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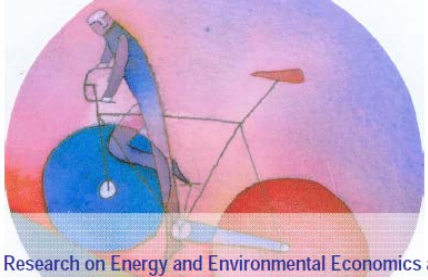

Are European natural gas prices converging? An analysis for industrial consumers

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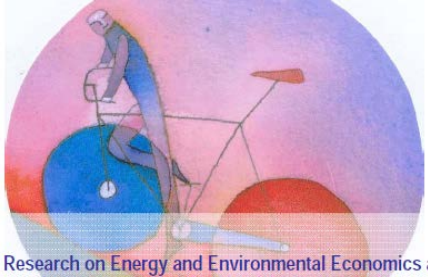

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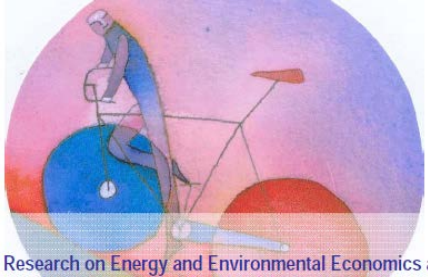
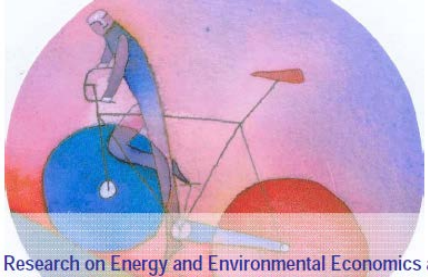


Background

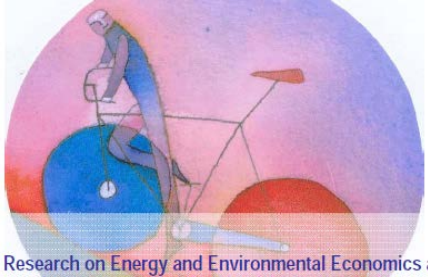
European Union (EU) devoted considerable efforts for the creation of a **single energy market**. Three milestones in legislation:

1. First Gas Directive in 1998, 98/30/EC: gas markets opened up to competition by facilitating the entry in the competitive segments of the industry. New common rules for transmission, distribution, supply and storage of natural gas.
2. Second Gas Directive (2003/55/EC): unbundling the vertically integrated gas operators and making the transport networks of gas independent from production and supply. Non-household consumers (industrial consumers) free to choose their suppliers since July 2004, while for household consumers the date has been delayed to July 2007.
3. Third Gas Directive (2009/73/EC): improve the functioning of the internal energy market and resolve structural problems, plus unbundling of energy suppliers from network operators.



Related literature

- Asche et al. (2001): study of degree of market integration of French import prices from Netherlands, Russia and Norway
- Asche et al. (2002): degree of integration of German market using monthly long-term import prices from Netherlands, Russia and Belgium, finding differences in average prices from the three suppliers.
- Neumann et al. (2006): price convergence among three EU gas spot markets until 2005. Interconnector pipeline between UK and Belgium has improved price convergence over time.
- Asche et al. (2013): relationship between spot and long-term prices in Europe. High degree of integration of natural gas markets in Western Europe, independently of how gas prices are determined.
- Growitsch at al. (2013): introduction of the entry-exit system in Germany, in 2007 using cointegration analysis and Kalman filter.
- Robinson (2007): price convergence for end-users occurred over the period 1978 – 2003, following the 1986 Single European Act.
- Renou-Maissant (2012): impact of EU Gas Directives on natural gas prices for industrial end-users in six Western European Countries, from 1991 to 2009.



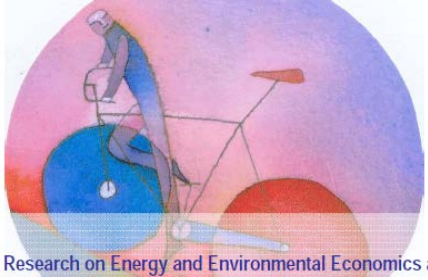
Research question

Our contribution:

- Extend the dataset to the latest available data and to eight countries, in order to better appreciate the evolution of the convergence.
- Account for the different effects of taxation, analyzing also price series with all taxes and with non-recoverable taxes included.

Research questions:

- Are European natural gas markets integrated? Or, put it differently: is there a Single European Market (SEM) for gas?



Data

- Industrial consumers gas price data provided by Eurostat, quoted in €/GJ. Prices are available:
    - before tax
    - including not recoverable taxes
    - with all taxes included.
- Biannual price series from 1991 to 2014
- Eight European countries: Austria, Belgium, France, Germany, Italy, Netherlands, Spain and UK
- Medium consumption band (1000 to 10000 GJ per year)
- Each of the chosen markets is interconnected with at least one of the other countries
- All countries were part of the European Union before the liberalization policies started.

