ &\partial P/\partial S < 0;\ \ \partial P/\partial T > 0;\ \ \partial P/\partial c > 0;\ \ \partial P/\partial C = ? \end{aligned} \tag{2}$$

With spatial competition, we expect a higher station density *S* to reduce equilibrium price. As already mentioned, the alternative hypothesis would be *no* or even a *positive* relation between station density and price, if stations collude in price setting so that they effectively eliminate competition between them. Larger consumer transport costs *T* and larger marginal costs *c* increase price. Expectations are ambiguous concerning the effects of market concentration *C* on price.

In (1) and (2) we have assumed that entry decisions precede price competition, that is that station density is a predetermined variable with respect to price. We will, however, test whether *S* and *P* are simultaneously determined by estimating (1) and (2) as simultaneous equations below.

3 The data

To test the predictions of spatial competition as outlined in Section 2, we first assembled a comprehensive list of gasoline stations in Austria as of the beginning of 2001. Unfortunately, there does not exist a comprehensive list of stations from a single source, therefore we had to construct a list from the sources *Statistik Austria* (Austrian Statistical Office), the *ÖAMTC* (an Austrian automobile club), and information provided by the petroleum companies (in the order of their market shares) OMV AG, BP Austria AG, SHELL, ESSO, AGIP and ARAL. Thus, we could localize 2,856 gasoline stations in Austria by address (zip code and address). Additionally, we know the name of the oil company operating the stations or whether the station is operated by an independent retailer. According to the *Fachverband der Mineralölindustrie* (Association of the Petroleum Industry in

[8] See Weiss (1989) for a survey of concentration–price studies. See Barros (1999) for a model on multi-branch firms and evidence on Portugal.

Austria), there were 2,957 operating gasoline stations in Austria as of the beginning of 2001, thus our list covers 96.6% of all gasoline stations in Austria.

We use the number of gasoline stations rather than output or sales as the basis to calculate concentration figures. This has the advantage that our measures of concentration are less subject to the kind of endogeneity problems mentioned by Evans et al. (1993).[9]

For 1,603 (54.2%) gasoline stations operated by the firms OMV AG, BP Austria AG, SHELL, AGIP and ARAL we obtained retail price information on a daily basis for the period 1 November 2000 until 30 March 2001 for the gasoline brand *EUROSUPER* (unleaded gasoline containing 95 octane), which is the most important brand in Austria. This implies that we do not have price information on independent retailers. We include, however, the percentage of stations operated by independent retailers in the pricing regressions presented in Section 4 as an additional control.

A rather tricky problem is the delineation of local gasoline markets and the definition of "regions". Austria consists of nine federal states subdivided into 121 districts, which consist of roughly 2,400 municipalities (i.e. zip-code level). We use the districts as relevant regions. This choice compromises on the market definition being too narrow (as is probably the case if we take zip codes or the like as our region) or too wide (if we took e.g. federal states).[10] Note, however, to the extent that we measure the relevant market inaccurately, our estimates are likely to underestimate the true relationships. Unless the inaccuracy is correlated with our variables of interest, the most likely effect is increased white noise reducing statistical significance. In any case, we present robustness tests using the narrow market definition at the zip-code level.

For each of the 121 districts, we calculate the variables as defined in Table 1. The dependent variables are margin M and the density of gasoline stations S in a particular district, with $M=P-c$. P is the daily retail price charged for *EUROSUPER* net of all taxes (a 20% sales tax and a gasoline quantity tax of 5.61 ATS/l) in ATS per liter averaged over the period 1 November 2000 and 31 March 2001 and averaged over all stations within a district. To obtain estimates of marginal cost c we utilize information on *PLATT* product notations in Amsterdam. The market in Amsterdam and more generally the "*ARA* area" (Amsterdam–Rotterdam–Antwerp) is the most important spot market determining gasoline prices in Europe. More than 14% of European refinery capacity and most of European petroleum imports are located in this area (Puwein and Wüger 1999). Our strategy to proxy marginal costs for Austrian gasoline stations is therefore to apply a limit pricing argument in that marginal costs are equal to these *PLATT* prices plus transportation costs (to and within Austria) and variable remuneration of gasoline operators.

Specifically, marginal cost c is proxied by the sum of (1) the average daily *PLATT* price of *EUROSUPER* in Rotterdam over the period 1 November 2000 and 31 March 2001 converted to ATS from USD using daily exchange rates (which

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[9] Concentration–price regressions suffer mainly from two sources of bias: first, concentration normally is a function of endogenous firm outputs or revenues. Second, performance feeds back into market structure, that is concentration causes price, but price also causes concentration. Using the number of gasoline stations as the basis of our concentration measures should reduce the first bias.

[10] Defining the relevant market is beyond the scope of this paper. See Slade (1986) for such an attempt.

