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AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

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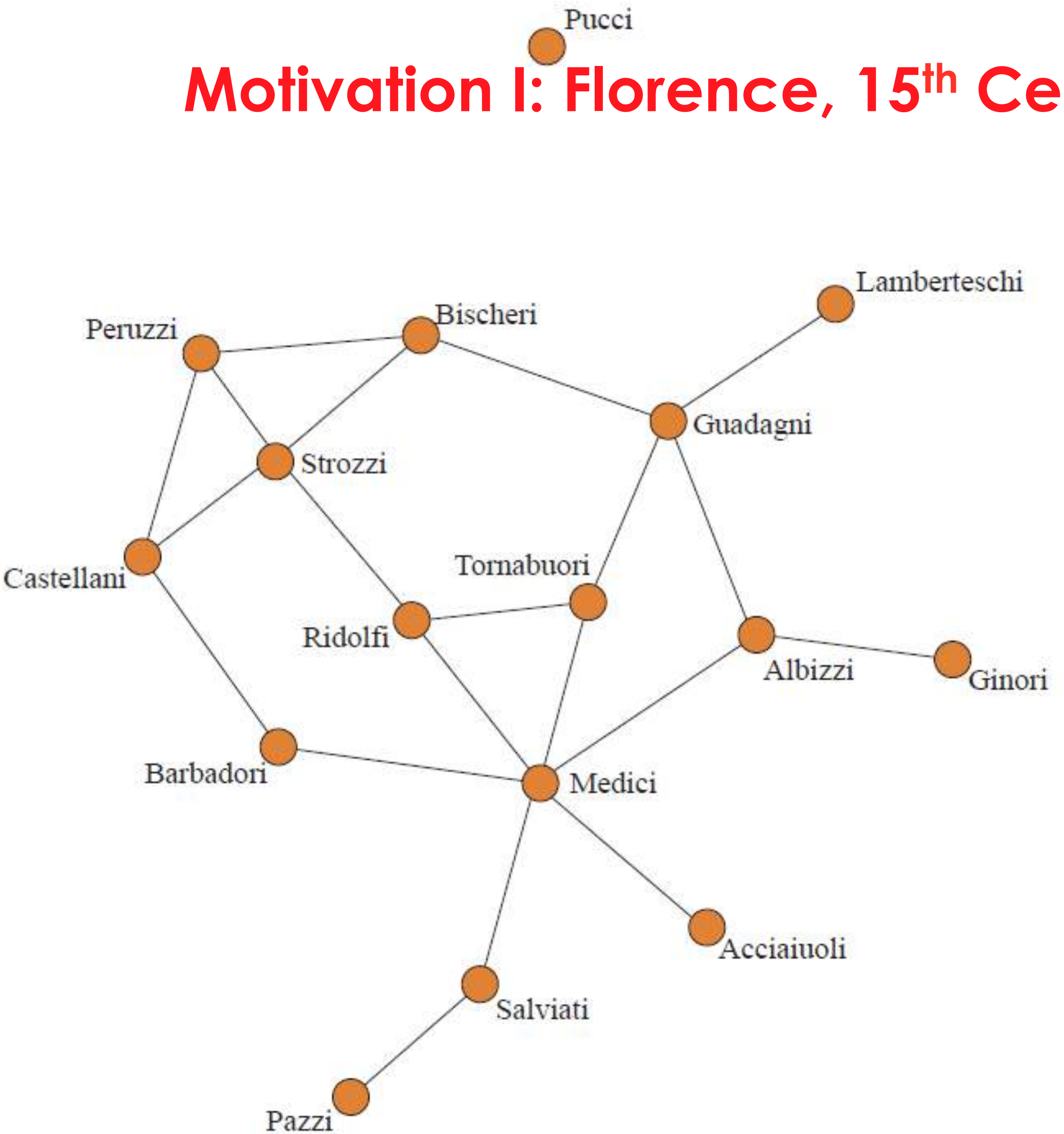
Space, Centrality and Prices

Matthias Firgo, Dieter Pennerstorfer & Christoph Weiss

Winterseminar der GfR, Innsbruck/Igls, 25.02.2015

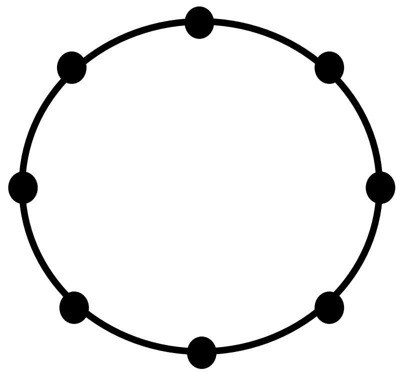
Motivation I: Florence, 15th Century



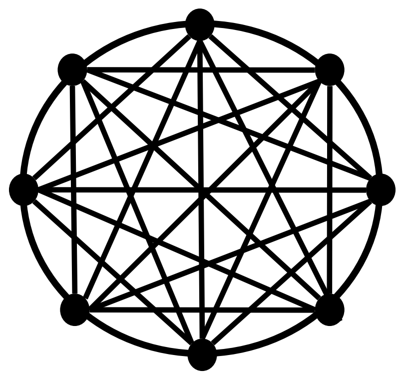
Introduction I

- Strong assumptions wrt symmetry
  - Hotelling (1929)

  - Salop (1979)

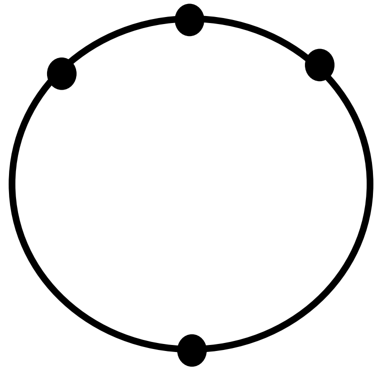


  - Chamberlin (1933)

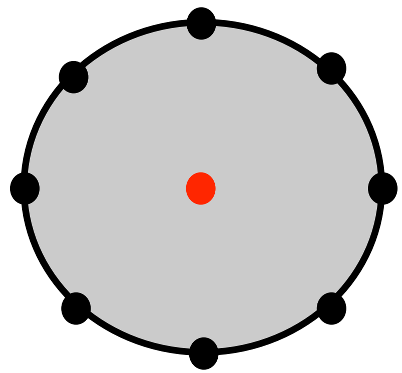


Introduction II

- Fik (1991)



