WORKING PAPER

Spatial interactions in location decisions: Empirical evidence from a Bayesian spatial probit model

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Abstract

In the period from 2003-2011 in the Austrian retail gasoline market remarkable movements have been noticed. A short analysis shows that 10.9% of the stations had left the market and a percentage of 29.6% had either left the market or had changed the brand. This paper provides empirical insight for drivers of this process. A special characteristic of this market is the local competition structure which is characterized by spatial dependencies along local competitors. To capture these spatial dependencies and since the dependent variable is binary in nature (an exit had taken place or not), we apply a Bayesian spatial probit model using MCMC estimation on station level data for the whole Austrian retail gasoline market. Our results suggest, that the decision to leave the market, does not only depend on own characteristics, but also on competitors. In particular, we found the exit decisions to exhibit a negative spatial correlation. Moreover, our model allows to quantify spatial spillover effects of this market.

Keywords: Bayesian Spatial Probit Model, Exit, Gasoline retailing, Spatial competition.

1 Introduction

Economists have long recognized a central tradeoff in spatial location choice: 'stealing' customers by locating closer to competitors comes at the cost of intensified price competition (Marshall, 1920). While there is a large volume of theoretical research analyzing strategic location decisions, only very few empirical studies (Seim (2006) and Watson (2005)) explicitly consider the spatial dimension when investigating firms' entry and/or exit decisions. The present paper uses a unique panel-data set for retail gasoline stations in Austria for the periode from 2003 to 2011 to investigate firms' exit decisions econometrically. The geographical location of each gasoline station is linked to information on the Austrian road system which allows generating accurate measures of distance (measured in driving time in minutes) as well as the neighbourhood relations between all gasoline stations in the network of roads.

In the past few decades the Austrian retail gasoline market has experienced considerable structural changes. According to the annual reports of the Austrian Economic Chamber the number of gasoline stations has decreased from 4,061 in 1988 to 2,575 stations at the end of 2011. This corresponds to a decline by almost 37%.[1] Between 2003 and 2011, 10.9% of the stations were shut down and 29.6% had either left the market or had changed the brand. The aim of this paper is to identify the key factors of and to shed light on the rationalization process of the Austrian retail gasoline market.

In terms of econometric methods to investigate this issue, it is important to note that individual exit decisions are binary in nature (exit 'yes' or 'no'). To investigate discrete exit choices in a spatial context, we apply a Bayesian spatial probit model using MCMC estimation (LeSage (2000) and LeSage and Pace (2004)) on station level data for the Austrian gasoline market.[2] In this model we incorporate the

[1]Similar changes have been observed for the US and Canadian gasoline markets (Eckert and West, 2005).

[2]In the past thirty years spatial econometric models have become a standard tool in empirical research. Nevertheless applications in binary-choice models remain scarce. Anselin (2010) provides an excellent overview of the development of this field.

spatial competition structure of the gasoline market to test if distance and local market characteristics, as well as individual and neighboring station characteristics have an influence on the exit probability of a gasoline station.

A special characteristic of the gasoline market is that competition is highly localized. Consumers typically prefer to buy gasoline at stations in the neighborhood of their residence (van Meerbeck, 2003) or at stations lying on their commuting path (Houde, 2009). Search and transportation costs play a crucial role in the demand for gasoline. Therefore, as in most spatial markets, retailers recognize only their nearest neighbors as relevant competitors (Benson et al., 1992). Despite the many stations in the analyzed market, oligopolistic interdependencies are present in each of these local markets. Market structure is characterized by a few large companies or retail chains, so called 'majors', dominating the market and operating outlets in most local markets. There also exists a large number of small firms ('independent' or 'unbranded' stations) which are only active in a few or even only one local market. Further, gasoline is a homogeneous product with respect to its chemical properties and stations differentiate by providing additional services (shops, opening hours, attendant service etc.) as well as in terms of space. Previous studies for the gasoline market suggest that the spatial interdependence between adjacent competitors can have significant price effects. Pennerstorfer (2009) and Firgo et al. (2012) analyze different aspects of pricing in this market and provide evidence for the existence of spatial correlation. Ignoring this neighborhood effects can lead to biased parameter estimates (LeSage and Pace, 2009).

The contribution of this paper should on the one hand be a detailed analysis of the exits in the Austrian retail gasoline market, as to our knowledge no such study exits. Therefore, its first aim is to identify the influencing parameters of these movements. On the other hand, in our model we will also incorporate the different types and the ownership structure of stations.