Table 1 Variable definitions and data sources

Variable	Definitions	Source(s)
Pop_k	Number of inhabitants in district k.	SA
A_k	Area of district k in square kilometers.	SA
F_k	Number of firms operating gasoline stations in district k as of beginning of 2001.	SA; ÖAMTC; "Majors"
N_k	Number of gasoline stations in district k as of beginning of 2001.	SA; ÖAMTC; "Majors"
P_k	Retail price charged for *EUROSUPER* (unleaded gasoline with 95 octane) (total of 1,603 gasoline stations) net of all taxes per liter averaged over the period 1 November 2000 and 31 March 2001 and averaged over all stations within district k in ATS* per liter, i.e. $P_k = \frac{1}{TN_k}\sum_{i=1}^{N_k}\sum_{t=1}^{T} P_{i,t}$, where T=151, the number of days between 1 November 2000 and 31 March 2001.	"Majors" without ESSO; Puwein und Wüger (1999); FV.
$M_k=P_k-c$	Difference between P_k and marginal cost in ATS* per liter. Marginal cost c is proxied by the sum of (1) the average daily *PLATT* product notations of *EUROSUPER* in Rotterdam over the period 1 November 2000 and 31 March 2001 (2) estimates of transportation to Austria per liter (3) estimates of distribution costs within Austria per liter and (4) estimates of the per liter remuneration of gasoline operators.	"Majors" without ESSO; Puwein und Wüger (1999); FV.
$S_k=N_k/A_k$	Density of gasoline stations in district k.	SA; ÖAMTC; "Majors"
$D_k=Pop_k/A_k$	Population density in district k.	SA
$C1_k$	Market share of the largest firm in district k defined as $C1_k = \frac{N_{1,k}}{N_k}$, where $N_{1,k}$ is the number of gasoline stations operated by the largest firm in district k.	SA; ÖAMTC; "Majors"
$C4_k$	Sum of market shares of the largest four firms in district k, $C4_k = \frac{\sum_{n=1}^{4} N_{n,k}}{N_k}$, where $N_{n,k}$ is the number of gasoline stations operated by the n largest firm in district k.	SA; ÖAMTC; "Majors"
$HERF_k$	Sum of squared market shares of all firms in district k, $HERF_k = \sum_{n=1}^{F_k}\left(\frac{N_{n,k}}{N_k}\right)^2$.	SA; ÖAMTC; "Majors"
$INDEPENDENT_k$	Share of gasoline stations operated by independent retailers in district k.	SA; ÖAMTC; "Majors"
V_k	Degree of motorization defined as the number of motor-operated vehicles per head in district k.	SA
$ALPS_k$	Share of alps and woods of total area in district k.	SA

SA Statistik Austria (Austrian Statistical Office) FV ... Fachverband der Mineralölindustrie (Association of the petroleum industry)
*13.76 ATS=1 EURO
**The largest six Austrian oil companies are often called "majors" (i.e. OMV AG, BP Austria AG, SHELL, ESSO, ARAL and AGIP)

equaled 3.01 ATS/l), (2) estimates of transportation costs to Austria per liter (0.20 ATS/l; Source.: Puwein and Wüger 1999), (3) estimates of distribution costs within Austria per liter (0.10 ATS/l; Source: Puwein and Wüger 1999), and (4) estimates of the per liter remuneration of service station operators (0.30 ATS/l, Source: *Fachverband der Mineralölindustrie*). Therefore, we estimate marginal costs c at 3.61 ATS/l over the period of analysis. This strikes us to be the most plausible estimate of marginal costs. We experimented with a number of values ranging from 3 to 4 ATS/l, however the results for the margin equation in Section 4 are virtually the same.

Several additional arguments defend our approach. First, the whole Austrian territory can be supplied by three refineries: Schwechat, Mestre, and Ingolstadt, with more than 60% of total supply stemming from Schwechat. There is a product pipeline in Austria, transporting the overwhelming bulk of gasoline. Thus, there is not much variation in the production and distribution technology of wholesale supply of gasoline. Second, as Puwein and Wüger (1999) note transportation costs within Austria are a minor component of marginal costs. Thus, it is likely that marginal costs of gasoline do not vary substantially at the station across Austria. Nevertheless, we include federal state and/or district dummies in the margin equations estimated below. Fixed federal state or district effects may arise due to differing distribution and remuneration costs and thus differing marginal costs within Austria.

Figure 1 displays the evolution of average P (net of all taxes) in Austria and the *PLATT* notations for *EUROSUPER* as well as *BRENT* crude oil in Rotterdam. As can be seen, retail prices first decrease until around mid of January 2001 increase until mid of February and then remain roughly constant. *PLATT* notations are a bit more volatile than retail prices in Austria (coefficient of variation of 0.10 for

