Market power across the Channel: Continental gas markets isolated?

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Motivation

- **Post-liberalization:** emergence of spatially localized spot markets interconnected throughout a network.

Are the arbitrages performed between these markets efficient?

Map 2: US natural gas spot prices at major trading hubs, 2006 ($/MBtu)

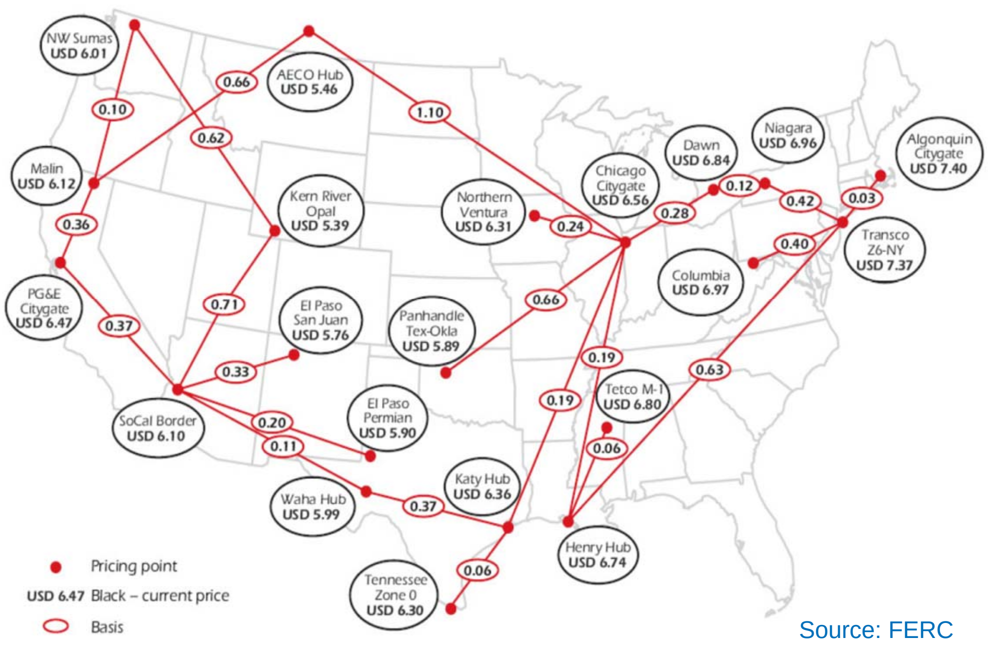

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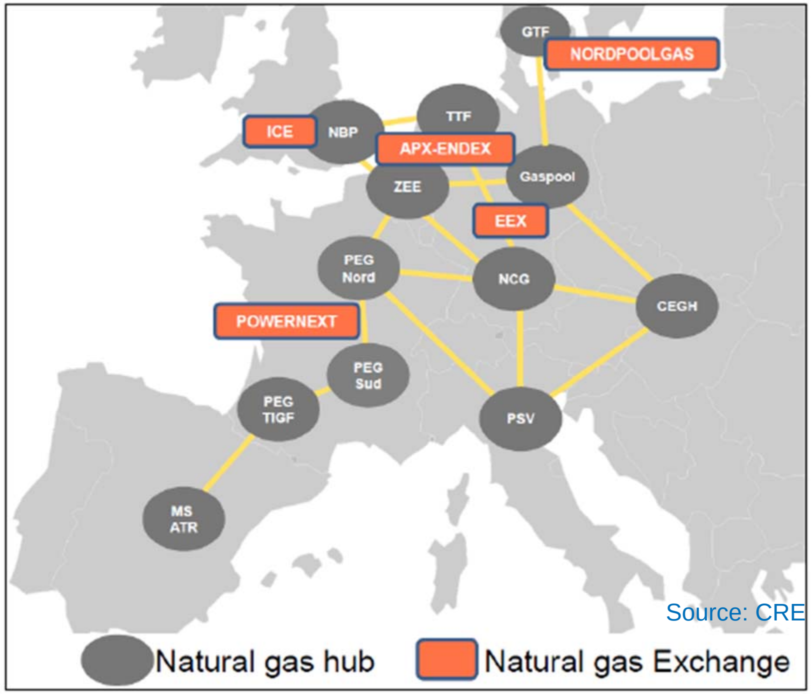
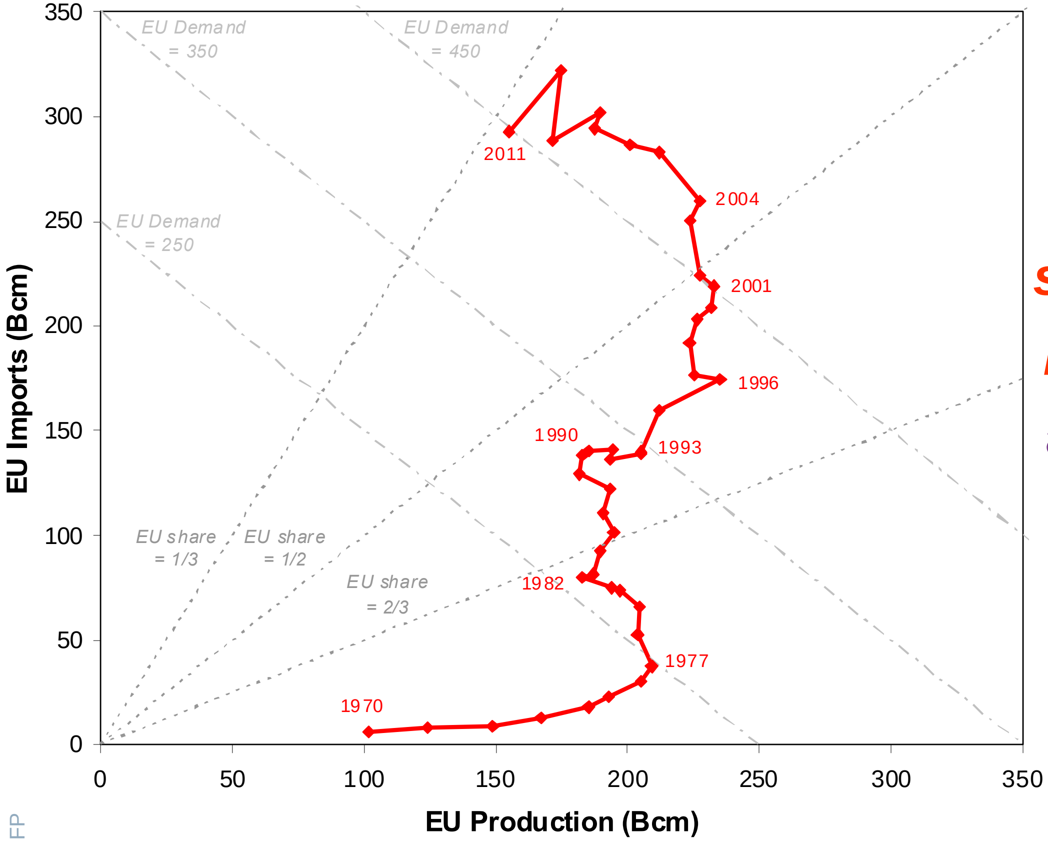
Figure 1: European gas hubs and gas exchanges



Background

- **The resurfacing of supply security concerns in Europe**



Source: BP (2012)

The EU regulatory debate emphasizes "*the importance of short-term spatial arbitrages as a means to prevent balkanization*" and insure an efficient supply of natural gas (Vazquez et al., 2012).

Objectives of the paper

- **Propose an empirical methodology to assess the arbitrages performed between two gas markets linked by a capacity-constrained pipeline system**

$$j \xrightarrow{\quad Q_{ji} \leq K_{ji} \quad} i$$

- **This methodology is designed to:**
  - **(i) detect if markets are "integrated,"**

    i.e., if all the spatial arbitrage opportunities are exploited
  - **(ii) decompose the observed spatial price differences**

    into factors such as transportation costs, transportation bottlenecks, and the oligopolistic behavior of the arbitrageurs.

- **As an application, we study the spatial arbitrages in the UK-Belgium "Interconnector" pipeline**

Previous empirical approaches

- **<u>Stigler and Sherwin (1985):</u>** Two geographical markets for a tradable good are integrated if the spatial price difference between these two markets equals the unit transportation cost.

