

Are European natural gas prices converging? Recent evidence for industrial consumers

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Outline

1. Background and motivation
2. Overview of the literature
3. Data and methods: convergence
4. Results
5. Catch-up regression
6. Conclusions / Policy implications

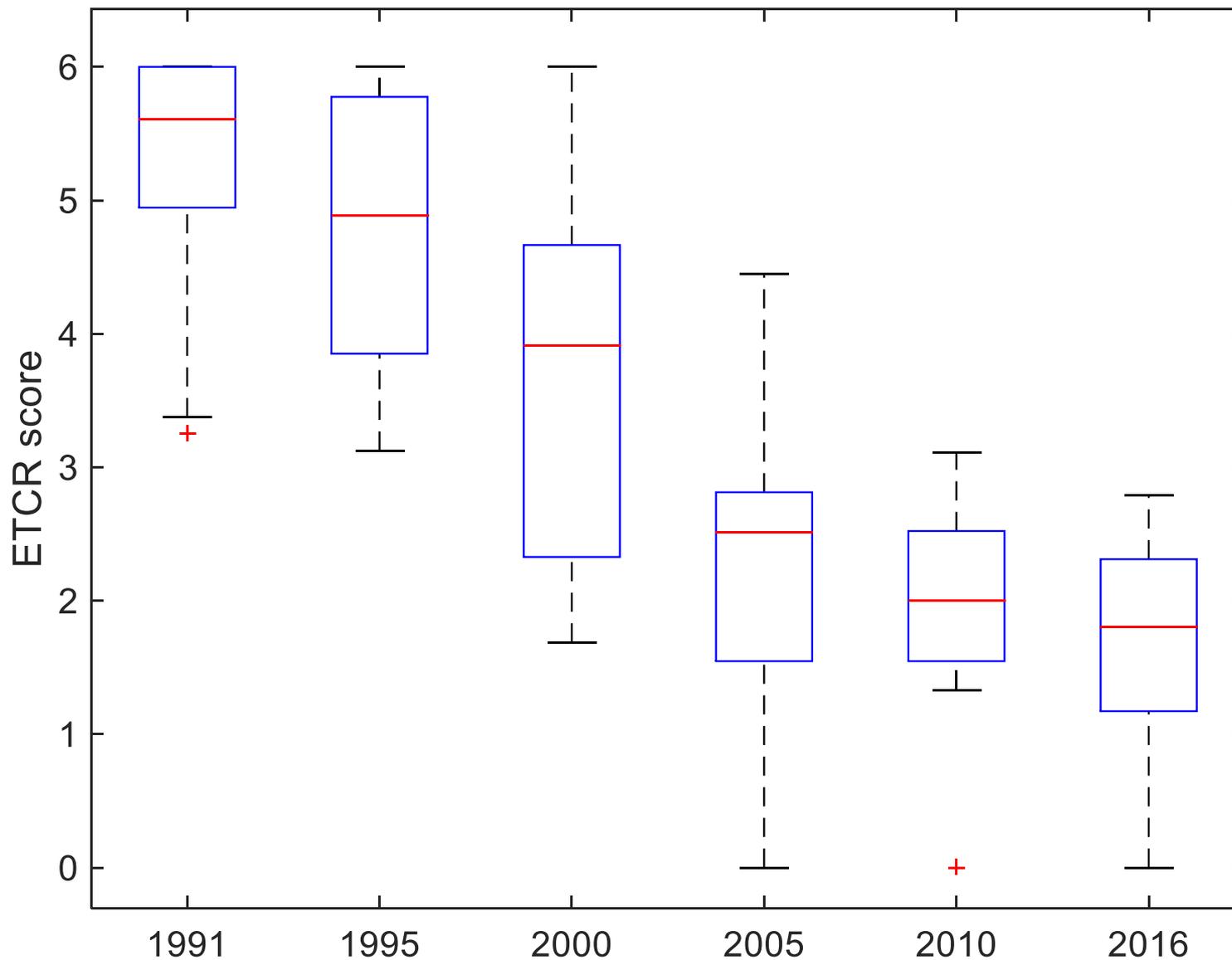
Background and motivation

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

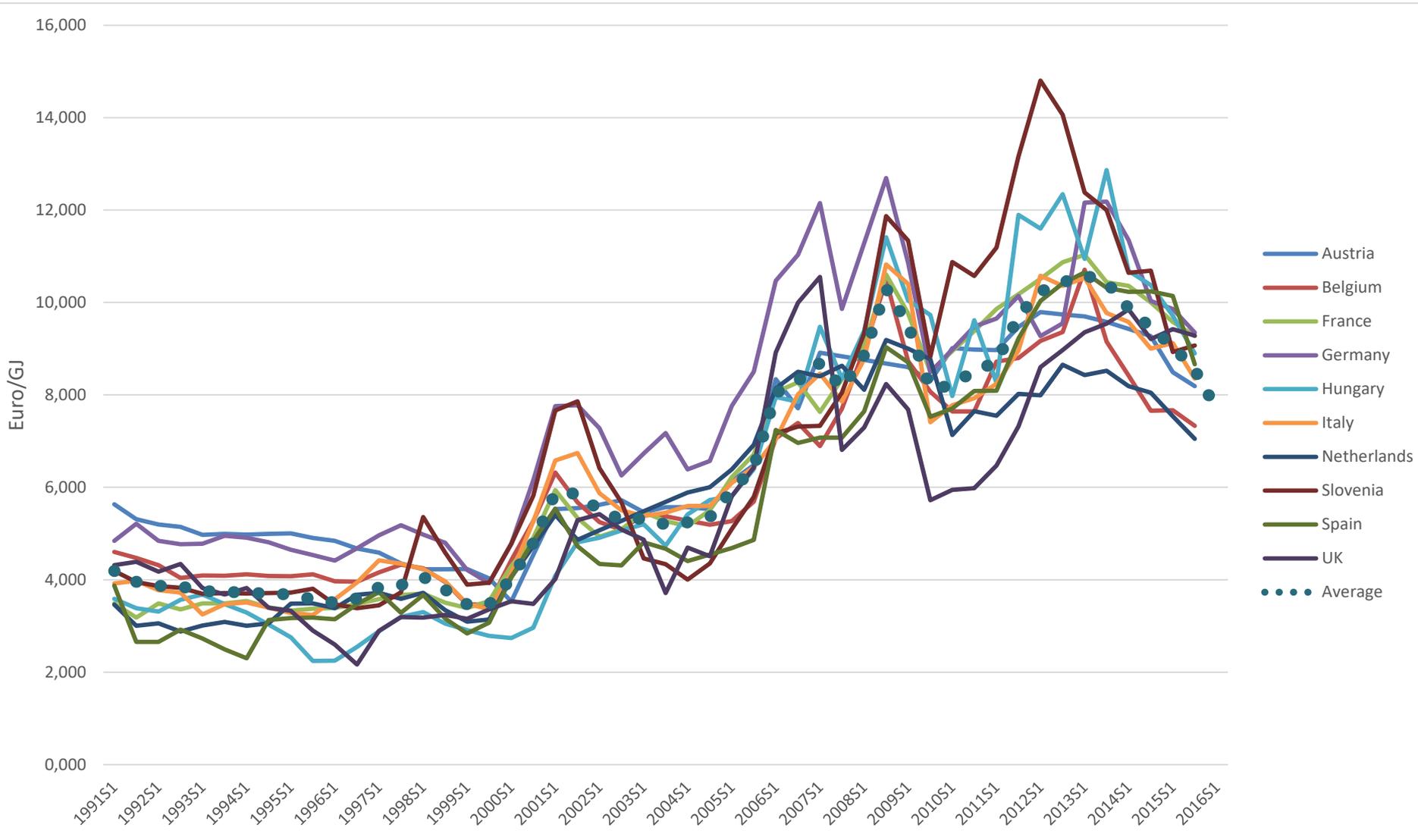
1. First Gas Directive in 1998 (98/30/EC): gas markets opened up to competition by facilitating the entry in the competitive segments of the industry. New common rules for transmission, distribution, supply and storage of natural gas.
2. Second Gas Directive in 2003 (2003/55/EC): unbundling the vertically 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 in 2009 (2009/73/EC): improve the functioning of the internal energy market and resolve structural problems, plus unbundling of energy suppliers from network operators.
4. Recent EU legislation affecting natural gas markets: (i) Proposal for a Regulation “concerning measures to safeguard the security of gas supply and repealing Regulation (EU) No 994/2010” (COM(2016)52/F1), (ii) “Clean Energy For All Europeans” package (“Winter Package”), published on 30 November 2016, consisting of numerous legislative proposals together with accompanying documents, aimed at further completing the internal market for electricity and implementing the Energy Union.