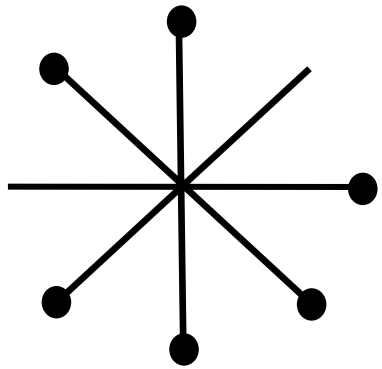
- Balasubramanian (1998)
  Bouckaert (2000)
  Madden and Pezzino (2011)



Introduction III

- Chen and Riordan (2007)

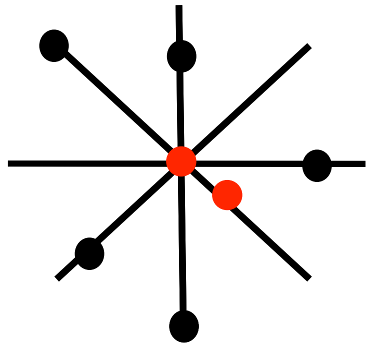
  Spokes Model



- A ‚Modified Spokes Model'

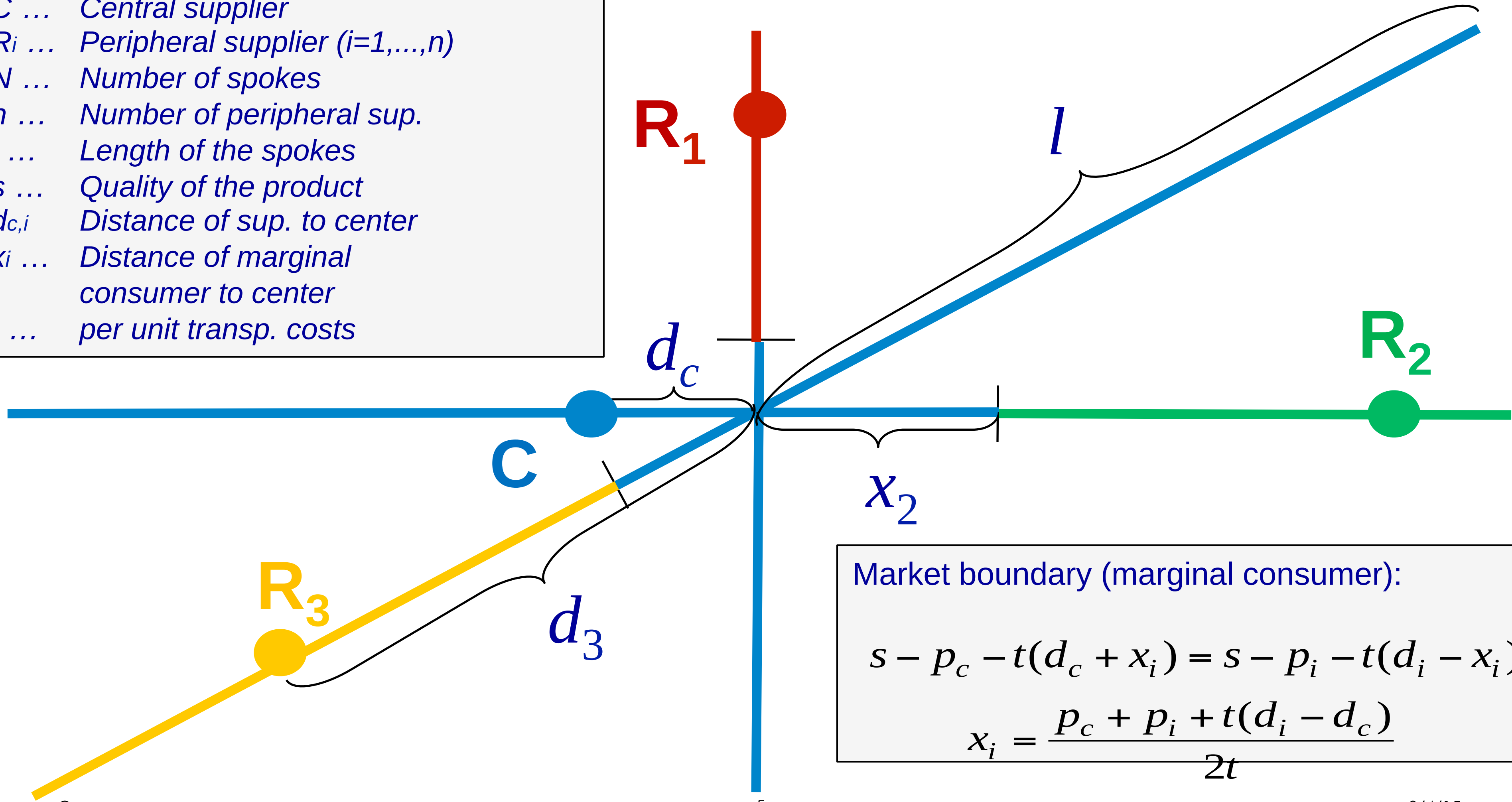
  Distinguish between Central (C) and Remote (R) firms in space

  „Asymmetric competition" between firms



Model I

C …	*Central supplier*
R_i …	*Peripheral supplier (i=1,...,n)*
N …	*Number of spokes*
n …	*Number of peripheral sup.*
l …	*Length of the spokes*
s …	*Quality of the product*
$d_{c,i}$	*Distance of sup. to center*
x_i …	*Distance of marginal consumer to center*
t …	*per unit transp. costs*



Market boundary (marginal consumer):

$$s - p_c - t(d_c + x_i) = s - p_i - t(d_i - x_i)$$

$$x_i = \frac{p_c + p_i + t(d_i - d_c)}{2t}$$

Model II

$$\pi_C = (p_C - c_C)\left[\sum_{i=1}^{n} x_i + l(N - n + 1)\right].$$

$$R_C \equiv p_C = \frac{1}{2}\left[\frac{\sum p_i}{n} + t\left(\frac{\sum d_i}{n} - d_C\right) + c_C\right] + tl\left(\frac{N-n}{n}\right).$$

$$\pi_i = (p_i - c_i)(d_i - x_i).$$

$$R_i \equiv p_i = \frac{1}{2}\left[p_C + t(d_C - d_i) + c_i\right] + tl.$$

Model III

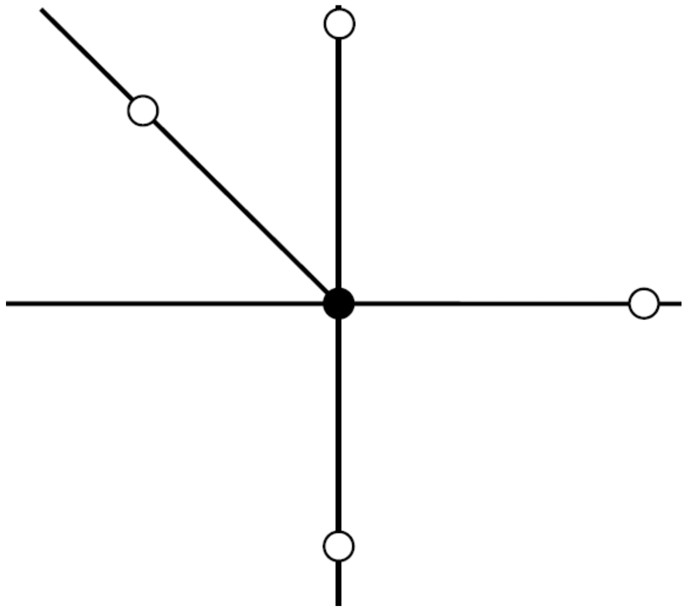
Market Size and Price Transmission:
The reaction of a firm to a price change by a different firm in the local market decreases on average as market size increases.