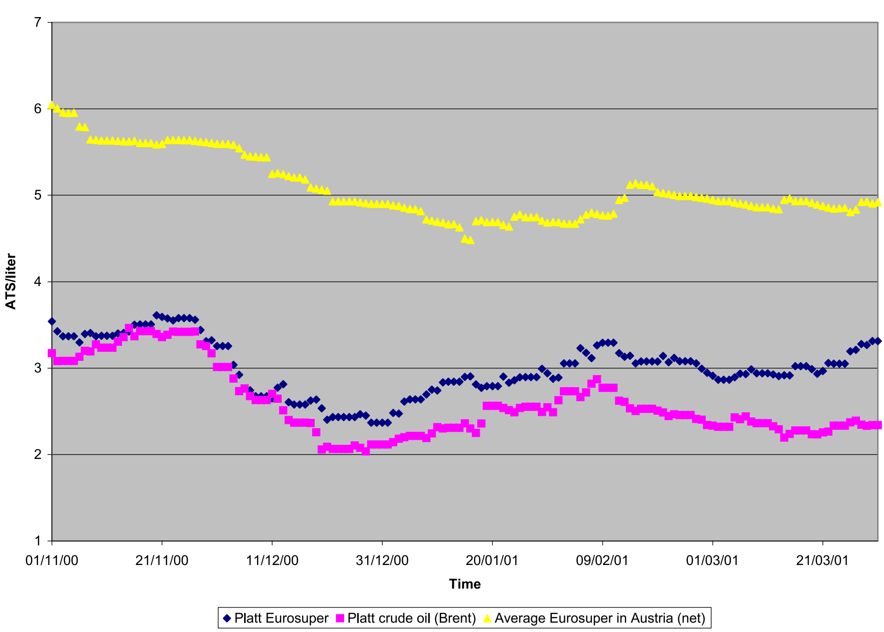

Fig. 1 Average *EUROSUPER* retail price in Austria and *PLATT's* notations

EUROSUPER and 0.15 for *BRENT* versus 0.07 for average retail prices in Austria). Therefore, we are confident that the time period is long enough and the turbulence in the markets was sufficiently low so that we capture structural differences in *M* across districts and not merely short-run disequilibrium phenomena.

Table 1 presents detailed definitions of the variables used in the subsequent regression analysis. Table 2 presents summary statistics.

On average, districts extend to around 700 km^2 with nearly 70,000 inhabitants. An average of 5.6 firms operate 23.7 gasoline stations per district. The mean before tax price of a liter of *EUROSUPER* was 5.07 ATS with a quite sizeable range of 4.66 to 5.40 across districts. The average margin is 1.46 ATS. On average, the patch of a service station is 31.6 km^2(=$1/S$) and the median population density is 87.3 inhabitants per square kilometer. The largest firm on average operates more than a quarter of gasoline stations, average *C4* is 65.1% and the average *HERF* is 16.1%. Around one third of gasoline stations are operated by independent marketers. The degree of motorization *V* varies considerably across districts with a mean of 0.72 motorized vehicles per person and a maximum of more than two. Nearly 40% of the area is alpine or covered with woods.

4 Results

This section presents our results in two steps. First, we explain the density of gasoline stations. These regressions give insight into the determinants of entry into the Austrian retail market of gasoline. From Section 2 we hypothesize that the main determinants of the density of gasoline stations are population density and the degree of motorization as proxies of demand, and market concentration. Second, we present the results on the price equation. Here the main theoretical prediction is

Table 2 Summary statistics on the district level

	Mean	Stand dev.	Median	Max	Min	No of obs.
Pop_k (inhabitants)	67,335	37,873	59,370	241,530	1,740	121
A_k (in km^2)	703.7	629.5	669.1	3,270.1	1.5	121
F_k (firms)	5.6	3.2	5.0	17.0	1.0	121
N_k (stations)	23.7	15.5	21.0	96.0	1.0	121
P_k (in ATS)	5.07	0.14	5.08	5.40	4.66	121
M_k (in ATS)	1.46	0.14	1.47	1.79	1.05	121
$1/S_k$ (km^2/station)	31.6	26.8	29.2	113.3	0.3	121
D_k (inhabitants/km^2)	1,888.7	4,706.7	87.3	26,028.6	21.1	121
Cl_k (in %)	25.8%	10.2%	23.5%	100.0%	10.7%	121
$C4_k$ (in %)	65.1%	13.3%	62.5%	100.0%	35.7%	121
$HERF_k$ (in %)	16.1%	10.0%	14.0%	100.0%	5.9%	121
$INDEPENDENT_k$ (in %)	33.6%	13.8%	33.3%	87.5%	0.0%	121
V_k (number of motor-vehicles/head)	0.72	0.20	0.73	2.24	0.37	121
$ALPS_k$ (in %)	39.3%	24.3%	39.0%	80.8%	0.0%	121

For definitions of variables, see Table 1 that the price is decreasing in station density (or increasing in the average distance between gasoline stations). Controls include the share of independent marketers and additional proxies of transport costs.

4.1 The density of gasoline stations

From (1), gasoline station density is explained by variables proxying for demand and market structure[11]

$$\ln S_k = \alpha_0 + \alpha_1 DEMAND_k + \alpha_2 C_k + \varepsilon_k \tag{3}$$

where $k=1,\ldots, 121$ denotes administrative districts in Austria; $\ln S_k$ the (logarithm of the) number of gasoline stations per square kilometer in district k; $DEMAND_k = \{\ln D_k, \ln V_k\}$ the (logarithms of the) number of inhabitants per square kilometer in district k as well as the number of motorized vehicles per capita in district k; $C_k = \{\ln C1_k$ or $\ln C4_k$ or $\ln HERF_k\}$ the (logarithms of the) share of the largest, the largest four firms or the Herfindahl-index in district k; and ε_k an error term.[12]

Table 3 presents the results.

As theory would predict population density virtually completely determines the density of gasoline stations. Population density explains more than 95% of the cross-district variation in the density of gasoline stations. Figure 2 shows that the fit is nearly perfect.

The coefficient estimate of 0.81 (t=41.10) implies that for each percentage increase in the number of inhabitants per square kilometer the number of gasoline stations increases by around 0.8% per square kilometer. This conforms to predictions of models of spatial competition that the number of outlets increases less than proportional to consumer density, since the greater proximity of shops reduces the equilibrium price.