Regulation in EU natural gas markets: ETCR score

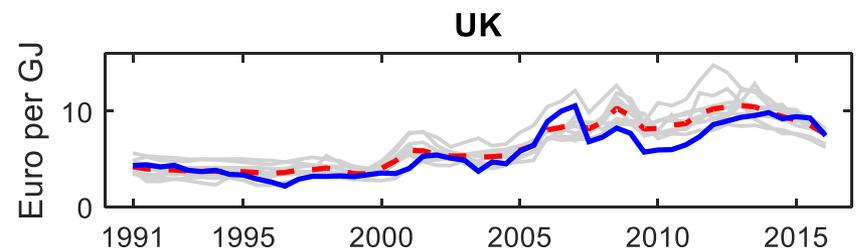
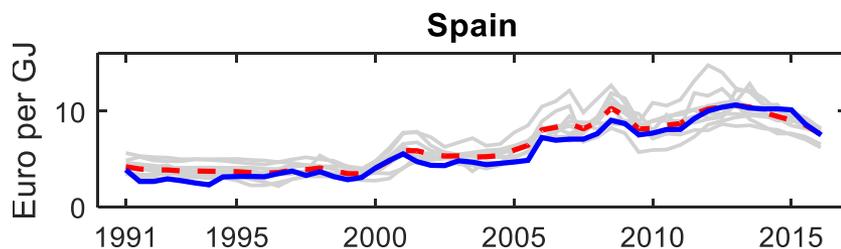
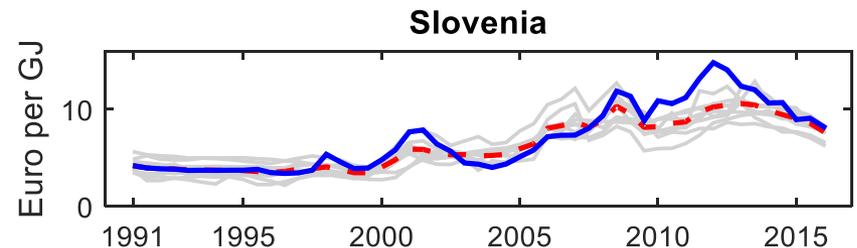
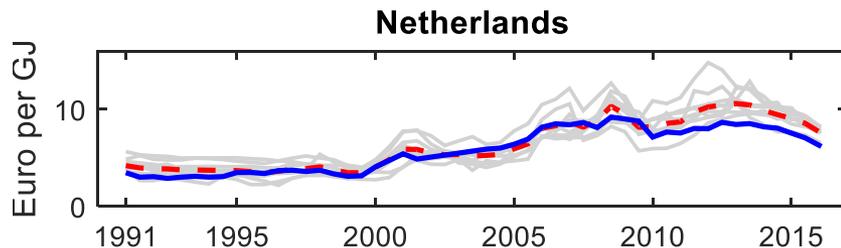
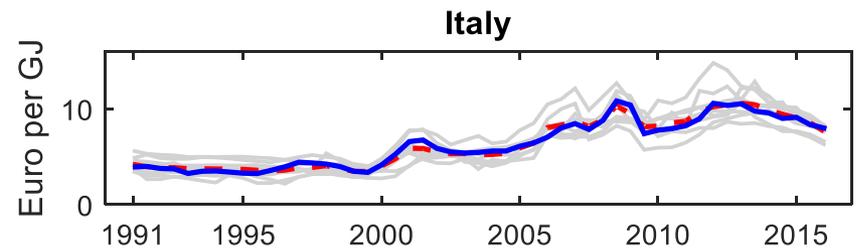