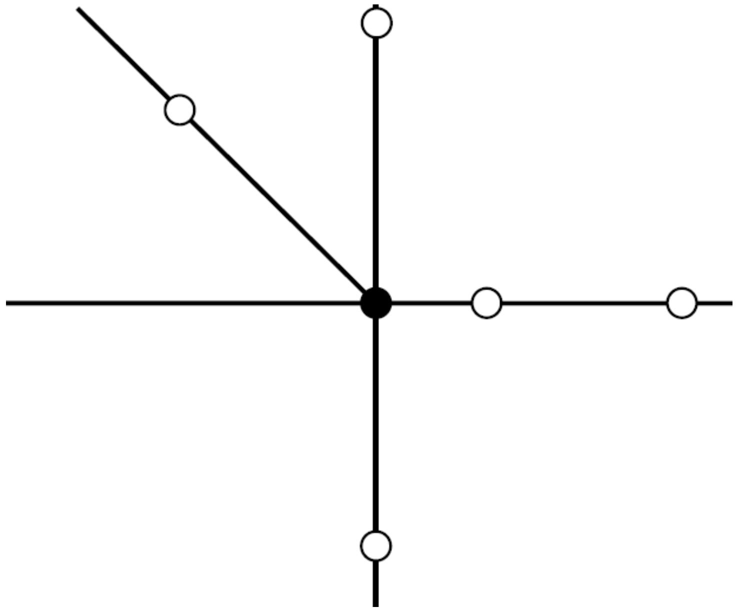
$$\frac{\sum_i \sum_{j \neq i} \frac{\partial p_i}{\partial p_j}}{n(n+1)} = \frac{1}{2n}$$

Centrality and Asymmetry:
The reaction of remote firms to a price change by a central supplier is stronger than the reaction of central firms to a price change by a peripheral supplier. The reaction of on remote firm to a price change by another remote firm is even weaker.

$$\frac{\partial p_i}{\partial p_c} = \frac{1}{2} > \frac{\partial p_c}{\partial p_i} = \frac{1}{2n} > \frac{\partial p_j}{\partial p_i} = 0, \ \forall n > 1 \,\text{und}\, i \neq j \,\text{und}\, i, j \neq c$$

Additional Remark





$$\frac{\sum_i \sum_{j \neq i} \frac{\partial p_i}{\partial p_j}}{n(n+1)} = \frac{1}{2n}$$

$$\frac{\partial \overline{p}_i}{\partial p_c} > \frac{\partial p_c}{\partial \overline{p}_i} > \frac{\partial \overline{p}_j}{\partial \overline{p}_i}, \; \forall n > 1 \, \text{und} \, i \neq j$$

Next steps

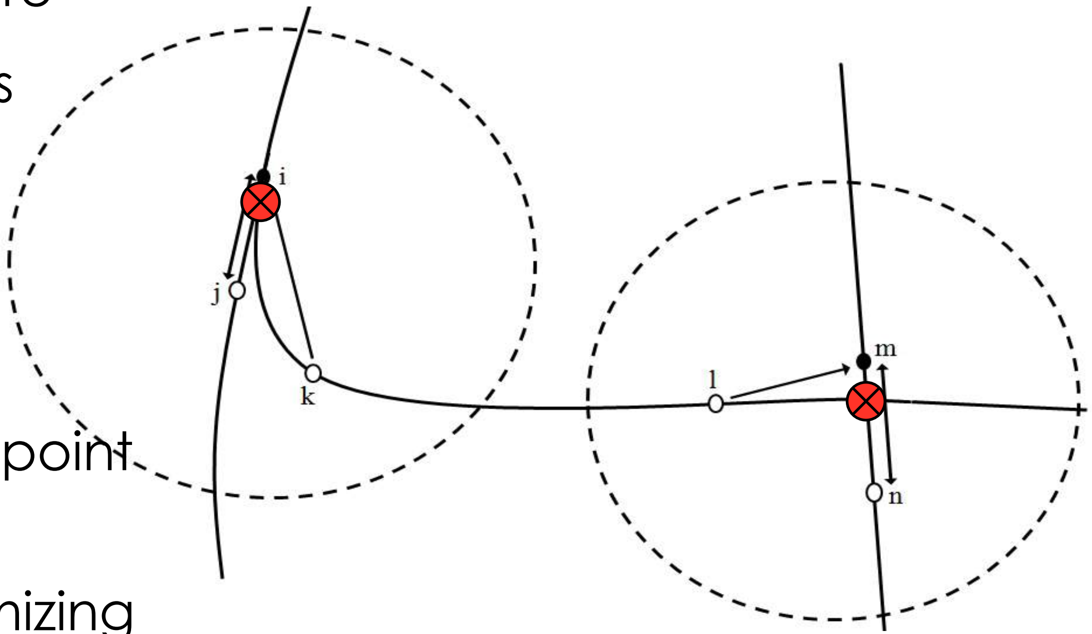
- Gap between simple model and real world
  - Alternative I: all markets / firms are considered; each firm is assigned a different `degree of centrality´

    (as done by Firgo / Pennerstorfer / Weiss (hopefully 2015):
    Centrality in Pricing in Spatially Differentiated Markets: The Case of Gasoline
  - Alternative II: only local markets the fit the theoretical model are considered (conceptionally similar to Breshnahan und Reiss (1991))

- Next steps:
  - Market definition
  - Finding market centers
  - Determining central suppliers

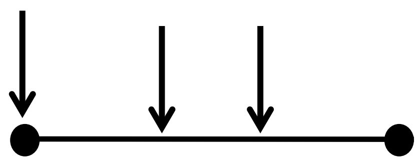
Definition of Local Markets, Market Center and Central Supplier I