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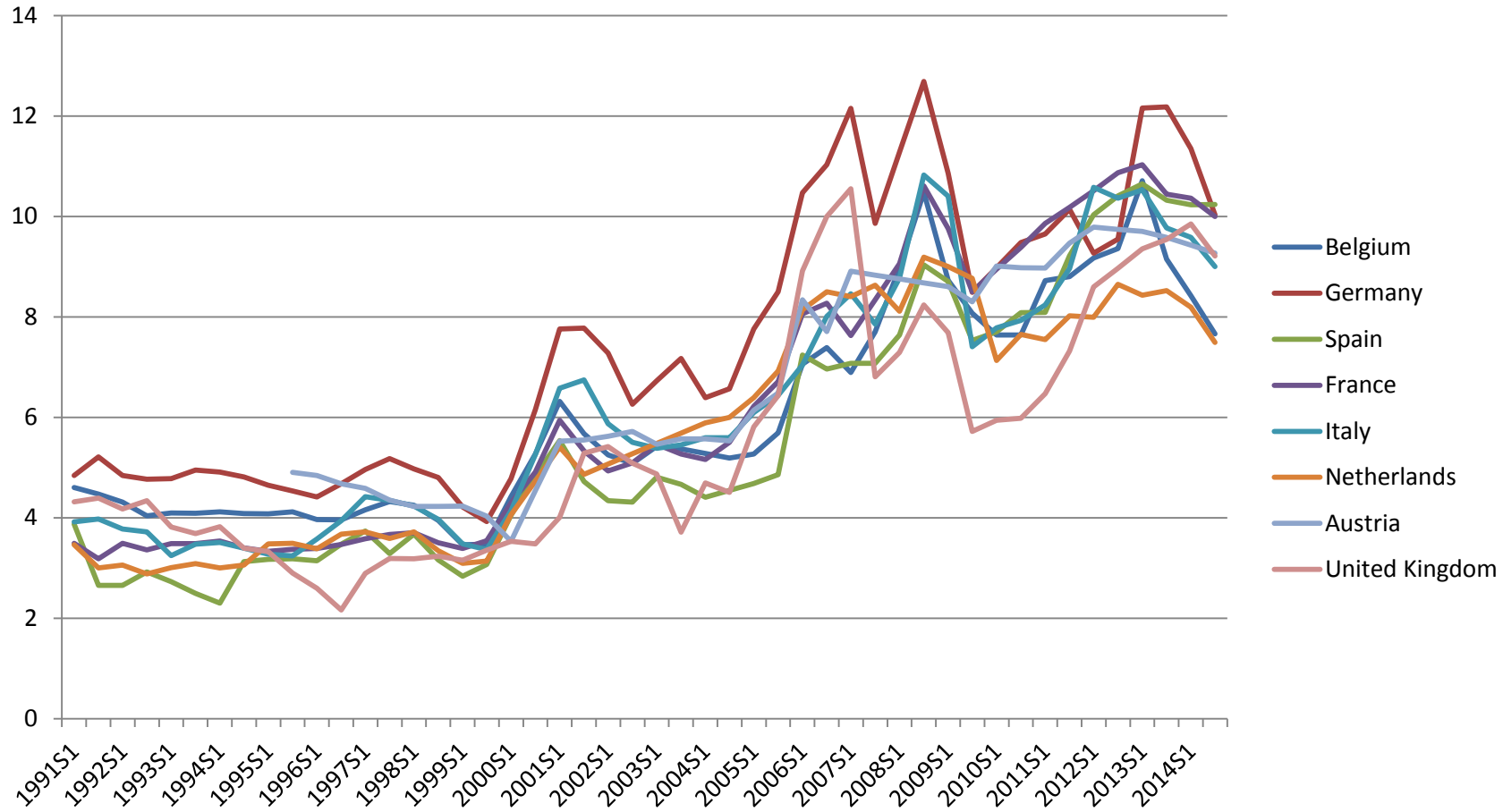
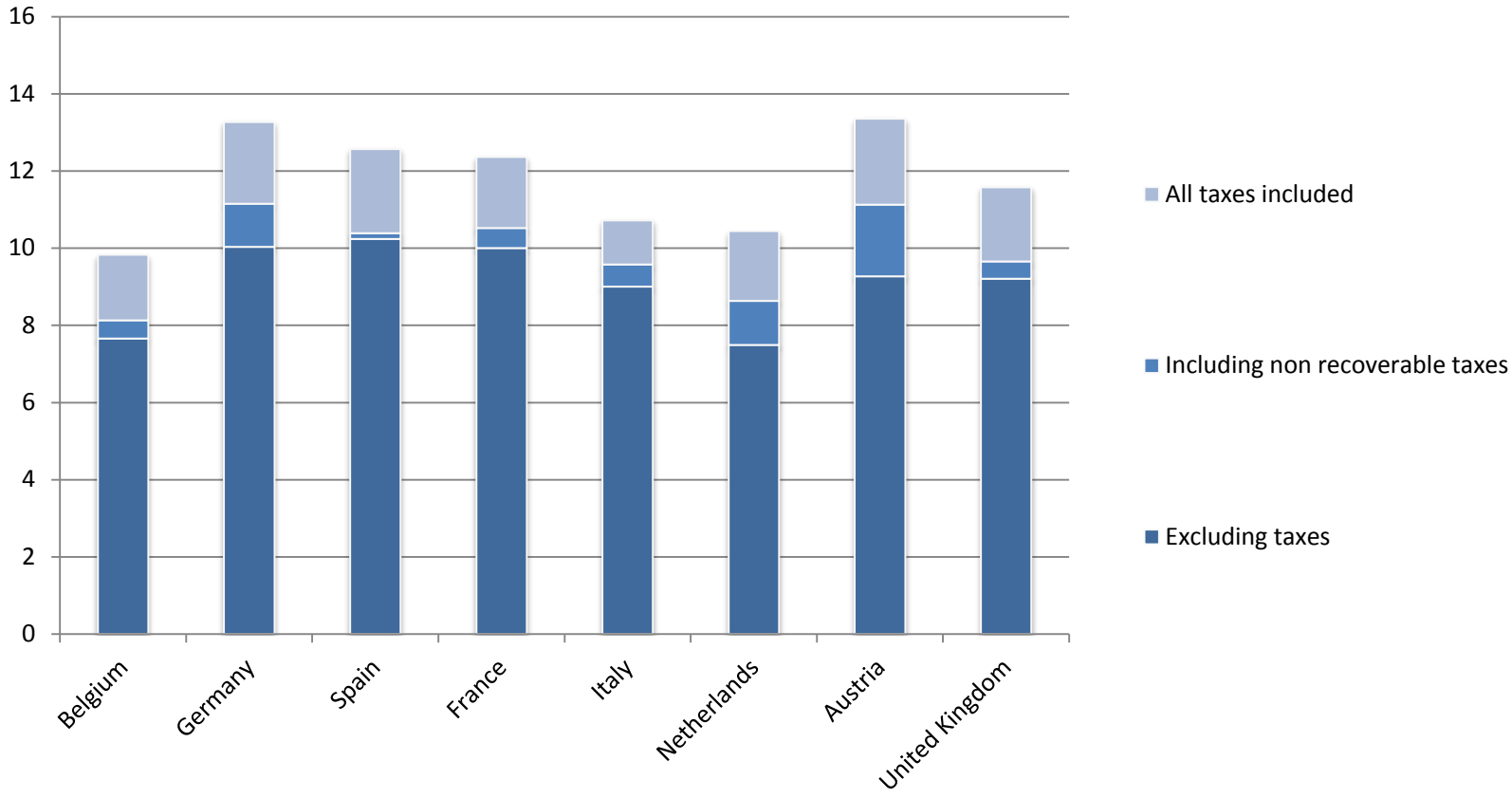
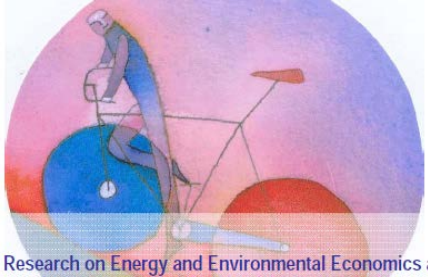
Data description: biannual prices before taxes (euro/GJ)