Equation 2 of Table 3 includes 0–1 dummies for federal states of which there are nine in Austria. We include federal state effects because entry conditions may differ across federal states due to differing regulations, e.g. concerning the environment, building regulation etc, which affect fixed entry and exit costs. Our estimates are robust to the inclusion of these dummies and the coefficient on *lnD* rises to 0.90 with a t-value of 17.77. The F-statistic indicates that fixed federal state effects are not significant at conventional levels thus we leave them out in Eqs. 3, 4, 5, 6, and 7. These tests show that differences across federal states are not large enough to significantly affect entry/exit decisions, what counts is population density. We will return to fixed federal state effects when we analyze the margin equation, however.

Population density is fairly skewed across districts due to the presence of urban areas, most notably Vienna. It may be the case that entry decisions are influenced by quite different factors in cities than in the countryside e.g. by the availability of

[11] We tried $ALPS_k$ in Eq. 3 as a proxy for consumer transport costs T. Since this variable was always insignificant and its inclusion never changed the results on the other variables, we do not report it.

[12] Since we do not have quantity or sales data we cannot estimate a fully structural model and estimate reduced forms. However, if gasoline demand is fairly inelastic (which is likely to be true, see Puwein and Wüger (1999), estimating a demand elasticity of only 0.2), our demand proxies, population density and number of cars, are likely to capture variation in demand across sub-markets accurately.

Table 3 The density equation, district level

Dependent variable: $\ln S_k$														
Sample:	All districts				Districts excluding Vienna		All districts							
Equation	1		2		3		4		5		6		7	
Independent variables	Coef	*t*-value	Coef	*t*-value	Coef	*t*-value	Coef	*t*-value	Coef	*t*-value	Coef	*t*-value	Coef	*t*-value
$\ln D_k$	0.810	41.10	0.900	17.77	0.829	11.94	0.816	48.40	0.832	51.63	0.835	47.35	0.873	50.48
$\ln Cl_k$							−0.132	−0.89						
$\ln C4_k$									−0.613	−3.20				
$\ln HERF_k$											−0.306	−2.14	−0.465	−5.05
$\ln V_k$													0.268	1.95
Constant	−7.014	−75.03	−7.481	−29.87	−7.096	−24.02	−7.229	−32.07	−7.406	−59.05	−7.729	−22.81	−8.148	−39.74
Fixed federal state effects	No		Yes		No		No		No		No		No	
F-test of fixed effects (*p* value)			0.239											
adjusted R^2	0.953		0.957		0.873		0.954		0.957		0.958		0.963	
No Obs	121		121		98		121		121		121		121	

Note: Estimation method is OLS with White (1980) heteroscedasticity consistent standard errors

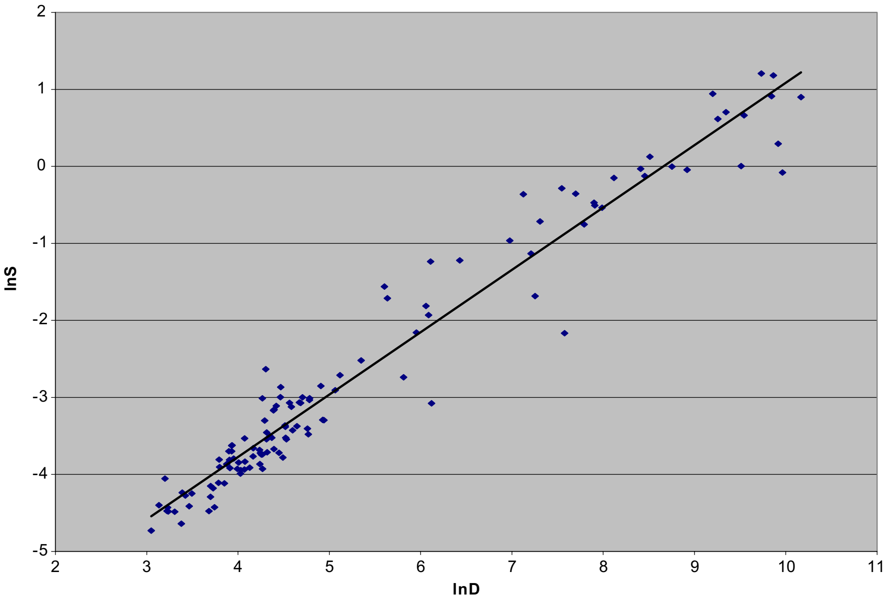

Fig. 2 The relationship between population and gasoline station density

space etc. Therefore we test for the robustness of our results by excluding the 23 districts of Vienna. Equation 3 shows that results are unaltered and the influence of population density is virtually the same in Vienna than in other administrative districts. When we restrict the sample to those districts where population density is smaller than 500 inhabitants per square kilometer (and thus effectively restricting the sample to the 90 mostly rural districts), the coefficient rises to 0.90 (t=12.70). Thus, there is some evidence that entry decisions in rural areas depend even more on population density than entry decisions in more densely populated areas.

Equations 4, 5, and 6 add our measures of market concentration to the estimating equation. Recall our measures of market concentration are based on the relative size of firms in the market as measured by the number of gasoline stations operated by them. The logarithm of the share of the largest firm ln*C1* has the expected negative sign but is insignificant while a larger *C4* and Herfindahl-index significantly reduce station density.