- Delimitation of local markets
  - Several criteria used in the literature
  - Stores with next-neighbor-relations grouped together
  - Creates non-overlapping markets
- Market center
  - Graph theory: 1-median location point (Hakimi, 1964)
  - Unique location (on a road) minimizing the sum of distances to all stores $\left(\min d_c + \sum d_i\right)$
- Central supplier:
  - store located closest to the market center



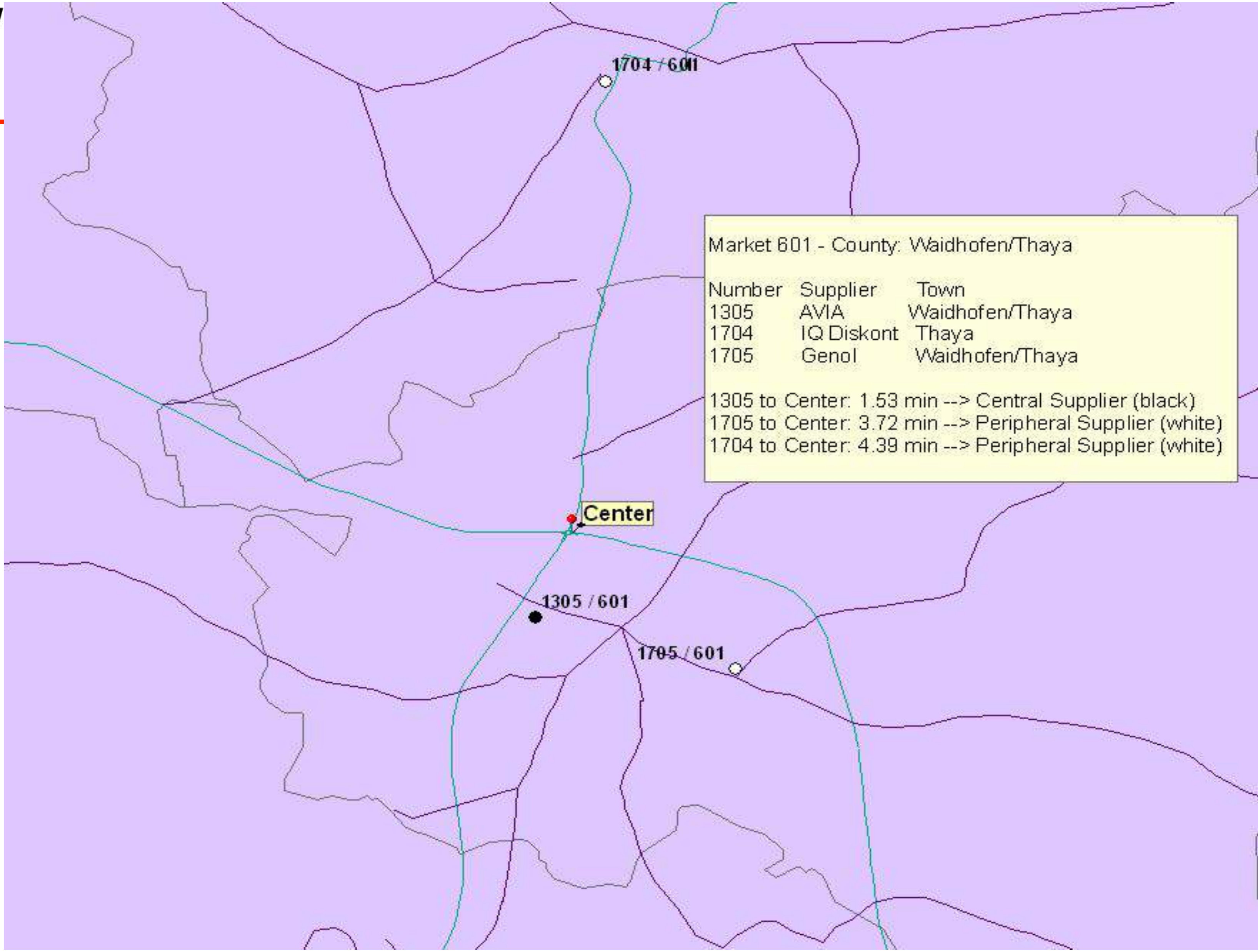
Definition of Local Markets, Market Center and Central Supplier II

- Delimitation of local markets
  - Easy to implement
  - Can be solved for all observations (with probability →1)
  - Creates non-overlapping ('isolated') markets
- Market center
  - Difficult to implement (each local market looks different)
  - Cannot be solved for all observations
  - Problem of finding a unique point
  - 'This is tedious work, but straightforward.'



- Central supplier:
  - Easy to implement
  - Can be solved for all observations (with probability →1)

W


1704 / 601
Market 601 - County: Waidhofen/Thaya
Number Supplier Town
1305 AVIA Waidhofen/Thaya
1704 IQ Diskont Thaya
1705 Genol Waidhofen/Thaya
1305 to Center: 1.53 min --> Central Supplier (black)
1705 to Center: 3.72 min --> Peripheral Supplier (white)
1704 to Center: 4.39 min --> Peripheral Supplier (white)
Center
1305 / 601
1705 / 601

Data I

Application to the gasoline market

- Quarterly price data for Diesel
- Oct. 1999 – March 2005 (23 periods)
- 596 – 1,383 gasoline stations (unbalanced panel)
- Location (and station characteristics) for all 2,814 gasoline stations in Austria
- Merged with GIS information on road network (ArcGIS extension of WIGeoNetwork)
- Distance between stations in driving time in minutes
- Other station characteristics:
  - Number of pumps; speed limit at road; brand; shop; …
- Regional characteristics:
  - Tourists; Commuters; Income; …

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Data II

market size	entire sample cross section # of markets	# of stations	with market center and prices for all firms unbalanced panel # of markets	# of stations
2	241	482	0	0
3	176	528	392	1,176
4	151	604	254	1,016
5	93	465	94	470
6	42	252	43	258
7	27	189	0	0
8	12	96	0	0
9	9	81	0	0
10	1	10	0	0
11	5	55	0	0
12	3	36	0	0
16	1	16	0	0
total	761	2,814	783	2,920

Empirical specification I

Symmetric Model

$$p_{ikt} = \sum_{m=3}^{M} \rho_m \sum_{j(\in k)\neq i} p_{jkt} + X_{ikt}\beta + \mu_k + \theta_t + \varepsilon_{ikt}$$

Hypothesis:

$$\rho_m > \rho_{m'} \quad \text{for all} \quad m < m'$$

Empirical specification II

Asymmetric Model

$$p_{ikt} = \sum_{m=3}^{M}\left\{\left(\rho_m^{C\to R}\sum_{j\neq i}(1-c_{ik})c_{jk}\,p_{jkt}\right)+\left(\rho_m^{R\to C}\sum_{j\neq i}c_{ik}(1-c_{jk})p_{jkt}\right)+\left(\rho_m^{R\to R}\sum_{j\neq i}(1-c_{ik})(1-c_{jk})p_{jkt}\right)\right\}$$
$$+X_{ikt}\beta+\mu_k+\theta_t+\varepsilon_{ikt}$$