- **Earlier empirical analyses focus on co-movements among prices**

  e.g. Cointegration tests ; Granger causality tests; ECMs models; analyses based on the Kalman Filter approach to examine the degree of price convergence ; AR models of pairwise price differentials.

- **<u>Some concerns:</u>**

  A lack of theoretical connections with spatial economic models

  Enke (1951); Samuelson (1952); Takayama and Judge (1971)

  Existing empirical models cannot be used to test for the competitive nature of the observed arbitrages

Methodology

Spatial equilibrium with a capacity-constrained infrastructure

Case A: Perfectly competitive spatial arbitrages

$$j \xrightarrow{Q_{jit}} i$$

$$\underset{Q_{jit}}{Max} \quad \Pi^{C}_{jit}\left(Q_{jit}\right) = \left(P_{it} - P_{jt} - \tau_{jit}\right) Q_{jit}$$

$$\text{s.t.} \quad Q_{jit} \le K_{jit}$$

$$Q_{jit} \ge 0$$

$$\text{KKT:} \quad 0 \le Q_{jit} \quad \perp \quad P_{it} - P_{jt} - \tau_{jit} - \xi_{jit} \le 0$$

$$0 \le \xi_{jit} \quad \perp \quad Q_{jit} \le K_{jit}$$

Case B: Monopolistic spatial arbitrages

$$\underset{Q_{jit}}{Max} \quad \Pi^{M}_{jit}\left(Q_{jit}\right) = \left(p_{it}\left(S_{it} + Q_{jit}\right) - p_{jt}\left(S_{jt} - Q_{jit}\right) - \tau_{jit}\right) Q_{jit}$$

$$\text{s.t.} \quad Q_{jit} \le K_{jit}$$

$$Q_{jit} \ge 0$$

$$- \gamma Q_{jit}$$

$$\text{KKT:} \quad 0 \le Q_{jit} \quad \perp \quad P_{it} - P_{jt} - \tau_{jit} + \left(p'_{it} + p'_{jt}\right) Q_{jit} - \xi_{jit} \le 0$$

$$0 \le \xi_{jit} \quad \perp \quad Q_{jit} \le K_{jit}$$

Empirical specification (1/4)
An extension to Barrett & Li (2002)

A taxonomy of 7 regimes:

		Trade $0 < Q_{jit} \leq K_{jit}$	**No trade** $Q_{jit} = 0$
Marginal profits to spatial arbitrages	**= 0**	**Regime I**	**Regime II**
	> 0	**Regime III_a** iff $Q_{jit} < K_{jit}$ **Regime III_b** iff $Q_{jit} = K_{jit}$	**Regime IV**
	< 0	**Regime V**	**Regime VI**

The ambition is to estimate λ_r the probabilities to observe these regimes

Empirical specification (2/4)
A Parity Bounds Model

Assumptions and notations:

- the observable portion of the marginal rent to arbitrage is:

$$R_{jit} \equiv P_{it} - P_{jt} - T_{jit}$$

- the marginal arbitrage cost is $\tau_{jit} \equiv T_{jit} + \alpha_{ji} + Z_{jit}\beta_{ji}$

Modeling the marginal profits to arbitrage

- Regimes I & II $\quad R_{jit} - \left(\alpha_{ji} + Z_{jit}\beta_{ji}\right) - Q_{jit}\gamma = \varepsilon_{jit}$

- Regimes III_a, III_b & IV $\quad R_{jit} - \left(\alpha_{ji} + Z_{jit}\beta_{ji}\right) - Q_{jit}\gamma = \varepsilon_{jit} + \mu_{jit}$

- Regimes V & VI $\quad R_{jit} - \left(\alpha_{ji} + Z_{jit}\beta_{ji}\right) - Q_{jit}\gamma = \varepsilon_{jit} - \upsilon_{jit}$

where

$$\varepsilon_{jit} \sim N\left(0, \sigma_{\varepsilon}^2\right) \qquad \mu_{jit} \sim N^+\left(0, \sigma_{\mu}^2\right) \qquad \upsilon_{jit} \sim N^+\left(0, \sigma_{\upsilon}^2\right)$$

Empirical specification (3/4):