Equation 7 adds the variable *lnV*, another proxy for demand, which takes on the expected positive sign and is marginally significant at the 5% level.

We chose to present the results on the log–log specification (Eq. 3). It should be noted, however, that our results do not depend on the specific functional form chosen. We experimented with a number of different functional forms and specifications, e.g. the linear model, the linear model including squared terms, or explicitly estimating a power function by non-linear least squares. None of our results changes and the results from these regressions are available upon request. In particular, all estimations produce a similar concave relationship between *S* and *D*. This can be interpreted as an additional specification test of Eq. 1.

4.2 The margin equation

The second main prediction of models of spatial competition concerns the relationship between the price and therefore the margin that is charged and competition intensity as implied by the distance to the closest competitors: the farther away gasoline stations are from one another on average the higher will be the margin charged.[13] Thus, we operationalize Eq. 2 and estimate

$$\begin{aligned}\ln M_k &= \ln(P-c)_k \\ &= \beta_0 + \beta_1 \ln S_k + \beta_2 C_k + \beta_3 ALPS_k + \beta_4 INDEPENDENT_k + \nu_k\end{aligned} \tag{4}$$

where $k=1,\ldots,121$ again denotes administrative districts in Austria; $\ln M_k = \ln(P-c)$ the (logarithm of the) average price charged in district k minus our estimate of marginal cost; $\ln S$ the (logarithm of the) number of gasoline station per sqkm in district k. This is an inverse proxy of the average distance between gasoline stations. A larger value of S therefore indicates more intense competition, and we expect $\beta_1<0$ if spatial competition plays a role in the determination of margins. $\ln C_k=\{\ln C1_k$ or $\ln C4_k$ or $\ln HERF_k\}$ is the (logarithms of the) share of the largest, the largest four firms or the Herfindahl-index in district k; $ALPS_k$ the share of alps and woods of total area in district k as an additional proxy for differing transport costs across districts; and ν_k is an error term. As already mentioned, we do not have price data on independent retailers, but we include $INDEPENDENT_k$, the share of independent marketers in district k.

Table 4 presents the results for Eq. 4.

In all specifications the coefficient on ln$S$ is negative and significant at the 5% level or better indicating that the closer competitors on average are to each other the lower is the margin. The margin equations indicate that—contrary to the gasoline density equation before—fixed federal state effects are significant and explain a fair portion of the cross sectional variation in margins. The inclusion of these dummies does not render ln$S$ insignificant, on the contrary, coefficients and significance levels rise. One explanation is that our measure of marginal cost which we assumed invariant across districts and thus federal states in fact varies across them, e.g. due to differing distribution and remuneration costs. The fixed federal states effects (partially) correct for this. Below we present robustness tests running the margin equation on the zip-code level and including 120 district dummies. Our main results hold up.

Equations 1, 2, and 3 include (respectively) *lnC1*, *lnC4* and *lnHERF* as explanatory variables, however, we do not detect a significant influence of market concentration on the margin at the district level. *INDEPENDENT* takes on negative signs, however, it is only significant when we restrict the sample to the 98 districts outside of Vienna (see Eq. 5).

As we have seen in Section 4.1. gasoline station density in an area is determined by demand and cost conditions in a particular market. Equation 4 estimates Eq. 4

[13] We report the results on retail margins rather than markups as Borenstein (1991) does. However, results are similar if we take markup as the dependent variable in Eq. 4. We also experimented with a number of other explanatory variables such as the percentage of highway stations in a geographical market (expected positive effect) or whether a geographical market borders to an Eastern European country (expected negative effect). For these variables we generally find the predicted effects. These results are available upon request.

Table 4 The margin equation, district level

Dependent variable: $\ln M_k$										
Sample:	All districts								Districts excluding Vienna	
Equation	1		2		3		4		5	
Method	OLS		OLS		OLS		2SLS		2SLS	
Independent variables	Coef	*t*-value	Coef	*t*-value	Coef	*t*-value	Coef	*z*-value	Coef	*z*-value
$\ln S_k$	−0.036	−3.15	−0.035	−2.99	−0.036	−3.10	−0.039	−3.68	−0.045	−3.90
$\ln Cl_k$	−0.020	−0.54								
$\ln C_4$			0.023	0.48						
$\ln HERF_k$					−0.009	−0.32	−0.010	−0.34	−0.047	−1.38
$ALPS_k$	0.054	0.89	0.047	0.77	0.054	0.90	0.065	1.05	0.068	1.01
$INDEPENDENT_k$	−0.095	−1.47	−0.064	−0.86	−0.085	−1.16	−0.087	−1.38	−0.207	−2.56
Constant	0.299	5.11	0.327	9.72	0.307	5.23	0.301	5.16	0.230	3.36
Fixed federal state effects	yes		yes		yes		yes		yes	
F-test of fixed effects (*p* value)	0.000		0.000		0.000		0.000		0.000	
adjusted r^2	0.413		0.414		0.408		0.433		0.472	
No Obs	121		121		121		121		98	

Estimation method below "OLS" is OLS with White (1980) heteroscedasticity consistent standard errors