Empirical specification II

Asymmetric Model

$$p_{ikt} = \sum_{m=3}^{M} \left\{ \left(\rho_m^{C \to R} \sum_{j \neq i} (1 - c_{ik}) c_{jk} p_{jkt} \right) + \left(\rho_m^{R \to C} \sum_{j \neq i} c_{ik} (1 - c_{jk}) p_{jkt} \right) + \left(\rho_m^{R \to R} \sum_{j \neq i} (1 - c_{ik})(1 - c_{jk}) p_{jkt} \right) \right\}$$
$$+ X_{ikt}\beta + \mu_k + \theta_t + \varepsilon_{ikt}$$

Central Supplier:

$$p_{ikt} = \sum_{m=3}^{M} \left\{ \left(\rho_m^{R \to C} \sum_{j \neq i} c_{ik} (1 - c_{jk}) p_{jkt} \right) \right\}$$
$$+ X_{ikt}\beta + \mu_k + \theta_t + \varepsilon_{ikt}$$

Remote Supplier:

$$p_{ikt} = \sum_{m=3}^{M} \left\{ \left(\rho_m^{C \to R} \sum_{j \neq i} (1 - c_{ik}) c_{jk} p_{jkt} \right) + \left(\rho_m^{R \to R} \sum_{j \neq i} (1 - c_{ik})(1 - c_{jk}) p_{jkt} \right) \right\}$$
$$+ X_{ikt}\beta + \mu_k + \theta_t + \varepsilon_{ikt}$$

Empirical specification II

Asymmetric Model

$$p_{ikt} = \sum_{m=3}^{M} \left\{ \left(\rho_m^{C \to R} \sum_{j \neq i} (1 - c_{ik}) c_{jk} p_{jkt} \right) + \left(\rho_m^{R \to C} \sum_{j \neq i} c_{ik} (1 - c_{jk}) p_{jkt} \right) + \left(\rho_m^{R \to R} \sum_{j \neq i} (1 - c_{ik})(1 - c_{jk}) p_{jkt} \right) \right\}$$
$$+ X_{ikt}\beta + \mu_k + \theta_t + \varepsilon_{ikt}$$

Central Supplier:

$$p_{ikt} = \sum_{m=3}^{M} \left\{ \left(\rho_m^{R \to C} \sum_{j \neq i} p_{jkt} \right) \right\}$$
$$+ X_{ikt}\beta + \mu_k + \theta_t + \varepsilon_{ikt}$$

Remote Supplier:

$$p_{ikt} = \sum_{m=3}^{M} \left\{ \left(\rho_m^{C \to R} \sum_{j \neq i} c_{jk} p_{jkt} \right) + \left(\rho_m^{R \to R} \sum_{j \neq i} (1 - c_{jk}) p_{jkt} \right) \right\}$$
$$+ X_{ikt}\beta + \mu_k + \theta_t + \varepsilon_{ikt}$$

Empirical specification II

Asymmetric Model

$$p_{ikt} = \sum_{m=3}^{M} \left\{ \left(\rho_m^{C \to R} \sum_{j \neq i} (1 - c_{ik}) c_{jk} p_{jkt} \right) + \left(\rho_m^{R \to C} \sum_{j \neq i} c_{ik} (1 - c_{jk}) p_{jkt} \right) + \left(\rho_m^{R \to R} \sum_{j \neq i} (1 - c_{ik})(1 - c_{jk}) p_{jkt} \right) \right\}$$
$$+ X_{ikt} \beta + \mu_k + \theta_t + \varepsilon_{ikt}$$

Hypotheses:

$$\rho_m^{C \to R} > \rho_m^{R \to C} > \rho_m^{R \to R}$$

$$\rho_m^{C \to R} = \rho_{m'}^{C \to R} \quad \text{for all } m, m'$$
$$\rho_m^{R \to C} > \rho_{m'}^{R \to C} \quad \text{for all } m < m'$$

Empirical specification II

Asymmetric Model

$$p_{ikt} = \sum_{m=3}^{M} \left\{ \left(\rho_m^{C\to R} \sum_{j\neq i} (1-c_{ik}) c_{jk} p_{jkt} \right) + \left(\rho_m^{R\to C} \sum_{j\neq i} c_{ik} (1-c_{jk}) p_{jkt} \right) + \left(\rho_m^{R\to R} \sum_{j\neq i} (1-c_{ik})(1-c_{jk}) p_{jkt} \right) \right\} + X_{ikt}\beta + \mu_k + \theta_t + \varepsilon_{ikt}$$

Hypotheses:

$$\rho_m^{C\to R} > \rho_m^{R\to C} > \rho_m^{R\to R}$$

$$\rho_m^{C\to R} = \rho_{m'}^{C\to R} \quad \text{for all } m, m'$$

$$\rho_m^{R\to C} > \rho_{m'}^{R\to C} \quad \text{for all } m < m'$$

Methodology

- Spatial autoregressive (SAR) model with multiple spatial lags of endogenous variable
- Spatially lagged prices are endogenous
- Maximum Likelihood (ML) techniques
- (residuals clustered at station level)

Spatial Autoregressive Parameters

Market Size	Effect	Symmetric Model Coef.	(S.D.)	Sign.
3		0.317	(0.005)	***
4		0.212	(0.004)	***
5		0.166	(0.003)	***
6		0.131	(0.004)	***

Spatial Autoregressive Parameters

Market Size	Effect	Asymmetric Model Coef.	(S.D.)	Sign.
3				
4				
5				
6				
3	C → R			
3	R → C			
3	R → R			
4	C → R			
4	R → C			
4	R → R			
5	C → R			
5	R → C			
5	R → R			
6	C → R			
6	R → C			
6	R → R			