Data description: industrial prices (euro/GJ) in the second semester of 2014





Methodology

- Law on One Price (LOP): in case of full integration of two markets, industrial consumers should pay the same price, once accounted for transaction costs.
- We want to investigate on the following relationship:

$$p_{1t} = \alpha + \beta p_{2t} + \varepsilon_t$$

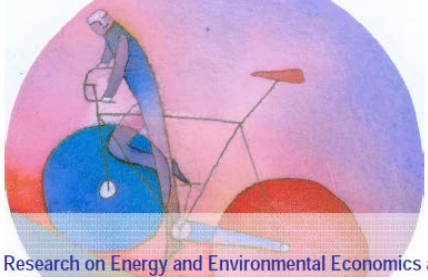
- Specified by the following equation:

$$lnp_{1t} = \alpha + \beta lnp_{2t} + \varepsilon_t \qquad (1)$$

- LOP cannot be tested using a simple regression equation because it would give spurious results.
- We first find cointegrating relationships and then test on the LOP
- Then, we estimate a recursive version of (1)

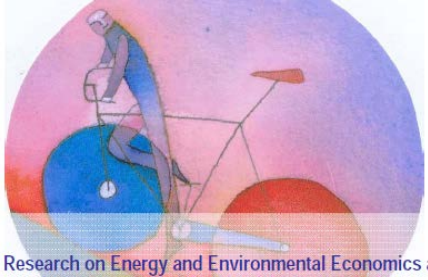
$$lnp_{1t} = \alpha + \beta_t lnp_{2t} + \varepsilon_t \qquad \varepsilon_t \sim i.i.d.N(0; H_t) \qquad (2)$$

$$\beta_t = \tilde{\theta} + F\beta_{t-1} + \nu_t \qquad \nu_t \sim i.i.d.N(0; Q_t) \text{ for } t = 1,\ldots, T \qquad (3)$$