Early work regarding retail location comes from Hotelling (1929), who shows how the own location as well as the location of rival firms effect the own profit maximization. Reilly (1931), for instance, established a retail gravitation law and related it to shopping behavior and store location decision. Clustering behavior which is often observed in retail industries was explained, among others, by Fujita and Smith (1990), Brown (1994), Hinloopenaand and van Marrewijk (1999).

Our paper makes also a contribution to the broader literature on entry and exit, which can be divided into inter and intra industry studies. Berry and Reiss (2007) give an excellent overview for work on structural models of entry, exit and market concentrations, who in a game-theoretical framework analyze the long run equilibrium number of firms. Whereas Geroski (1995) surveys empirical work regarding entry, exit and turnover patterns in different industries. He established seven stylized facts about entry, exit and industry dynamics and linked the empirical evidence to the theory.[3] He summarizes papers which analyze the location decisions of homogenous and heterogeneous firms within and between industries. The majority of this research has been done for the manufacturing sector.

A closely related paper to ours is Eckert and West (2005). The authors estimate a probit model using station, market structure, demographic, locational and firm type characteristics as explanatory variables to test different rationalization hypotheses for the Canadian gasoline market in the period from 1991 to 2002. [4]

The existing literature on entry and exit in the retail industry uses spatial explanatory variables to incorporate the spatial dimension of competition of this markets. In contrast, we use the geographical information on stations to model the spatial dependency among stations explicitly via an autoregressive spatial probit model. Our empirical analysis explicitly controls for the various station, market and demographic characteristics, spatial neighborhood effects as well as the ownership structure of gasoline stations (membership in large networks). Furthermore, these type of models allow for differentiating between direct as well as indirect effects of exogenous variables (the effect of variables on the exit probability of the observed station as well as the effect on the exit probability of neighboring stations).

[3]Another survey on this research topic is from Caves (1998).

[4]Eckert and West (2005) do not ignore the possibility of spatial correlation. Moran's I test does not reject the null hypothesis of no spatial correlation in the estimated errors which implies that estimating a simple probit model is appropriate.

In general, we find a significant negative spatial correlation regarding the exit decision of stations in the Austrian gasoline market. These results suggests, that the probability to exit the market is lower if the neighbor left the market. Overall, it seems that the exit of stations is not only influenced by own characteristics but also by competitors characteristics and by the composition of the own limited market.

The rest of the paper is organized as follows: in section 2 we describe the data, section 3 introduces the estimation procedure and reports the empirical results and section 4 concludes.

2 Data

The empirical analysis utilizes three different data sets. The first contains information on the spatial and site characteristics of all gasoline stations in Austria in the year 2003 collected by Experian Catalist. The second data set contains the same information for all active stations in the year 2011 obtained from Petrolview, a split-off company from Catalist[5]. By merging the two data sets, we are able to identify the structural changes which occured in this market between 2003 and 2011. We categorized the stations into four groups: still active, changed brand, shut down and new station. If a station is active both in 2003 and 2011 in the same place and under the same brand, it was categorized as 'still active'. The category 'changed brand' represents stations that are operated on the same location but have changed their brand between 2003 and 2011. If a gasoline station no longer is operated in 2011, it was classified in the third category 'shut down'. Stations which are only present in the dataset from 2011 represent market entries and thus were classified as 'new stations'. The third data set contains information on the population and size of the municipalities and the districts of this region, as a part of the population census collected by the Austrian statistical office in 2001.

For the purpose of estimating the exit probability of one station, we defined the binary dependent variable as follows:

[5]See www.catalist.com and www.petrolview.com for company details.

$$y = \begin{cases} 1, & \text{if category 'changed brand' or 'shut down'} \\ 0, & \text{if category 'still active'} \end{cases} \tag{1}$$

Our paper also addresses the question whether the exit probability is different for the different types of outlets ('branded' and 'unbranded' stations).

	Unbranded	Branded	Total
Exit	220	617	837
Percentage of all Exits	26.28%	73.72%	100%
Percentage in station category	33.63%	28.22%	

Nr. of stations = 2,822; Unbranded = 654; Branded = 2,168

Table 1: Exits by station types

Table 1 reports the number of exits of the Austrian gasoline market by station types. From all 837 station exits between 2003 and 2011 the majority (73.72%) are branded stations. However, the table suggests that the share of exiting stations seems to be larger for unbranded stations compared to branded stations. Whereas 33.63% of all unbranded stations exited, only a portion of 28.22% of all branded stations left the market. In the econometric model we test whether there is an assummetry in the exit probability of branded and unbranded stations and if the presence of an unbranded station has an impact on the exit probability of branded stations which was stated by Eckert and West (2005).