$$\frac{\partial p_i}{\partial p_c} = \frac{1}{2}$$

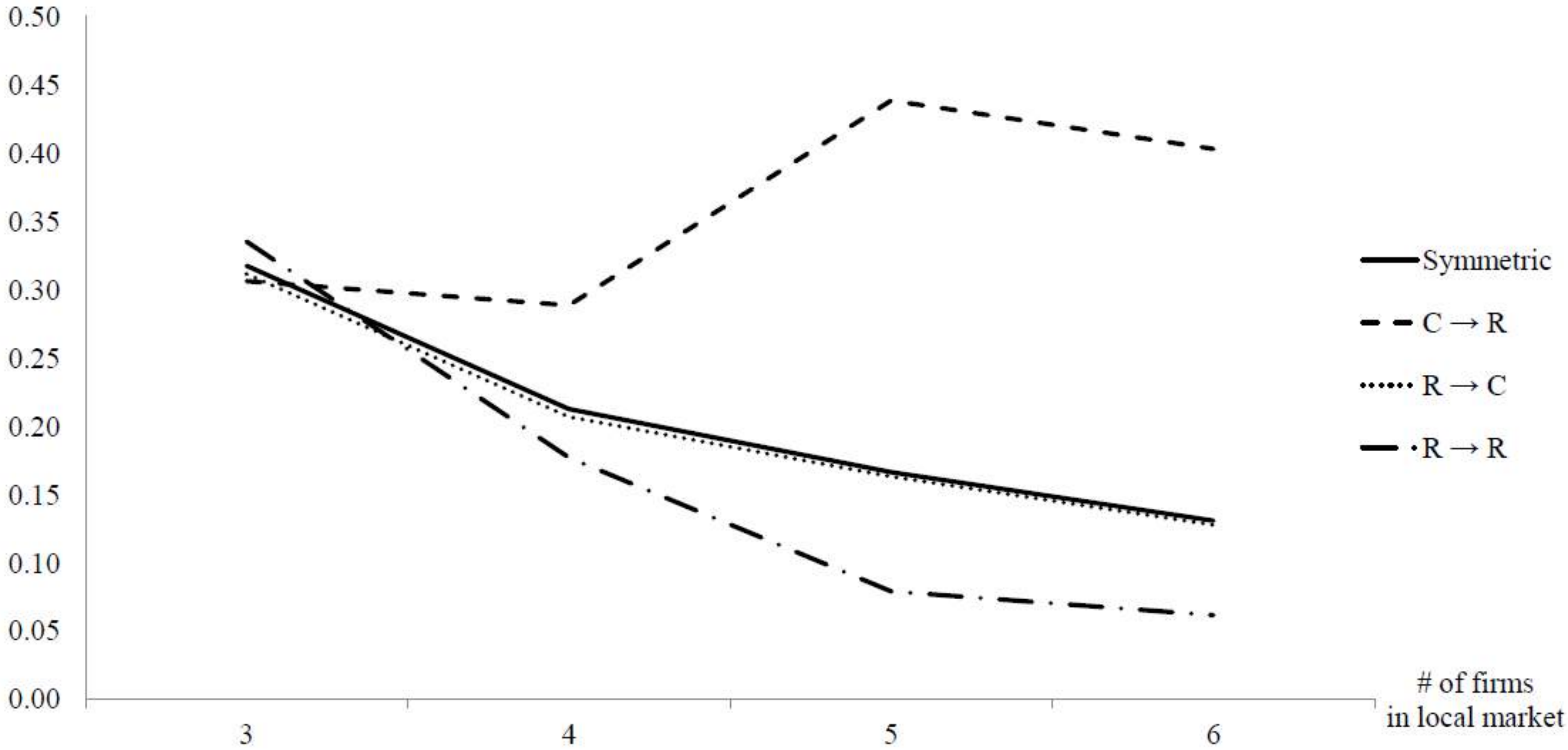
$$\frac{\partial p_c}{\partial p_i} = \frac{1}{2n}$$

$$\frac{\partial p_j}{\partial p_i} = 0$$

Spatial Autoregressive Parameters

Market Size	Effect	Symmetric Model Coef.	(S.D.)	Sign.	Asymmetric Model Coef.	(S.D.)	Sign.
3		0.317	(0.005)	***			
4		0.212	(0.004)	***			
5		0.166	(0.003)	***			
6		0.131	(0.004)	***			
3	C → R				0.306	(0.033)	***
3	R → C				0.311	(0.006)	***
3	R → R				0.335	(0.032)	***
4	C → R				0.288	(0.029)	***
4	R → C				0.207	(0.004)	***
4	R → R				0.177	(0.015)	***
5	C → R				0.438	(0.002)	***
5	R → C				0.163	(0.004)	***
5	R → R				0.079	(0.001)	***
6	C → R				0.403	(0.103)	***
6	R → C				0.127	(0.004)	***
6	R → R				0.061	(0.027)	**

Illustration of Results



Limitations

- Ideally: Exogenous (random) shocks at various points in the network as a (quasi-)experiment
- Also, we do not observe or model a demand system
- We do not solve – or even address – Manski's (1993) reflection problem:

$$p = \rho Wp + X\beta + WX\delta + \varepsilon$$

- The spatial patterns might come from prices causally influencing other prices, but might come from other stations characteristics or spatially correlated unobservables.

Nevertheless

- Expectation $$\frac{\partial \overline{p}_i}{\partial p_c} > \frac{\partial p_c}{\partial \overline{p}_i} > \frac{\partial \overline{p}_j}{\partial \overline{p}_i}, \quad \forall n > 1 \,\text{und}\, i \neq j$$
- Finding $$\frac{\partial \overline{p}_i}{\partial p_c} > \frac{\partial p_c}{\partial \overline{p}_i} > \frac{\partial \overline{p}_j}{\partial \overline{p}_i}, \quad \forall n > 2 \,\text{und}\, i \neq j$$

- The main result is that prices are more strongly correlated with the price charged by station in that is located closest to the market center.

- Highlights: Useful and necessary to take the complex geography of the market into account