Methodology: steps

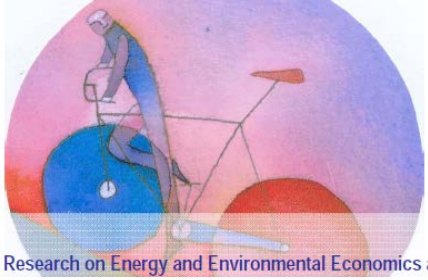
1. Check for series stationarity
2. Bivariate **Johansen test** for each pair of gas prices:
    - H_0: the economic system has zero cointegrating vectors;
    - H_1: there are more than zero cointegrating vectors.
    - If we reject the null hypothesis of non-cointegration, then we can conclude that two markets are integrated since a long-run relation can be established between them.
    - Once found the cointegrating vectors, we perform VECM estimates to obtain information on the short-run and long-run dynamics of the price relationships.
    - Following Asche (1990), we test the LOP by applying the Likelihood Ratio Test (LRT) and imposing restrictions on β vector: $\beta' = [\ 1,-1\ ]$
3. Check for parameters stability
4. Space state model using **Kalman filter** (Kalman, 1960), to account for changes in the relationship of two markets over time.



1. Check for series stationarity: unit root testing

	ADF Test		DFGLS Test		PPerron Test		KPSS Test	
Country	(Log)Level	First Difference	(Log)Level	First Difference	(Log)Level	First Difference	(Log)Level	First Difference
Austria	-0.577	-5.870***	-0.963	-5.784***	-0.556	-5.870***	1.82***	0.117
Belgium	-0.663	-3.624**	-1.063	-4.225***	-0.744	-4.646***	0.928***	0.0853
France	-0.672	-5.058***	-0.095	-3.220***	-0.202	-5.476***	2.33***	0.108
Germany	-1.116	-4.477***	-0.915	-5.029***	-0.865	-5.119***	1.13***	0.053
Italy	-0.702	-4.556***	-0.434	-4.125***	-0.744	-4.550***	1.18***	0.059
Netherlands	-0.992	-6.231***	-0.218	-3.854***	-0.6	-6.232***	2.28***	0.125
Spain	-0.733	-7.032***	-0.318	-2.955***	-0.187	-7.380***	2.25***	0.142
UK	-0.777	-6.146 ***	-1.009	-6.217***	-0.746	-6.133***	1.82***	0.136

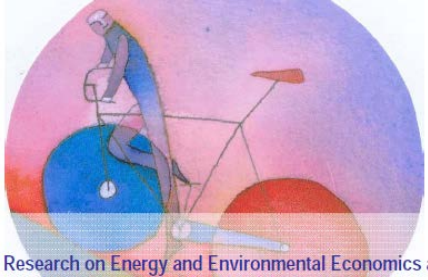
Notes: the asterisks *,**, *** denote the rejection of the null hypothesis at 1%, 5%, 10% levels respectively. The ADF lag length is selected according to the Schwarz Information Criterion. The lag length in PPerron test is such that the Newey-West standard errors account for serial correlation. **Contrary to the others, the KPPS test has stationarity as the null hypothesis.**



2. Results: Bivariate Johansen test (no tax included)

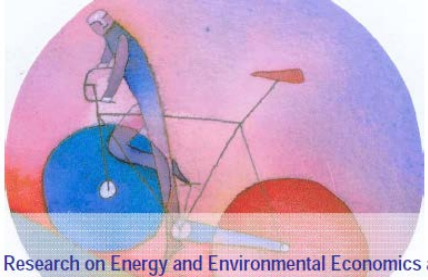
	Austria	Belgium	France	Germany	Italy	Netherlands	Spain
Belgium	19.532**						
	(0.011)						
France	19.379**	**21.86*****					
	(0.012)	(0.004)					
Germany	18.823**	10.009	12.292				
	(0.015)	(0.28)	(0.143)				
Italy	**22.34*****	12.457	15.871**	11.622			
	(0.004)	(0.136)	(0.043)	(0.175)			
Netherlands	15.690**	11.97	6.404	**22.26*****	15.97**		
	(0.046)	(0.158)	(0.647)	(0.004)	(0.042)		
Spain	15.043*	9.811	10.597	9.393	15.39*	6.631	
	(0.058)	(0.295)	(0.237)	(0.330)	(0.051)	(0.62)	
UK	14.138*	10.993	9.657	14.584*	10.701	10.149	9.092
	(0.0792)	(0.211)	(0.3080)	(0.068)	(0.23)	(0.269)	(0.356)

Notes: the asterisks *,**, *** denote the rejection of the null hypothesis at 1%, 5%, 10% levels respectively. Standard errors in parentheses.



Results: Johansen test (No tax included) – Cont.ed

- We can reject the null hypothesis of no cointegration for 13 market-pairs.
- Only three market-pairs result strongly integrated at 1% level: **Austria-Italy**, **France-Belgium** and **Germany-Netherlands**
- For most of the market-pairs, the absence of a cointegrating vector is rejected at 5% implying a good degree of integration.
- A weak integration is found only among four market pairs (rejection of H_0 at 10%).
- Austria is by far the country better pairwise integrated.
- Spain and UK are the countries that exhibit more independency from the other European markets.