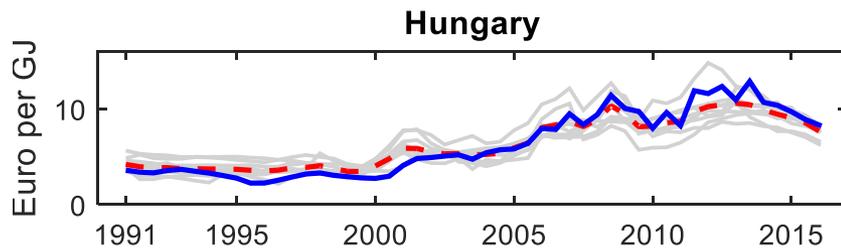
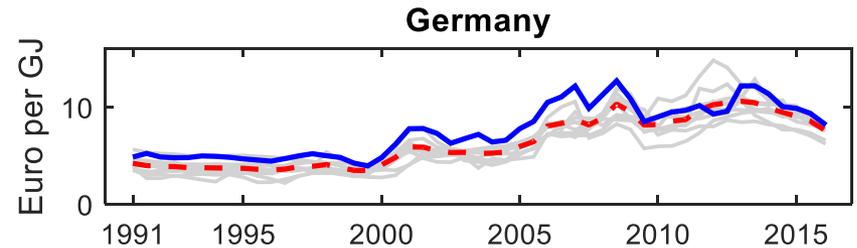
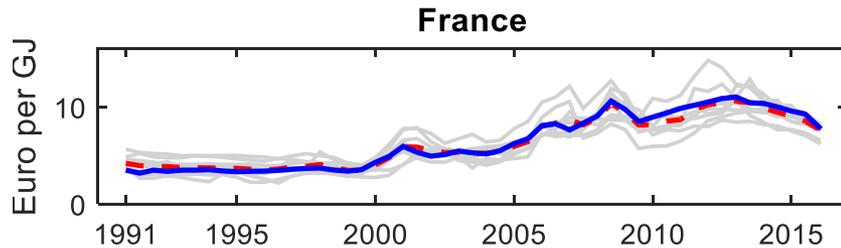
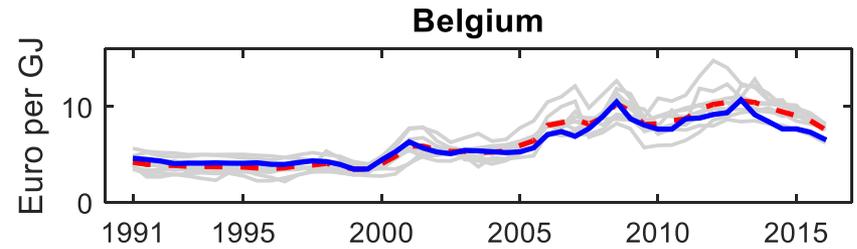
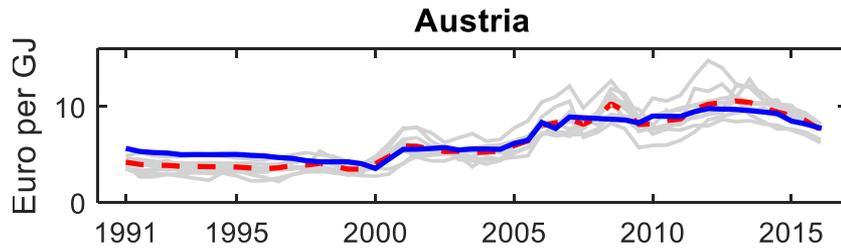
Regulation in natural gas markets