3 Estimation and Results

Since the dependent variable in this case is binary, firm i had exit the market or not, a model for the analysis of binary outcomes has to be applied. A conventional probit model would explain variation in the binary dependent variable y using the matrix of exogenous variables $\boldsymbol{X}$ which is associated with the vector of estimated parameters β, under the assumption that the observations are independent of each other. However, Moran's I test rejects the null hypothesis of no spatial correlation in the residuals obtained from a standard probit model. Spatial correlation in the residuals could be the result of similar unobserved characteristics of adjacent competitors or could indicate the existence of a strategic interdependence in exit decisions between neighbours: whether or not an individual gasoline stations survives might not only depend on its own characteristics but could also be influenced by characteristics of its neighbours. To account for this spatial interdependence, we apply a Bayesian spatial probit model, which was introduced by LeSage (2000) and extends earlier work by Albert and Chip (1993). This spatial autoregressive probit model has the following form:

$$\begin{aligned} y^* &= \rho \boldsymbol{W} y^* + \beta \boldsymbol{X} + \epsilon, \\ \epsilon &\sim \mathrm{N}(0, \boldsymbol{I_n} \sigma^2) \end{aligned} \tag{2}$$

where y^* represent the latent underlying unobservable utility level of the exit decision (e. g.: expected profit) of dimension $m \times 1$ with m being the total number of gasoline stations. The block diagonal spatial weights matrix $\boldsymbol{W}$ captures the spatial structure of the market (closeness between the individual gasoline stations). More specifically, the element w_{ij} of the spatial weights (distance decay) matrix $\boldsymbol{W}$ of dimension $m \times m$ is the inverse of the driving time from station i to station j, if station j is among the ten nearest neighbors of i, and $w_{ij} = 0$ otherwise. By construction, $\boldsymbol{W}$ is row-stochastic (non-negative and row sums equal 1). This results in the $m \times 1$ vector Wy^* consisting of the spatially weighted average of competitors utility or profit from leaving the market. Wy^* represents the mechanism for modeling strategic interaction between gasoline stations in the decision to leave the market. ρ is the spatial correlation coefficient of the lagged dependent variable and measures the strength of dependence.

The k exogenous variables are represented by the matrix $\boldsymbol{X}$ (including a constant) of dimension $m \times k$ and β is the $k \times 1$ vector of coefficients of the exogenous variables. ϵ is the $m \times 1$ vector of independent and identically distributed errors. The explanatory variables included in $\boldsymbol{X}$ are location specific characteristics (convenience stores, opening hours, attendant service, surface area), demand indicators (commuting rates, population growth rates, a purchasing power proxy), the speed limit of the street where the gas station is located and property prices as indicators for the value of alternative use. Furthermore, we include dummy variables to capture the impact of branded and unbranded stations, which indicate if the station operates independently or belongs to one of ten major brands of the Austrian retail gasoline industry.

The Bayesian approach[6] of modeling binary dependent variables treats the binary 0/1 observations of y as the unobserved net utility concerned with the exit/no exit decisions, where the unobserved utility underlies the observed choice outcomes. For example, in our case where the binary observed variable represents the closed/not closed status of the stations, the decision to close the station would be made if the net profit when shutting down versus staying in the market would be grater than zero. The Bayesian way of estimating this latent profit is to replace it with parameters that are estimated. In the case of a SAR probit model and when the estimates of the unobserved parameter values y^* are given, one can proceed to estimate the remaining model parameters β and ρ from the same conditional distributions that are used in the continuous dependent variable variant of the SAR model.[7]

More formally, the choice to exit/not exit the market depends on the difference in the net profit: $\pi_{1i} - \pi_{0i}$, $i = 1, \ldots, n$ associated with the 0/1 indicators. π_{1i} represents the profit of firm i when leaving the market and π_{0i} represents firm $i's$ profit of staying in the market. The probit model assumes that this difference $y^* = \pi_{1i} - \pi_{0i}$ follows a normal distribution. We do not observe y^*, only the choice made, which are reflected in

$$y_i = \begin{cases} 1, & \text{if } y_i^* > 0 \\ 0, & \text{if } y_i^* \leq 0 \end{cases} \tag{3}$$

If the vector of latent profits y^* would be known, we would also know y, which

[6]For an introduction in Bayesian Econometrics see Koop (2003) and Koop et al. (2007).