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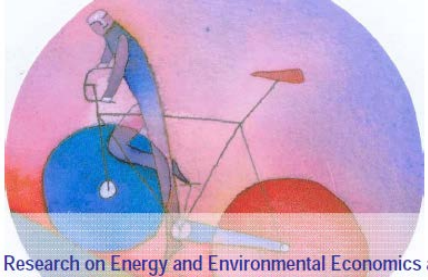
2. Results: Bivariate Johansen test for cointegration (non recoverable taxes included)

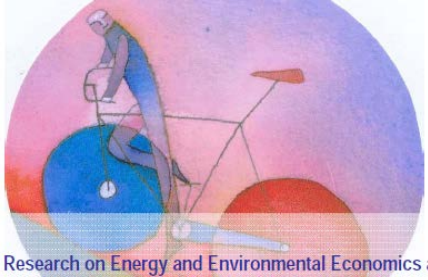
	Austria	Belgium	France	Germany	Italy	Netherlands	Spain
Belgium	13.23						
	(0.106)						
France	11.86	18.817**					
	(0.163)	(0.0152)					
Germany	17.534**	8.7583	9.451				
	(0.024)	(0.388)	(0.325)				
Italy	14.624*	11.453	14.429*	10.879			
	(0.067)	(0.185)	(0.071)	(0.219)			
Netherlands	11.114	13.4345*	7.446	**22.782****	19.446**		
	(0.204)	(0.099)	(0.526)	(0.003)	(0.012)		
Spain	10.69	8.799	11.31	7.39	13.844*	9.097	
	(0.231)	(0.384)	(0.192)	(0.532)	(0.087)	(0.356)	
UK	14.614*	10.353	9.523	13.963*	10.757	11.20	9.119
	(0.067)	(0.254)	(0.319)	(0.083)	(0.226)	(0.199)	(0.354)

Notes: the asterisks *,**, *** denote the rejection of the null hypothesis at 1%, 5%, 10% levels respectively. Standard errors in parentheses.



Results: Johansen test (non recoverable taxes included) – Cont.ed

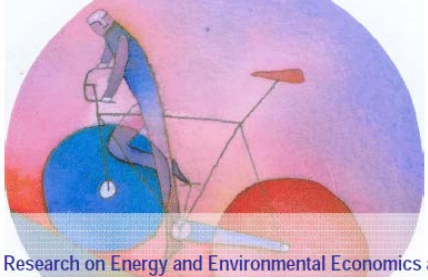
- We reject the null hypothesis of no cointegration for 10 market-pairs.
- Only the relationship **Germany - Netherlands** results strongly integrated at 1% level.
- The inclusion of taxation introduces a distortion that probably limits the scope for arbitrage across markets.



2. Results: Bivariate Johansen test for cointegration (all taxes included)

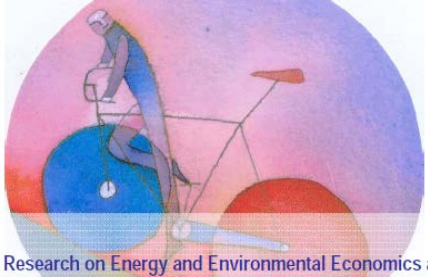
	Austria	Belgium	France	Germany	Italy	Netherlands	Spain
Belgium	17.69**						
	(0.023)						
France	15.631**	**19.65*****					
	(0.047)	(0.011)					
Germany	17.13**	9.011	9.228				
	(0.028)	(0.364)	(0.344)				
Italy	15.55**	10.70	13.62*	10.694			
	(0.049)	(0.23)	(0.094)	(0.231)			
Netherlands	14.91*	13.171	7.793	**22.63*****	18.27**		
	(0.061)	(0.108)	(0.487)	(0.003)	(0.018)		
Spain	9.77	7.753	9.762	6.662	13.089	7.874	
	(0.298)	(0.492)	(0.299)	(0.617)	(0.111)	(0.478)	
UK	11.07	10.354	9.647	13.090	10.733	11.07	9.069
	(0.207)	(0.254)	(0.308)	(0.111)	(0.228)	(0.207)	(0.3590)

Notes: the asterisks *,**, *** denote the rejection of the null hypothesis at 1%, 5%, 10% levels respectively. Standard errors in parentheses.



Results: Johansen test (all taxes included) – Cont.ed

- Adding recoverable taxation further reduces the number of cointegrated markets to 9, suggesting that the “true” convergence probably happens at a higher level of the supply chain, i.e. in the wholesale market.
- Only two pairs (Germany-Netherlands and France-Belgium) are strongly cointegrated at 1% level.
- Only the relationship **Germany – Netherlands** is consistently integrated throughout all price series at 1% level.
- The inclusion of taxation introduces a distortion that limits the scope for arbitrage across markets.
- Neighbouring markets tend to be better cointegrated.