- **The joint density function for the observation at time *t* is the mixture distribution:**

$$f_{jit}\left(\pi_{jit}\middle|(\lambda,\theta)\right) \equiv A_{jit}\left[\lambda_I f_{jit}^{I}\left(\pi_{jit}\middle|\theta\right)+\left(\left(1-B_{jit}\right)\lambda_{IIIa}+B_{jit}\lambda_{IIIb}\right)f_{jit}^{III}\left(\pi_{jit}\middle|\theta\right)+\lambda_V f_{jit}^{V}\left(\pi_{jit}\middle|\theta\right)\right]$$
$$+\left(1-A_{jit}\right)\left[\lambda_{II} f_{jit}^{II}\left(\pi_{jit}\middle|\theta\right)+\lambda_{IV} f_{jit}^{IV}\left(\pi_{jit}\middle|\theta\right)+\lambda_{VI} f_{jit}^{VI}\left(\pi_{jit}\middle|\theta\right)\right]$$

- **Estimation:**

$$\underset{(\lambda,\theta)}{\textbf{Max}} \quad \sum_{t=1}^{N}\log\left(f_{jit}\left(\pi_{jit}\middle|(\lambda,\theta)\right)\right)$$

$$\textbf{s.t.} \quad \sum_r \lambda_r = 1$$

This is a nonconvex NLP

$$\lambda_r \in [0,1], \quad \forall r$$

Empirical specification (4/4)

Correcting for serial correlation (Kleit, 2001)

- **Regimes I & II:**

$$R_{jit} - \left(\alpha_{ji} + Z_{jit}\beta_{ji}\right) - Q_{jit}\gamma - \rho_{ji}\mathrm{E}\left(\varepsilon_{ji(t-1)} \middle| \eta_{ji(t-1)}\right) = \varepsilon_{jit}$$

- **Regimes III$_a$, III$_b$ & IV**

$$R_{jit} - \left(\alpha_{ji} + Z_{jit}\beta_{ji}\right) - Q_{jit}\gamma - \rho_{ji}\mathrm{E}\left(\varepsilon_{ji(t-1)} \middle| \eta_{ji(t-1)}\right) = \varepsilon_{jit} + \mu_{jit}$$

- **Regimes V & VI**

$$R_{jit} - \left(\alpha_{ji} + Z_{jit}\beta_{ji}\right) - Q_{jit}\gamma - \rho_{ji}\mathrm{E}\left(\varepsilon_{ji(t-1)} \middle| \eta_{ji(t-1)}\right) = \varepsilon_{jit} - \upsilon_{jit}$$

where $\mathrm{E}\left(\varepsilon_{ji(t-1)} \middle| \eta_{ji(t-1)}\right)$ **is computed using:**

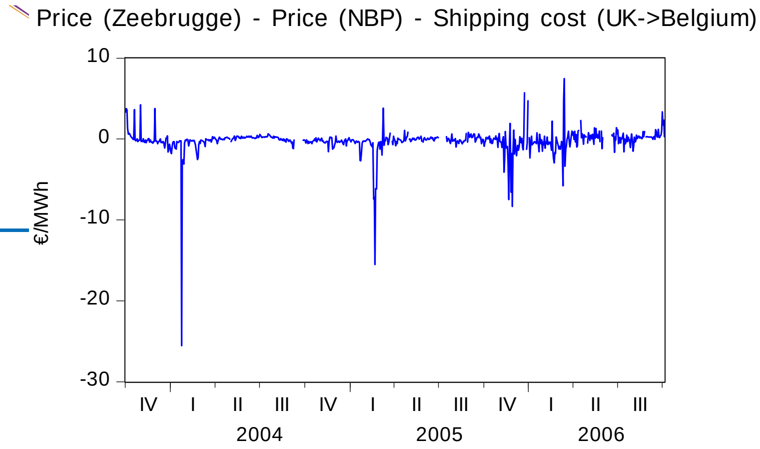
$$\mathrm{P}_{t-1}\left(r \middle| \eta_{ji(t-1)}, \theta_1\right) == \frac{\lambda_r f_r\left(\eta_{ji(t-1)} \middle| \theta_1\right)}{\sum_{k=I}^{VI} \lambda_k f_k\left(\eta_{ji(t-1)} \middle| \theta_1\right)}$$