Estimation method below "2SLS" is the two-stage least squares within estimator due to Balestra and Varadharajan-Krishnakumar using $\ln D_k$ as instrument for $\ln S_k$. r^2 for 2SLS is defined as "r^2 "=1−RSS/TSS, where RSS is the residual sum of squares and TSS is the total sum of squared residuals about the mean of the dependent variable

by 2SLS instrumenting *lnS* by *lnD*. This appears to be an ideal instrument, since population density is exogenous to gasoline prices and—as shown in Section 4.1. — almost completely determines station density. The results do not change and if anything the influence of ln*S* is larger if we instrument it. We also performed Hausman tests, which showed that endogeneity is not a likely problem, since the coefficients obtained with the less efficient but consistent estimates are not systematically different from the fully efficient estimates, i.e. $\chi^2(1)=0.57$. As a final check against endogeneity, we shall estimate Eqs. 3 and 4 simultaneously below.

ALPS, the area share of alps and woods as an additional proxy for transport costs, takes on the right signs, however it is not significant. One explanation is that *S* is highly correlated with *ALPS* (correlation coefficient of 0.72) and *S* is the dominant force explaining margins. This is confirmed by the fact that when we exclude *lnS*, *ALPS* takes on positive and significant coefficients.

4.3 Additional robustness tests

4.3.1 The relevant geographical market

Until now we assumed that districts are accurate in defining the relevant region for gasoline stations. We now test whether our results are changed if we narrow our

Table 5 Robustness

Panel A: The margin equation, zip-code level (z)

Dependent variable: $\ln M_z$

Sample:	All zipcodes								Zipcodes excluding Vienna	
Equation	(1)		(2)		(3)		(4)		(5)	
Method	OLS		OLS		OLS		2SLS		2SLS	
Independent variables	Coef	t-value	Coef	t-value	Coef	t-value	Coef	z-value	Coef	z-value
$\ln S_z$	−0.007	−2.90	−0.007	−2.95	−0.006	−2.84	−0.027	−3.09	−0.043	−3.30
$\ln Cl_z$	0.075	1.04								
$\ln C4_z$			0.125	2.97						
$\ln HERF_z$					0.032	2.00	0.125	3.77	0.045	2.19
$ALPS_z$	0.061	2.92	0.062	2.97	0.062	2.97	0.021	1.84	0.059	1.89
$INDEPENDENT_z$	−0.044	−2.07	−0.037	−1.69	−0.041	−1.88	−0.010	−1.41	−0.202	−2.32
Constant	0.333	16.03	0.272	9.34	0.416	11.95	0.557	7.82	0.235	3.11
Fixed federal state effects	yes		yes		yes		yes		yes	
F-test of fixed effects (p value)	0.000		0.000		0.000		0.000		0.000	
adjusted R^2	0.261		0.267		0.255		0.245		0.280	
No Obs	803		803		803		803		780	

Panel B: The density and the margin equation as simultaneous equations, district level (k)

Dependent variables	$\ln S_k$		$\ln M_k$	
Independent variables	Coef	z-value	Coef	z-value
$\ln S_k$			−0.031	−3.93
$\ln M_k$	0.207	0.47		
$\ln D_k$	0.876	38.77		
$\ln HERF_k$	−0.350	−3.43	−0.006	−0.21
$\ln V_k$	0.247	1.58		
$ALPS_k$			0.051	1.12
$INDEPENDENT_k$			−0.080	−1.37
Constant	−8.02	−23.92	0.395	8.54
Fixed federal state effects	No		Yes	
F-test of fixed effects (p value)			0.000	
"r^2"	0.962		0.466	
No Obs	121		121	

Note A: Estimation method below "OLS" is OLS with White (1980) heteroscedasticity consistent standard errors

Estimation method below "2SLS" is the two-stage least squares within estimator due to Balestra and Varadharajan-Krishnakumar using $\ln D_z$ as instrument for $\ln S_z$. R^2 for 2SLS is defined as "R^2 "=1−RSS/TSS, where RSS is the residual sum of squares and TSS is the total sum of squared residuals about the mean of the dependent variable

Note B: Estimation method is 3SLS with exogenous variables (the instrument list) $\ln D_k$, $\ln HEF_k$, $\ln V_k$, $INDEPENDENT_k$, $ALPS_k$, and eight federal state dummies. "r^2 " is defined as "r^2 "=1−RSS/TSS, where RSS is the residual sum of squares and TSS is the total sum of squared residuals about the mean of the dependent variable definition of the relevant region. Panel A of Table 5 presents the results on the margin equation at the *zipcode* level.[14] That is, all variables are now defined at the narrow level of municipalities. There are 2,383 municipalities in Austria. Of these, 1,173 do have gasoline stations. We have all the relevant data for 803 zip-code areas. On average, there are 2.4 stations per zip-code area and provided there is a station the range is 1 to 46 stations. Thus this market definition is very narrow.

As can be inferred from Panel A in Table 5, our results are robust to this change in market definition. Again, 2SLS estimates and restricting the sample to zipcodes outside of Vienna increases the estimated influence of *lnS* on the margin, consistent with prior reasoning. The measures of market concentration take on a positive sign and—with the exception of *C1*—are significant at the 5% level or better. The share of independent marketers decreases the margin that can be charged and the area share of alps and woods as a measure of transport costs increases the margin. These estimates imply that the operational definition of market boundaries does not change our results, with the possible exception of the influence of market (ownership) concentration.