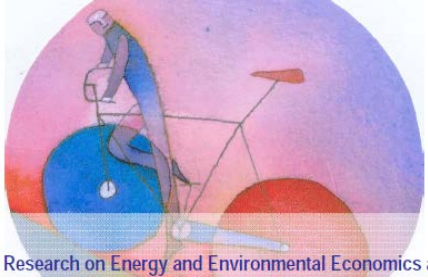
Methods: VECM and LOP

- Error Correction Models (ECMs) are a category of multiple time series models that directly estimate the speed at which a dependent variable returns to equilibrium after a change in an independent variable.
- Once found that the natural gas prices in two EU countries are cointegrated, we estimate the VECM parameters in order to better understand how this equilibrium relationship reacts if we move away from it.
- We model the VECM in two equations:

$$\Delta p_{1t} = \alpha_1 (p_{1t-1} - \beta p_{2t-1}) + \epsilon_{1t}$$

$$\Delta p_{2t} = \alpha_2 (p_{1t-1} - \beta p_{2t-1}) + \epsilon_{2t}$$

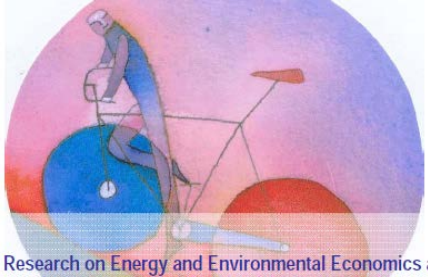
- Then test the LOP by applying the Likelihood Ratio Test (LRT) and imposing restrictions on β vector: $\beta' = [\ 1,-1\ ]$



2. Results: VECM (no tax included), part 1

Price relationship	β	α_1	α_2	*constant*	*LOP* (χ^2)
Austria -					
Belgium	-1.055	-0.134	0.663	0.055	**0.954**
	(0.06)	(0.174)	(0.192)	(0.109)	[0.328]
France	-0.811	-0.455	0.209	-0.361	4.556**
	(0.043)	(0.179)	(0.20)	(0.082)	[0.032]
Germany	-1.109	-0.149	0.391	0.365	**1.622**
	(0.084)	(0.13)	(0.183)	(0.171)	[0.202]
Italy	-1.008	-0.177	0.529	0.003	**0.014**
	(0.062)	(0.16)	(0.191)	(0.118)	[0.905]
Netherlands	-0.973	-0.343	0.072	-0.157	**0.06**
	(0.09)	(0.13)	(0.176)	(0.163)	[0.806]
Spain	-0.800	-0.072	0.478	-0.451	2.704*
	(0.075)	(0.161)	(0.232)	(0.132)	[0.10]
UK	-0.967	-0.049	0.544	-0.238	**0.085**
	(0.082)	(0.091)	(0.141)	(0.139)	[0.769]

Notes: the asterisks *,**, *** denote the rejection of the null hypothesis at 1%, 5%, 10% levels respectively. Standard errors in parentheses. P-values in brackets.



2. Results: VECM (no tax included), part 2

Price relationship	β	α_1	α_2	*constant*	*LOP* (χ^2)
Belgium -					
France	-0.724	-0.895	-0.806	-0.522	8.99***
	(0.025)	(0.23)	(0.179)	(0.045)	[0.002]
France -					
Italy	-1.161	0.041	0.483	0.269	7.434***
	(0.048)	(0.149)	(0.153)	(0.086)	[0.006]
Germany -					
Netherlands	-0.834	-0.603	-0.128	-0.566	3.666*
	(0.055)	(0.188)	(0.166)	(0.094)	[0.055]
UK	-0.861	-0.207	0.381	-0.573	**2.391**
	(0.075)	(0.151)	(0.195)	(0.123)	[0.122]
Italy -					
Netherlands	-0.932	-0.414	-0.132	-0.223	**0.613**
	(0.073)	(0.139)	(0.132)	(0.124)	[0.433]
Spain	-0.831	-0.467	0.036	-0.406	4.983**
	(0.05)	(0.20)	(0.262)	(0.082)	[0.025]

Notes: the asterisks *,**, *** denote the rejection of the null hypothesis at 1%, 5%, 10% levels respectively. Standard errors in parentheses. P-values in brackets.

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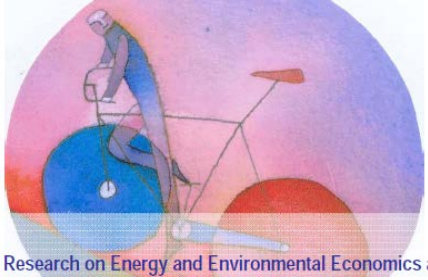
2. Results: VECM (not recoverable tax included)