[7]See LeSage and Pace (2009), chapter 5 and 10.

led Albert and Chip (1993) to conclude $p(\rho, \sigma^2|y^*) = p(\rho, \sigma^2|y^*, y)$. This means, if one views y^* as an additional set of parameters to be estimated, then the joint conditional posterior distribution for the model parameters β and σ takes the same form as in the continuous dependent variant of the Bayesian regression problem, rather than the problem involving a binary vector y. This approach was used by LeSage and Pace (2009) to implement a Bayesian MCMC estimation procedure for the spatial probit model.

When rearranging equation 2 so that the dependent variable y^* appears on the left hand side only, one comes to the following expressions:

$$\begin{aligned} y^* &= (\boldsymbol{I_m} - \rho \boldsymbol{W})^{-1} \beta \boldsymbol{X} + (\boldsymbol{I_m} - \rho \boldsymbol{W})^{-1} \epsilon, \\ \boldsymbol{S}(\rho) = (\boldsymbol{I_m} - \rho \boldsymbol{W})^{-}1 &= \boldsymbol{I_m} + \rho \boldsymbol{W} + \rho^2 \boldsymbol{W}^2 + \rho^3 \boldsymbol{W}^3 + \dots \end{aligned} \tag{4}$$

$\boldsymbol{S}(\rho)$ is the so called spatial spillover matrix which acts like a multiplier matrix and captures the spatial spillover effects of higher - order neighboring relations.

Due to the non-linearity in the normal probability distribution the parameter estimates $\widehat{\beta}$ of non-spatial probit models do not have the same marginal effects interpretation as in standard regression problems. Thus the change in the dependent variable y due to changes in the explanatory variable x_r is determined by the standard normal density in the following way:

$$\partial E[y|x_r]/\partial x_r = \phi(x_r, \beta_r)\beta_r \tag{5}$$

where β_r ia a non-spatial probit model estimate and $\phi(\cdot)$ is the density of the standard normal distribution.

In the SAR Probit model the non-spatial model estimates β_r are replaced with $E(\partial y/\partial x_r') = (\boldsymbol{I_m} - \rho \boldsymbol{W})^{-1} \boldsymbol{I_m} \beta_r$, which is a $m \times m$ matrix. The diagonal elements represent the direct effects - the effect of the change in the ith observation of the exogenous variable x_{ir} on the own observation y_i. The off-diagonal elements capture the indirect or spatial spillover effects - the effect of the change in the ith observation of the exogenous variable x_{ir} on other observations y_j, $j \neq i$. By replacing β_r in equation 5 we can calculate the marginal effects for the spatial probit model. For reporting issues we again have adopted the approach from LeSage and Pace (2009), who built average summary measures for the diagonal and off-diagonal elements of the coefficient matrix and thus report average direct, indirect and the average total effects being the sum of the direct and indirect effects.

The estimated coefficients, standard deviations, direct, indirect and total effects are reported in table 2. As already noted, the parameter estimates β from the SAR probit model cannot be interpreted as the effect on the probability of a station to exit the market due to changes in the explanatory variables.

The first point to note is that the spatial correlation coefficient ρ that is associated which the spatial lag of the dependent variable Wy is significantly different from zero at the 5% level. Thus the estimated coefficient ρ of -0.08 points to a negative spatial dependence in firms' decision to exit the market. Namely, the probability to exit for a particular gasoline station declines if its' neighbor is more likely to exit the gasoline market, ceteris paribus. Estimation experiments suggest that the effects of regional and firm characteristics on the probability of exit would be biased if these strategic interactions between neighboring competitors are ignored.

The effect estimates for the SAR Probit model are given in columns 4-6. These are the basis for inference for the effect of changes of explanatory variables on the exit probability of gasoline outlets as well as the spatial spillover effects on neighboring stations. Within the group of competition and spatial explanatory variables the average distance to the ten nearest neighbors exerts a significant and negative direct effect, implying a decrease in the exit probability of 0.42%, for a increase in the average distance to the ten nearest neighbors by one minute. Thus, exits are more likely for gasoline stations in markets where the degree of spatial differentiation is low: the probability of exit decreases with the average distance to the ten nearest neighbors. This finding is consistent with empirical studies on price setting in the gasoline market: a high density of gasoline stations is found to intensify competition and reduce prices. In contrast with the findings of Eckert and West (2005), we found no effect for the number of discount neighbors on the closure probability of gasoline stations in the Austrian market.