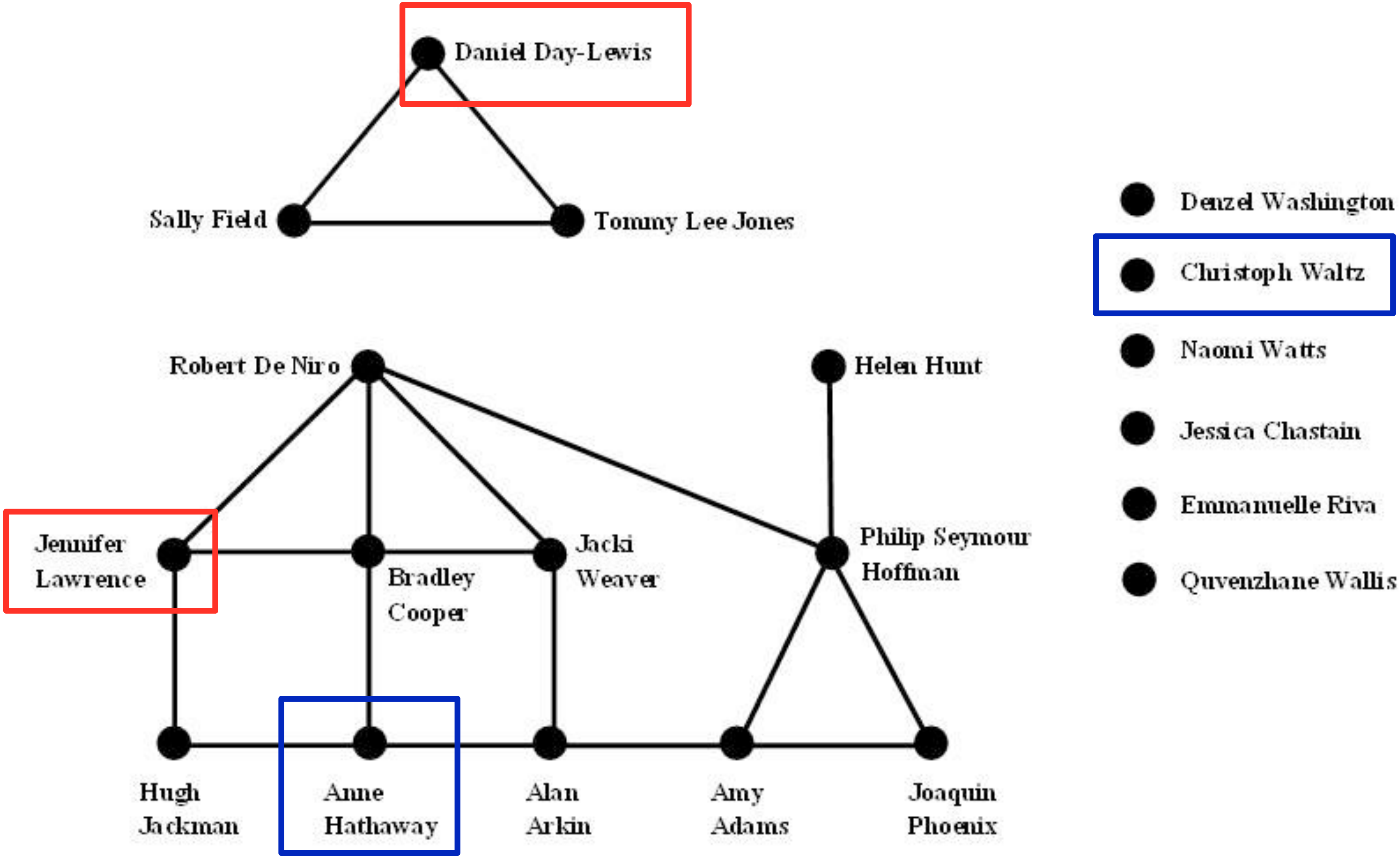
Extensions

- Entry and exit of firms/products
  - Endogenous location: Positioning becomes more important with asymmetric firms
  - Effect of entry is different (central / remote firm)

- Implications of joint ownership

Further slides

Motivation II: Oscar-Nominees 2013



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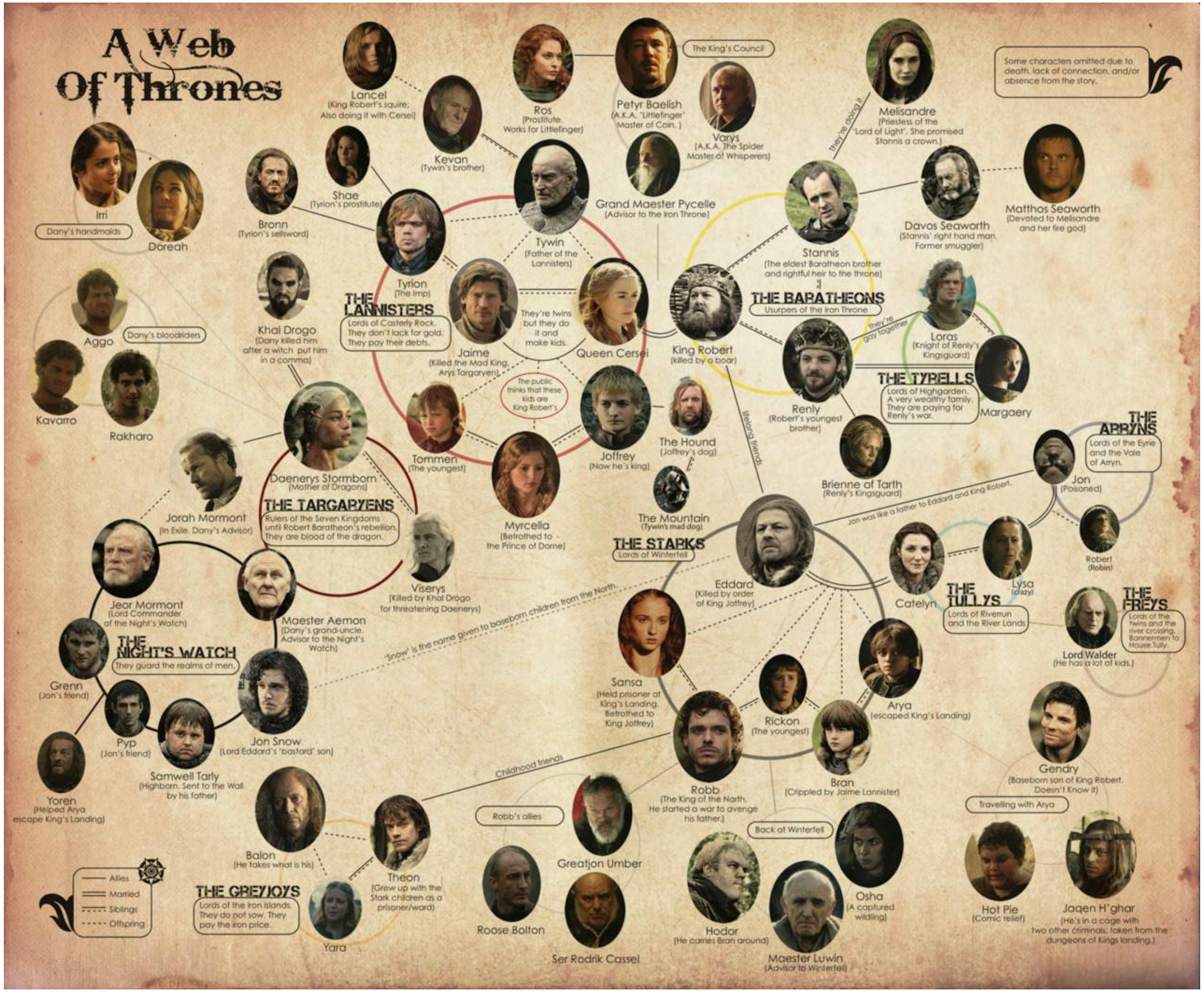
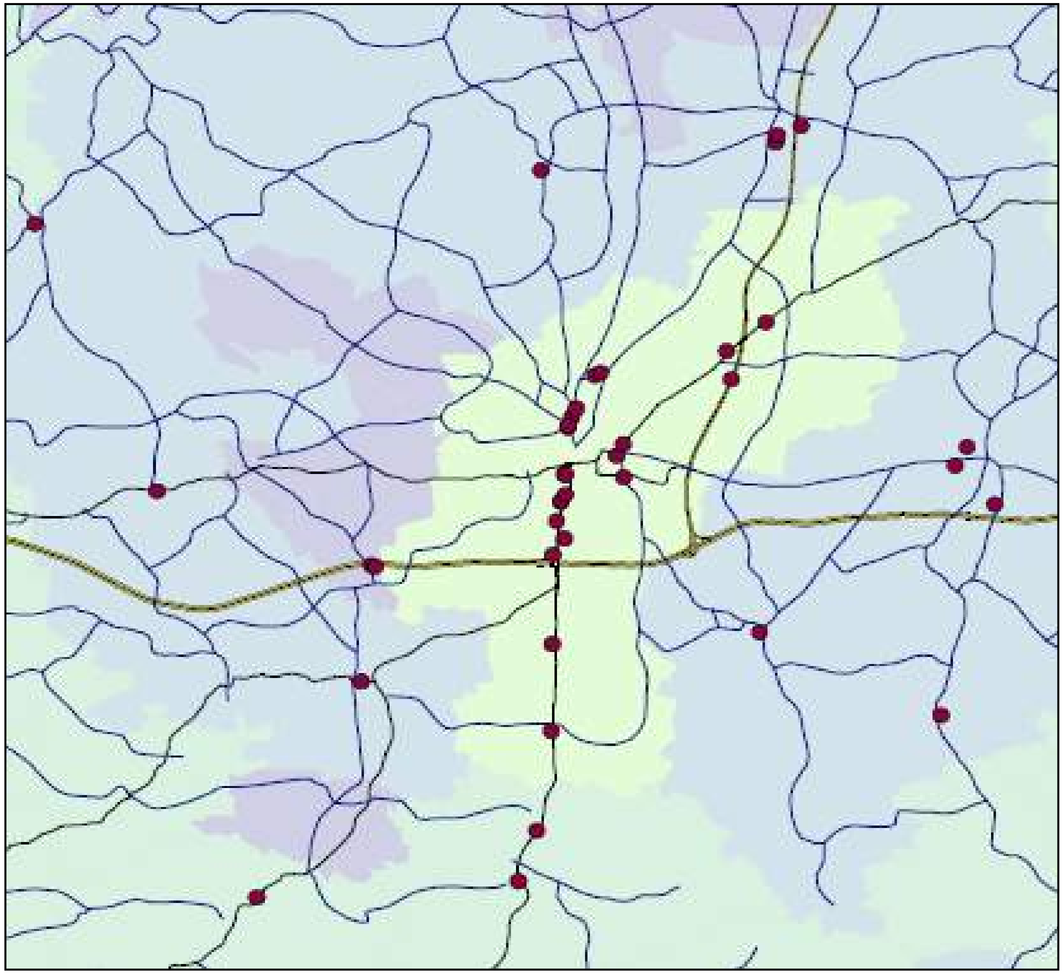
Motivation III: Game of Thrones