	VECM				
Price relationship	β	α_1	α_2	*constant*	*LOP* (χ^2)
Austria -					
Germany	-1.013	-0.142	0.315	0.103	**0.011**
	(0.103)	(0.165)	(0.199)	(0.224)	[0.915]
Italy	-0.993	-0.018	0.535	-0.122	**0.005**
	(0.083)	(0.157)	(0.19)	(0.165)	[0.941]
UK	-0.813	-0.011	0.645	-0.661	**2.474**
	(0.059)	(0.136)	(0.195)	(0.106)	[0.115]
Belgium -					
France	-0.779	-0.741	-0.693	-0.419	7.178***
	(0.03)	(0.209)	(0.156)	(0.055)	[0.007]
Netherlands	-0.493	-0.132	-0.23	-1.002	3.562*
	(0.115)	(0.076)	(0.067)	(0.217)	[0.059]
France -					
Italy	-1.19	0.021	0.524	0.386	9.899***
	(0.046)	(0.146)	(0.152)	(0.085)	[0.001]
Germany -					
Netherlands	-0.771	-0.607	-0.124	-0.656	3.619*
	(0.043)	(0.196)	(0.213)	(0.08)	[0.057]
UK	-0.825	-0.155	0.468	-0.720	4.087**
	(0.066)	(0.145)	(0.198)	(0.111)	[0.043]
Italy -					
Netherlands	-0.781	-0.597	-0.381	-0.442	5.487**
	(0.049)	(0.173)	(0.165)	(0.092)	[0.019]
Spain	-0.792	-0.535	0.065	-0.552	6.984***
	(0.044)	(0.211)	(0.272)	(0.072)	[0.008]

Notes: the asterisks *,**, *** denote the rejection of the null hypothesis at 1%, 5%, 10% levels respectively. Standard errors in parentheses. P-values in brackets.

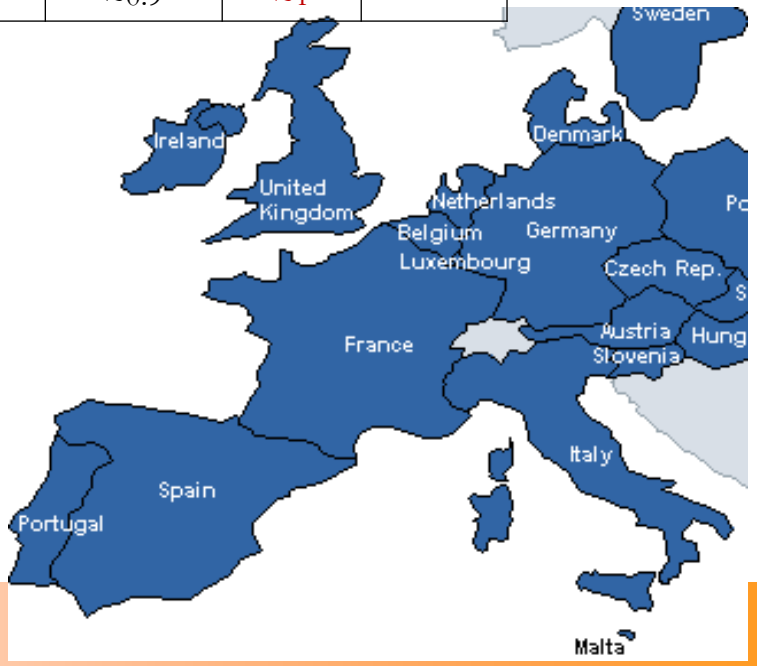


3. Check for parameters stability

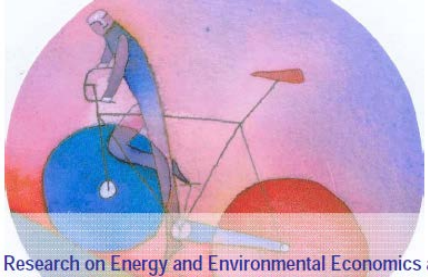
- Cointegration approach assumes parameters stability over time.
- However, the dramatic changes experienced by European markets in our analysed timeframe (e.g. liberalisation) make this assumption unlikely to hold.
- Therefore, a time varying coefficients model appears more suitable in this context. In other words, we now let β change over time.
- Before using this technique we test whether the parameters are actually unstable over time, analysing the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares recursive residuals (CUSUM squares).
- Except for the pair Austria-Belgium, all price relationships show parameters instability.

4.Results: Kalman filter β coefficients (no tax)

	Austria	Belgium	France	Germany	Italy	Netherlands	Spain	UK
Austria				≈1	≈1	≈1		
Belgium				≈1				≈1
France		nv			≈0.9		≈1	
Germany	≈0.9	≈0.9			≈1	≈1		≈1
Italy	≈0.9		≈1	≈0.9		≈1		≈1
Netherlands	≈0.9		≈1	≈0.9	≈1		≈1	≈0.9
Spain			≈1					
UK	nv		≈1	nv	≈0.9	≈0.9	≈1	



nv = LOP result which is not verified by Kalman filter



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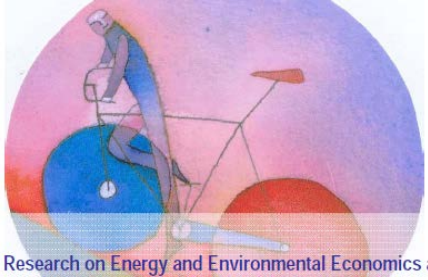
4. Results: Kalman filter final state variables (no taxes)

$$lnp_{1t} = \alpha + \beta_t lnp_{2t} + \varepsilon_t$$
$$\beta_t = \beta_{t-1} + \nu_t$$