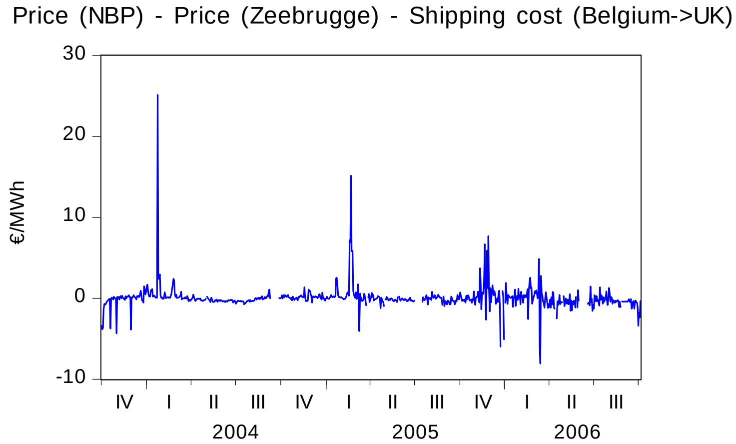
the probability to observe regime *r* at time *t-1*

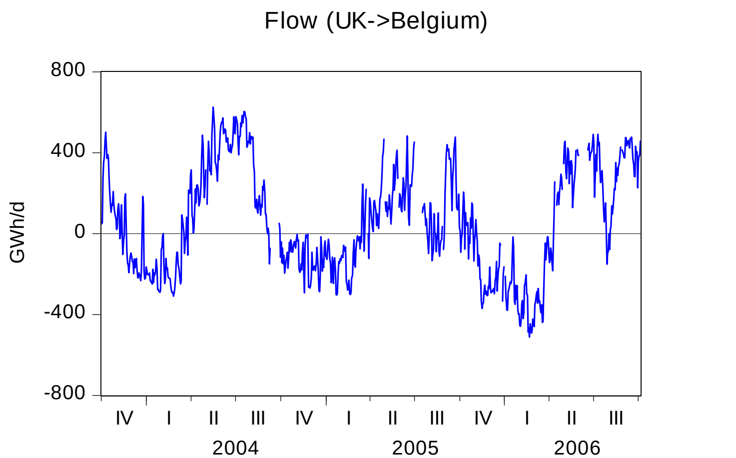
An application:
the case of the IUK pipeline

The case study

- **Period: Oct. 1, 2003, to Oct. 5, 2006.**
- **Data sources:**
  - prices: Platt's day-ahead natural gas prices (€/MWh).
  - flows and transportation costs: IUK







Estimation results (1/2)
Testing for perfect competition

	From UK to Belgium	From Belgium to UK
Mean parameters		
α	-0.3164***	-0.0990***
β_{time}	0.2019	-0.7017***
$\beta_{D_{2006-2008}}$	-0.0401	0.2442***
$\beta_{D_{2002-2006}}$	-0.2391**	0.5304***
γ	0.0012***	0.0026***
ρ	0.3396***	0.4860***
Log likelihood	-982.6623	-991.7400
LR tests		
H_0: $\gamma = 0$	128.868 *(0.000)*	115.345 *(0.000)*
Observations	723	723

Estimation results (2/2)
On market integration...

	From UK to Belgium	From Belgium to UK
Probabilities (in %)		
λ_{I}	48.56***	41.60***
λ_{II}	41.16***	50.50***
λ_{III_a}	2.45***	1.69***
λ_{III_b}	0.00	0.92**
λ_{IV}	2.88***	0.49
λ_{V}	0.00	3.05***
λ_{VI}	4.96***	1.76
Probability of spatial market equilibrium conditions (in %) $\left(\lambda_{I}+\lambda_{II}+\lambda_{III_a}+\lambda_{VI}\right)$	94.68	94.77

