Economics Letters 139 (2016) 79–83

Contents lists available at ScienceDirect

Economics Letters

journal homepage: www.elsevier.com/locate/ecolet

Network centrality and market prices: Empirical evidence☆

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HIGHLIGHTS

- We empirically investigate the importance of network centrality for pricing.
- Firms located closely to a local market center are more powerful in the pricing game.
- Centrality is more important in larger markets (as the number of firms increases).

ARTICLE INFO

Article history:
Received 21 September 2015
Accepted 24 November 2015
Available online 11 December 2015

JEL classification:
C21
D43
L11
L81
R12

Keywords:
Network centrality
Spatial competition
Retail markets
Gasoline prices

ABSTRACT

We empirically investigate the importance of centrality (holding a central position in a spatial network) for strategic interaction in pricing for the Austrian retail gasoline market. Results from spatial autoregressive models suggest that the gasoline station located most closely to the market center – defined as the 1-median location – exerts the strongest effect on pricing decisions of other stations. We conclude that centrality influences firms' pricing behavior and further find that the importance of centrality increases with market size.

1. Introduction and background

The theory of social networks has provided a number of important insights for explaining social phenomena in a wide variety of disciplines from psychology to economics (Borgatti et al., 2009). It is a fundamental axiom in social network research that the centrality of a node's position within a network determines the opportunities and constraints that it encounters and thus plays an important role in determining a node's power to influence other nodes and the network as a whole (Ballester et al., 2006, 2010; Bramoullé et al., 2014; Helsley and Zenou, 2014).

This paper contributes to a growing body of research on networks in industrial organization by investigating the importance of centrality for firms' pricing behavior empirically. While textbook models on spatial markets typically make strong symmetry assumptions, recent theoretical work in industrial organization devotes more attention to firm heterogeneity and the implications of specific positions within a network for firm performance. Vogel (2008), for example, studies location decisions of firms that differ in their marginal costs. In equilibrium, more efficient firms will be more isolated and will set higher markups (because their competitors offer relatively poor substitutes). In Braid (2013) and Firgo et al. (2015) firms are located in a network of links and nodes that can be interpreted as roads and intersections. Both papers argue that firms characterized by a more central position in a spatial network are more powerful in terms of having a stronger impact on their competitors' prices and on equilibrium prices.

In networks with spatial patterns similar to a star graph, Freeman (1979) shows that the centrality of the central node

☆ We gratefully acknowledge helpful comments from Klaus Gugler, Michael Pfaffermayr, Robert D. Weaver, and the participants of seminars and conferences in Athens, Boston, Chicago and Innsbruck. The work was generously supported by funds of the Oesterreichische Nationalbank (Anniversary Fund, project number: 12974).

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http://dx.doi.org/10.1016/j.econlet.2015.11.032
0165-1765/

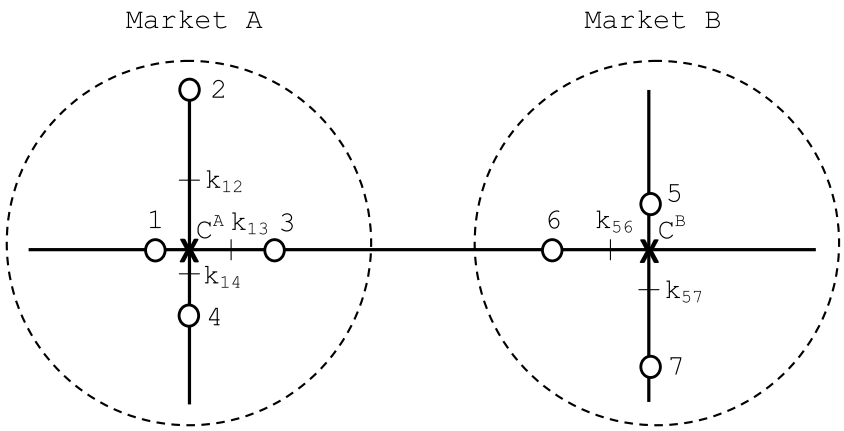

Fig. 1. Centrality on intersecting roads. Notes: The solid lines denote the road network, the white dots the firms, and the centers of the local markets are labeled by **X**. k_{ij} indicates the location of the marginal consumer (for particular prices and transportation costs) indifferent between purchasing at firm *i* or firm *j*, and the dashed lines denote the local market boundaries.

relative to remote nodes increases monotonically with the number of nodes, which holds for a number of different concepts of centrality. This suggests that the importance of a central supplier relative to remote firms in a pricing game increases with the number of firms in a local market.