Spatial Bayesian Probit Estimation

Dependent Variable: EXIT

	Coefficient	Sd. Dev.	Direct	Indirect	Total
Constant	-0.622	0.5599*			
Competition and Spatial Variables					
Nrnbdicount	-0.0168	0.0192	-0.005	0.0004	-0.0046
Average dist 10NB	0.0042	0.0034*	-0.001	0.0001	-0.0011
DealOwned	-0.0728	0.0674	-0.021	0.0019	-0.0198
Unbranded	0.0725	0.0792	0.021	-0.0018	0.0195
Location Specific Variables					
Shop	0.0296	0.0790	0.008	-0.0008	0.0078
24h open	-0.0315	0.0301***	-0.099	0.0083	0.0907
Speed below $40km/h$	-0.904	0.2000	-0.038	0.0031	-0.0352
Speed: $40-60km/h$	-0.1413	0.1800	-0.053	0.0044	-0.0491
Speed: $61-80km/h$	-0.1097	0.1919	-0.041	0.0033	-0.0382
Popdens	-0.0022	0.0017*	-0.0007	0.0001	-0.0006
Purchase Power	-0.5331	0.9367	-0.169	0.0150	-0.1546
Commuters	0.0947	0.3973	0.033	-0.0029	0.0309
Attendant service	0.2540	0.0678***	0.078	-0.0069	0.0715
Small size station	0.4365	0.0787***	0.138	-0.0120	0.1264
Medium size station	0.3395	0.0732***	0.107	-0.0093	0.0979
Property prices	-0.0001	0.0006	-0.0001	0.0001	0.0000
Spatial Correlation					
Wy	-0.0821	0.0525**			

***significant at 1%, **significant at 5%, *significant at 10%

Dummies for missing values and fixed effects for the 9 Austrian federal states included.

Table 2: SAR Estimation

However, our results suggests that stations operating non-stop have a lower exit probability of 9.9% compared to stations which have shorter opening hours. Worthwhile to point out is that the indirect effect of this variable exhibits a positive and highly significant effect - a station operated non-stop would actually raise the exit probability of its neighbors.

Moreover, small and medium size stores had a positive direct effect, increasing the probability of exiting. For categorical variables such as store size, we interpret the magnitude of the effects as how a change in category from the ommited category (in this case big size stations) would influence the probability of shutting down.

The population density has a negative direct impact in the exit probability of stations, whereas stations offering an attendant service are more likely to exit. It is important to note, that the spatial spillover effects represented by the indirect effect for the variables size, attendant service and population density all have the opposite sign compered to the direct effect. The other explanatory variables of this group, namely, the speed limit of the street where the station is located, a purchase power proxy, commuters and property prices do not contribute to the explanatory power of the SAR probit model.

Overall, in accordance with the findings of previous studies[8], our results suggest the exit probability to be lower for large gasoline stations that are open for 24 hours and located in a region with a high population density.

4 Conclusion

The present paper examines the shutdowns of retail gasoline stations in the Austrian market by estimating a Bayesian spatial probit model. The estimation results are in line with related empirical studies of the rationalization process in this market. The network of gasoline stations in Austria tends to fewer, bigger stations with

[8] Eckert and West (2005) observe that gasoline station in the Vancouver market operating non-stop have a lower exit probability. Carranza et al. (2012) examine the effect of a price floor in Quebec on station shutdown and find a negative effect for convenient stores, number of pumps and number of islands, but a positive effect for full service on the exit probability of gasoline stations.

no attendant service, but other costumer attracting features like extended opening hours. With a spatial econometric model we are able to capture the local competition character of this market. The exit probability of gasoline stations in Austria exhibit a negative spatial correlation, meaning that the shutdown of neighboring stations lowers the competitions in a local market and that this event has a spillover effect on other stations in this market. Our results thus provide some first empirical evidence on spatial interactions in firms strategic location decisions in the (Austrian) gasoline market.

In future research, the direct and indirect effects of explanatory variables as well as the effects of ownership structure (membership in large networks) on location decisions need to be investigated in more detail. We hope that empirical research along these lines will improve our knowledge of firms' entry and exit behaviour in a spatial context and thus contribute to our understanding of the determinants of local market power.

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