A few words seem in order to explain the validity of our distance measure *S*. *S* is a good (inverse) proxy for the average distance between gasoline stations if stations do not cluster in one spot in each market. That is, if entry decisions are taken as suggested by models of spatial competition under subsequent price competition (maximum differentiation), stations optimally locate as far away from each other as possible and *S* is an appropriate distance measure.[15] If stations do cluster, on the other hand, station density *S* may vary cross sectionally without changing the average distance between stations by much. We therefore need to assess whether clustering of gasoline stations is a problem. Figure 3 presents a frequency distribution of the number of stations per zip code. In 681 or 58.1% of the 1,173 zip codes with stations, there is only *one* station. In 85.8% of the zip codes, there are three or fewer stations, in only 31 zip-code areas, there are more than ten stations. This overwhelmingly suggests that clustering of stations does not occur on average, and thus that *S* is an appropriate measure of distance. Our distance measure *S* should work best in zip codes with only one station. If we restrict the sample to those 681 zipcodes with *only one* station, and estimate a regression like in Eq. 4 of Panel A in Table 5 by 2SLS, the coefficient and significance of $\ln S_z$ remain virtually unchanged (−0.025, $z=-2.88$). This again suggests that *S* is an appropriate measure of distance.

Finally, it should be mentioned that our results are not altered if we estimate an equation like 4 of Panel A in Table 5 at the station level, that is treating the 1,604 stations with price data as the unit of analysis, including district fixed effects, and essentially blowing up all explanatory variables. Given that the number of observations increases to more than 200,000, *t*-values on ln*S* increase to between 40 and 50. We chose not to report these results, because we view these *t*-values as inflated given the fact that our proxies of demand, costs and competition do not vary on a daily basis.

[14] We also analysed Eq. 3 at the zip-code level. Results mimic those obtained at the district level.
[15] In the symmetric circle model of Salop (1979) with consumers being uniformly distributed, stations are equi-spaced around the circle in equilibrium.

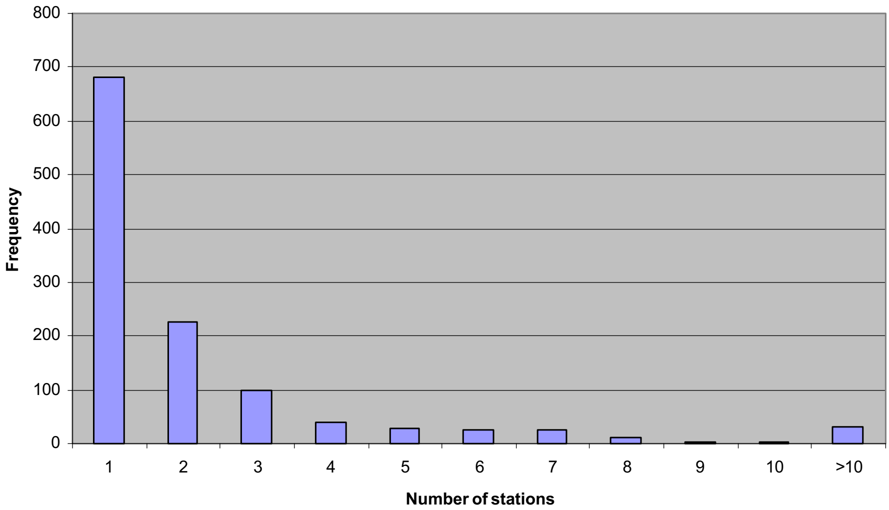

Fig. 3 Frequency distribution of the number of stations at the zip code level

4.3.2 Unobservable heterogeneity across sub-markets

A possible omitted variables bias would arise if more stations enter in exactly the markets with lower marginal costs, thus introducing a spurious negative correlation between station density and price, when in fact lower marginal costs are responsible for the findings. In Table 4 we effectively allowed marginal costs to vary across the nine federal states in Austria by including fixed federal state effects, which were highly significant. Although we additionally allowed for *ALPS* to influence marginal costs, it may be that marginal costs (or other unobservable factors affecting the pricing decision) vary across districts in ways we did not control for yet. For example, there may be some districts where road availability or quality is worse than in others even in the same federal state or given *ALPS*, and thus transport costs are higher.

If we introduce 120 district dummies in addition to the constant term and estimate an equation like 4 in Panel A of Table 5 by 2SLS, the *F*-test on the fixed district effects is 8.30 indicating significance beyond the 1% level.[16] The results on the other variables, however, remain unchanged. In particular, the coefficient on $\ln S_z$ *rises* to −0.031 (z=−3.21). This suggests that while there are unobservable differences across sub-markets affecting price, differential marginal costs at the district level are not responsible for our main findings.

4.3.3 Simultaneous determination of the entry and pricing decisions

Thus far we have assumed that station density is a predetermined variable with respect to price. Equilibrium price and density of stations, however, may be jointly

[16] This essentially assumes that the error terms for average prices in different zip codes are correlated within districts, whereas the error terms for zip codes located in different districts are independent.

determined. Higher equilibrium price and therefore margins should lure gasoline operators to enter the market, while higher station density should depress equilibrium prices. We have already presented 2SLS estimations, however, these do not explicitly take into account that the entry and pricing decisions may be taken simultaneously. As a final test of robustness, therefore, we test whether our results hold up if we estimate Eqs. 3 and 4 simultaneously by the full-information method 3SLS. All dependent variables are now explicitly endogenous to the system and as such are treated as correlated with the disturbances in the system's equations.