		P1															
		Austria		Belgium		France		Germany		Italy		Netherlands		Spain		UK	
		β	α	β	α	β	α	β	α	β	α	β	α	β	α	β	α
P2	Austria					1.251***	-0.499***	1.013***	0.129	1.057***	-0.131	1.045***	-0.178	1.241***	-0.589***	1.238***	-0.641***
						(0.01)	(0.147)	(0.011)	(0.124)	(0.011)	(0.137)	(0.011)	(0.145)	(0.011)	(0.158)	(0.016)	(0.185)
	Belgium					1.319***	-0.572***	1.043***	0.125**	1.169***	-0.296***	1.165***	-0.374***	1.364***	-0.771***	1.121***	-0.333**
						(0.008)	(0.078)	(0.008)	(0.072)	(0.007)	(0.079)	(0.012)	(0.108)	(0.011)	(0.109)	(0.16)	(0.163)
	France	0.736***	0.516***	0.722***	0.496***			0.774***	0.606***	0.871***	0.237***	0.889***	0.121**	1.024***	-0.163**	0.841***	0.166
		(0.007)	(0.081)	(0.006)	(0.041)			(0.008)	(0.051)	(0.006)	(0.052)	(0.008)	(0.057)	(0.008)	(0.082)	(0.015)	(0.111)
	Germany	0.849***	0.151	0.875***	0.041	1.88***	-0.582***			1.068***	-0.333***	1.089***	-0.461***	1.208***	-0.742***	1.076***	-0.472***
		(0.001)	(0.148)	(0.007)	(0.061)	(0.009)	(0.094)			(0.007)	(0.076)	(0.008)	(0.118)	(0.013)	(0.159)	(0.011)	(0.134)
	Italy	0.823***	0.351***	0.805***	0.341***	1.095***	-0.182***	0.875***	0.418***			0.988***	-0.065	1.136***	-0.374***	0.938***	-0.016
		(0.001)	(0.102)	(0.006)	(0.048)	(0.007)	(0.064)	(0.007)	(0.049)			(0.009)	(0.074)	(0.009)	(0.086)	(0.015)	(0.121)
	Netherlands	0.835***	0.389***	0.755***	0.491***	1.055***	-0.019	0.842***	0.548***	0.932***	0.198***			1.082***	-0.187**	0.886***	0.151
		(0.011)	(0.116)	(0.009)	(0.067)	(0.009)	(0.079)	(0.008)	(0.061)	(0.009)	(0.063)			(0.012)	(0.091)	(0.018)	(0.133)
	Spain	0.725***	0.615***	0.679***	0.652***	0.933***	0.231***	0.716***	0.792***	0.822***	0.421***	0.831***	0.322***			0.768***	0.385**
		(0.009)	(0.084)	(0.008)	(0.045)	(0.008)	(0.064)	(0.011)	(0.064)	(0.008)	(0.057)	(0.011)	(0.067)			(0.018)	(0.121)
	UK	0.651***	0.781***	0.694***	0.619***	0.953***	0.185	0.794***	0.657***	0.845***	0.373***	0.846***	0.285**	0.956***	0.058		
		(0.013)	(0.137)	(0.014)	(0.091)	(0.017)	(0.119)	(0.012)	(0.087)	(0.015)	(0.103)	(0.017)	(0.144)	(0.021)	(0.159)		

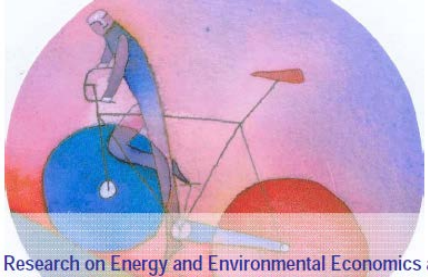
Notes: the asterisks *,**, *** denote the rejection of the null hypothesis at 1%, 5%, 10% levels respectively. Root mean square errors in parentheses.



4. Comments: Kalman filter

- Most of the countries, especially France, Germany, Italy and UK, show a very good degree of integration.
- Netherlands prices are the most “influential” over the price pattern of the analysed countries.
- Belgium has the lowest price convergence and, except for the market-pair Belgium-Germany where the price convergence is relatively high, the constant term is always statistically significant:
- Price differentials can be explained by the presence of relevant transaction and transportation costs.

Notes: the asterisks *,**, *** denote the rejection of the null hypothesis at 1%, 5%, 10% levels respectively. Root mean square errors in parentheses.



Final comments

- Good degree of market integration among European countries, especially the Continental markets, but accounting for taxation partially reduces integration

- On one hand, better interconnections help exploiting arbitrage opportunities
    - Market integration occurs more often between neighbouring countries

- On the other hand, end-user prices tend to rely increasingly on spot prices, especially TTF (e.g. Italy) and NBP (e.g. Spain) (see Abrigo, Bonacina & Sileo, 2013)

- Introducing taxation has the effect to reduce market integration, because it creates an additional transaction cost, which is heterogeneous across countries.

- Future policies will have to consider the issue of energy taxes harmonisation, if the objective is to create a completely integrated energy market.