Data (2)

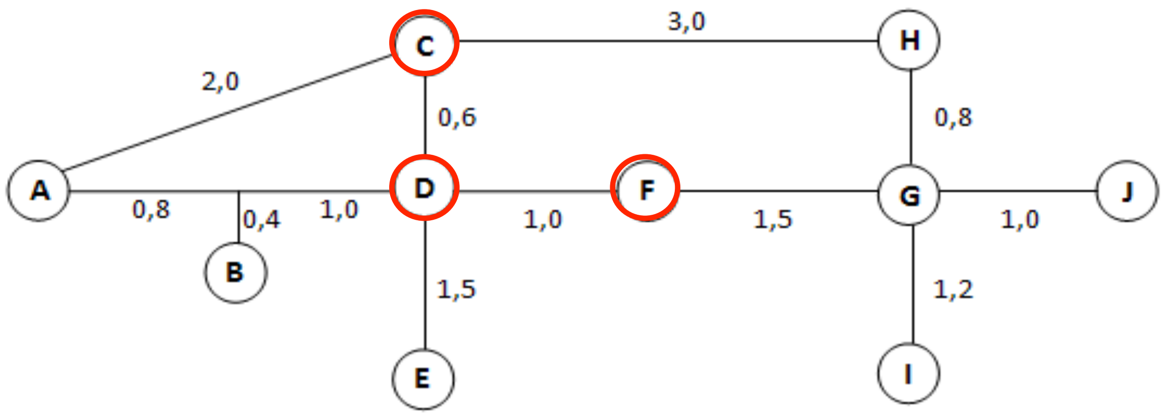
- Location of gasoline stations in the area of ‚St. Pölten‘
- Definition of Neighborhood and Distance
- Idenitification of ‚Central‘ and ‚Remote‘ station?
- ‚Degree of network centrality‘



Data (4)

Network of 10 observations (A to J), $\bar{h} = 2$

- C: 1x nearest neighbor (D), 1x 2nd n. nb. (E): $a_{1C} = \sum_j a_{1Cj} = 1; \quad a_{2C} = \sum_j a_{2Cj} = 1$
- D: 3x nearest neighbor (C,E,F), 2x 2nd n. nb. (A,B): $a_{1D} = 3; \quad a_{2D} = 2$
- F: 2x 2nd nearest neighbor (C,D): $a_{1F} = 0; \quad a_{2F} = 2$



Degrees of Centrality:

$$DC_{\bar{h}i} = \sum_{h=1}^{\bar{h}} \sum_{j=1}^{n} a_{hij}$$

A	1	F	2
B	1	G	4
C	2	H	3
D	5	I	0
E	0	J	2

Conclusions and …

- ‘Modified Spokes Model’ to highlight importance of ‘Centrality’
- Asymmetry in pricing: prices set by central suppliers have stronger impact on neighboring firms than prices set by peripheral firms
- Empirical application to gasoline market
  - Location is main source of product differentiation
  - Heterogeneity (exogenously) determined by the network of roads
- ‘Degree of Centrality’ influences strategic interactions between firms

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Data II

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7	27	189	15	105	0	0
8	12	96	7	56	0	0
9	9	81	5	45	0	0
10	1	10	1	10	0	0
11	5	55	4	44	0	0
12	3	36	3	36	0	0
16	1	16	0	0	0	0
total	761	2,814	209	1,039	783	2,920