Panel B in Table 5 presents the results. We present the results for the district level as the definition of the relevant region. Our results on both equations are not altered if we treat equilibrium margin and density of gasoline stations as jointly determined variables. While $\ln M_k$ takes on the expected positive coefficient in the density equation, the coefficient is insignificant and does not alter the influence of the demand and concentration variables. The coefficient on $\ln S_k$ remains negative and significant beyond the 1% level in the margin equation, even after controlling for the endogeneity of pricing and entry decisions, and the cross equation residual correlation.

4.3.4 Price dispersion

Although spatial competition models do not provide clear-cut explanations of price dispersion, it seems plausible that an increase in seller density by increasing competition between stations will decrease average price dispersion in a given market. Several authors have analyzed this topic for the retail gasoline market.[17] We obtain the following results for the 492 zip codes with at least two gasoline stations:

$$sd\left(\ln P_{i,j,t,z}\right)_{t,z} = 0.00852 - 0.00138 * \ln S_z + \eta_{t,z}$$
$$t = 110.4 \qquad t = 34.1$$
$$\mathrm{R}^2 = 0.3216;\ \mathrm{No.Obs.} = 74{,}292$$

where $sd(\ln P_{i,j,t,z})_{t,z}$ is the standard deviation of the logarithm of price of station i of firm j on day t in zip code z over all stations in z on day t. Thus, as possibly expected, we find that price dispersion is significantly lower in zip codes with a larger station density. We additionally included in the above regression four firm dummies (F=41.10) and 120 district dummies (F=370.4). Thus, price dispersion significantly differs across oil companies and districts. It should be noted that these results are not sensitive to the choice of geographical unit.

5 Conclusions

We have shown that the Austrian retail gasoline market conforms quite well to the main predictions of spatial competition models. That is, the density of stations rises less than proportionally with population density, since fiercer competition drives

[17] See Marvel (1976); Png and Reitman (1994); Adams (1997) and Barron et al. (2001).

price down. Equilibrium price and price dispersion are lower if competitors are nearer. Estimation as simultaneous equations confirms that causality runs from station density to price. We have also found that market concentration reduces the density of stations in a given region, however, we could not establish a consistent relationship of concentration and price. It appears that the main effects of concentration are on the entry decisions rather than on the pricing decisions.

Our results suggest that spatial competition is an appropriate benchmark for judging the intensity (or lack thereof) of competition in the retail gasoline market. Thus, by explicitly recognizing the spatial dimension of markets, competition authorities can identify market conduct, and need not rely on market concentration–price studies with the involved problems of reverse causality and endogeneity. It should be kept in mind, however, that competition in the retail gasoline market is not as simple as the basic model of spatial competition would have it. The price setting mechanism in reality may be quite intricate. In particular, prices are in general not set by individual gas stations. Stations can be owned and operated by the big companies directly, they can be owned and operated by independent dealers, and in between several combinations of these two extremes are possible. These refinements are certainly fruitful areas of future research.

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Appendix

In order to illustrate Eqs. 1 and 2 in the main text, we use the model of spatial competition of Salop (1979). The following summary is borrowed from Chapter 6 of Anderson et al. (1992), where further details can be found.

Assume that there is a continuum of consumers with measure N. They are uniformly distributed around a circle of circumference L, with density N/L. Each consumer buys one unit of the good at that shop where her total costs are smallest. Denote the location of consumer j as Z_j, and the location of shop i as z_i. The transport costs are given by

$$T_{ji} = \tau \left| Z_j - z_i \right|^{\beta} \tag{5}$$

where $|Z_j - z_i|$ is the length of the shortest arc linking Z_j and z_i on the circle, and τ and β are strictly positive parameters, with $\beta \geq 1$. Now suppose there are n identical shops which are equi-spaced around the circle, hence the distance between two successive shops equals L/n. Finally, denote the marginal costs of each shop as c. It can be shown that in a symmetric equilibrium the price is given by

$$P^* = c + \beta 2^{1-\beta} \tau (n/L)^{-\beta}. \tag{6}$$

Note that n/L corresponds to S, the density of gasoline stations, in the general case discussed in Section 2. Obviously, Eq. 6 is a special case of Eq. 2. Denoting the fixed entry costs as K the equilibrium profit π^* can be written as a function of the number of firms.

$$\pi^*(n) = N\beta 2^{1-\beta}\tau L^{\beta} n^{-\beta-1} - K \tag{7}$$

In the complete model entry decisions take place in the first stage and price competition takes place in the second stage. It is assumed that relocation of shops is costless, and it can be shown that in equilibrium shops will be equi-spaced as has been assumed above. Entry takes place as long as Eq. 7 remains non-negative if an additional firm enters the market. The equilibrium number of firms per unit of distance is given by

$$n^e/L = \left(\frac{\beta 2^{1-\beta}\tau}{K}\frac{N}{L}\right)^{\frac{1}{1+\beta}} \tag{8}$$

Note again that N/L corresponds to the population density D in Eq. 1. Clearly, Eq. 8 can be considered as a special case of Eq. 1.

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