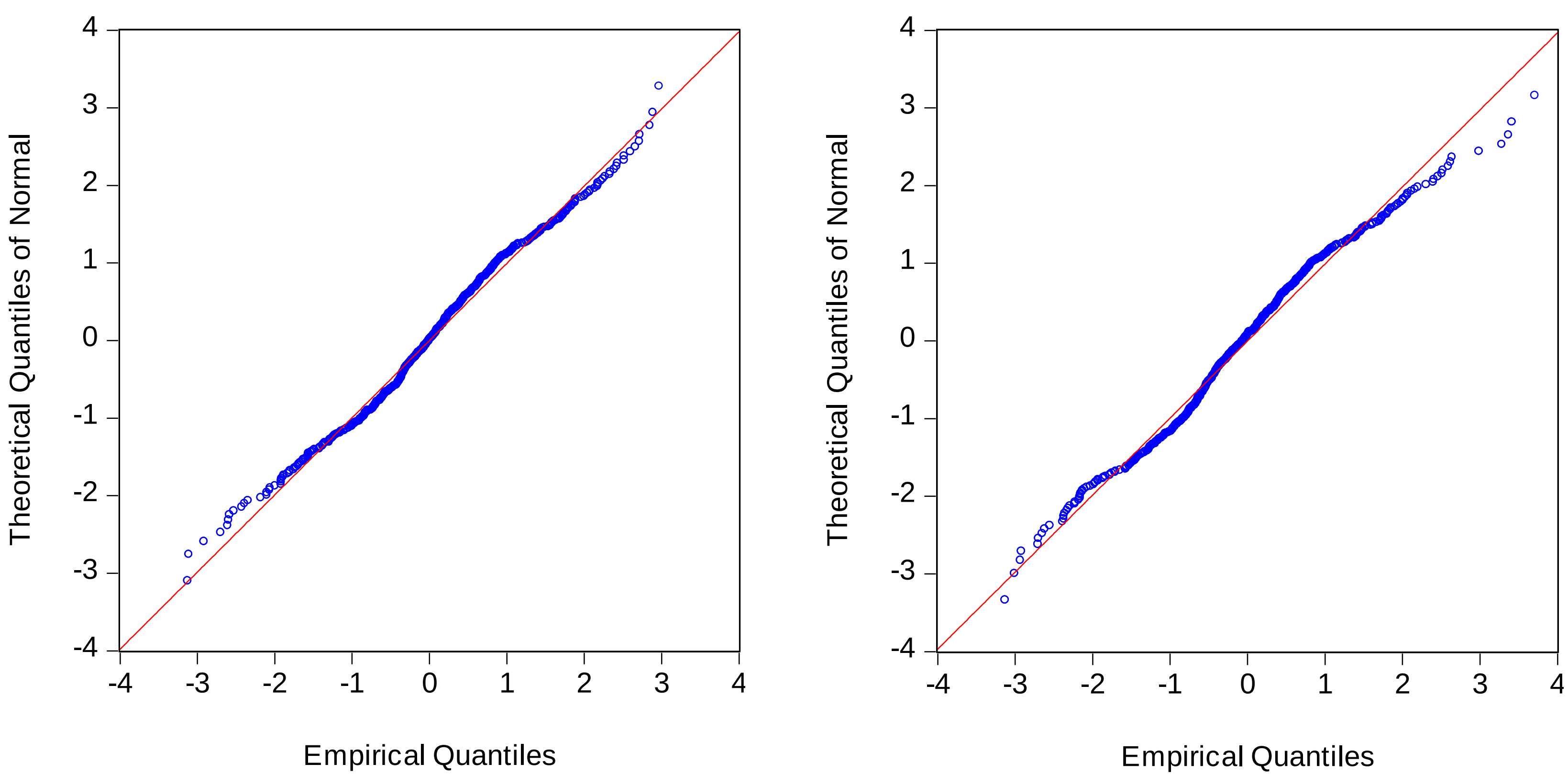
Model validation

- **For each observation, identify the regime with the highest probability.**
- **Then, select the observations explained by regimes I & II**

Figure 1. Q-Q plots of the standardized residual series (sample: $\hat{d}^{\,I}_{jit} + \hat{d}^{\,II}_{jit} = 1$)

From UK to Belgium

From Belgium to UK



Conclusion and implications

- **This paper provides**
  - **an extension of the standard Parity Bound Model**
    - **to model the role of capacity constraints**
    - **a dynamic specification to account for serial correlation and a time-varying variance.**
  - **a novel test for the presence of perfect competition in spatial arbitrages.**
  - **An application to the IUK pipeline**
- **Our findings**
  - **document the efficiency of the spatial arbitrages observed between Belgium and the UK.**
    - **Spatial equilibrium conditions hold with a high probability**
  - **document the presence of an unexplained transaction cost that is proportional to the trade flow**
    - **The assumption of competitive spatial arbitrages based on a constant unit transportation cost needs to be revised**

Thank you for your attention!

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