The following simple example illustrates the importance of centrality in firms' price interactions and outlines our contribution to the (scarce) empirical literature. Assume that seven firms (nodes) are located in a network of roads (edges) as in Fig. 1. Firms 1 to 4 are assigned to market A, firms 5 to 7 to market B.[1] Using standard assumptions in spatial competition models with respect to product characteristics, production costs and consumer behavior, this simple network suggests that firms 1 and 5 will have a more 'central' position in their markets than all other firms. Centrality, defined as the extent to which agents are connected to other agents, provides these two firms with a dominant role in strategic price interactions between firms. In market A (B), firm 1 (5) competes for the same marginal consumer $k_{1,j}$ ($k_{5,j}$) with all other *j* firms in this market. In contrast, the 'remote' firms (2, 3, and 4 as well as 6 and 7) compete for the same marginal consumer with the 'central' supplier only, but do not compete directly with other remote firms within their market. In their pricing decisions, remote firms will thus consider only the price charged by the central firm, but not the prices charged by other remote firms. The central firm, on the other hand, takes the prices charged by all other firms in the local market into account. Therefore, centrality endows the central supplier with a dominant role in strategic price interactions between firms in the respective local market: In their own pricing decisions remote firms will consider only the price charged by the central supplier, but not other remote firms' prices.

There is only very little empirical work on the importance of centrality in firms' pricing decisions.[2] In the remainder of the article we explore empirically whether central suppliers indeed play a more prominent role in pricing games in the Austrian retail gasoline market.

2. Data and identification of market centers

The empirical application is based on data for the geographical locations of the complete population of gasoline stations in Austria collected by the company Catalist in August 2003. Using the software ArcGIS, the geographical coordinates of each gasoline station are located and plotted on a map. The routing tool WiGeoNetwork by WiGeoGIS calculates distances between all gasoline stations. To account for differences in speed limits and one-way roads, all distances are measured in driving time. These spatial data are merged with an unbalanced panel of station-level pricing data collected and provided by the Austrian Chamber of Labor nationwide on a particular day every three months between October 1999 and March 2005 for a total of 23 points in time. These data are supplemented by Catalist data on station characteristics and regional data by Statistics Austria.

We follow Pinkse et al. (2002) and define markets via nearest-neighbor-relations. Each observation is connected to its spatially nearest neighbor, and all stations are considered to be in the same local market as long as they are connected by nearest-neighbor-relations. Applying this market definition all 2,814 gasoline stations are assigned to 761 non-overlapping local markets.[3]

The market center is defined as the unique point which minimizes the sum of distances to all gasoline stations in the local market (i.e. the 1-median location; see Hakimi, 1964). Potential market centers are restricted to points located on the road network. In Fig. 1, C^A and C^B represent the market centers for markets A and B. The central supplier (firm 1 in market A and firm 5 in market B) is the station located most closely to the market center, while all other stations are denoted as remote suppliers. Using actual data for the Austrian retail gasoline market, Fig. 2 illustrates four different local markets, their road networks, gasoline stations and market centers.

Observations are included in the empirical analysis only if prices are observed for all stations in the respective local market in a particular time period, which reduces the size of the initial sample to 501 stations in 171 local markets. We further exclude observations in 79 markets where a unique central position cannot be identified.[4] Eventually, the empirical analysis is based on an unbalanced panel of 343 stations in 92 different markets comprising three to six competitors (2,920 observations in total).

[1] The definition of markets will be discussed in more detail later.

[2] Firgo et al. (2015) assign different degrees of centrality to each supplier. The present paper is more closely related to a star-shaped graph which implies a dichotomous distinction between one central supplier and (all other) remote firms.

[3] In Fig. 1, for example, this approach defines two separate markets, comprising firms 1 to 4 and firms 5 to 7, respectively. The fact that this implies no interaction between local markets is a reasonable assumption in our application. In our sample, the average driving time to the closest station outside the respective local market is 4.3 min longer than the shortest (and 1.7 min longer than the average) distance to rivaling firms within the local market. This suggests that local markets (as defined by nearest-neighbor-relations) are only loosely related to other local markets.

[4] In 'linear city' (Hotelling, 1929) markets with an even number of firms, a unique (1-median) central location does not exist.