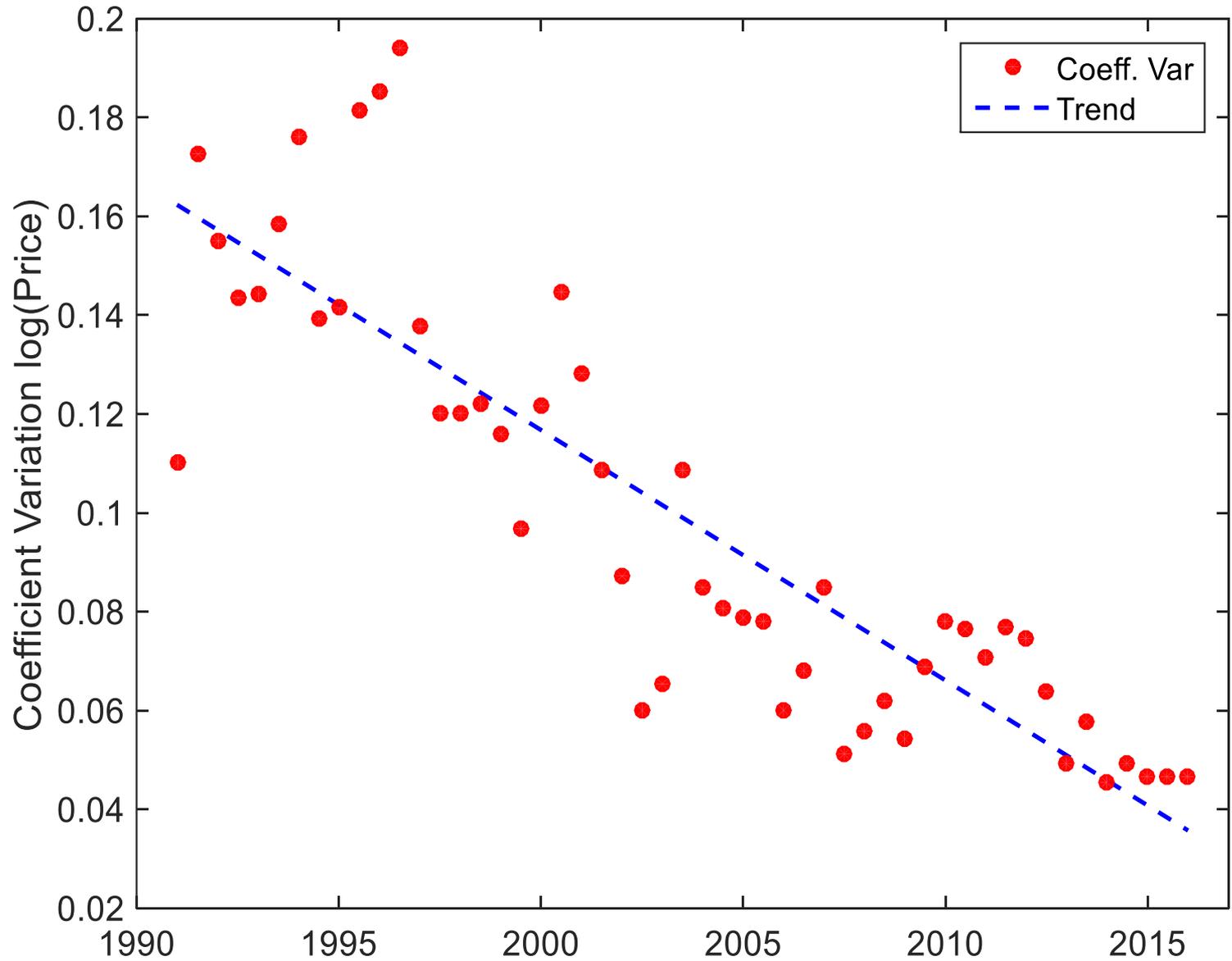
Natural gas price: 1991:H1 – 2016:H2



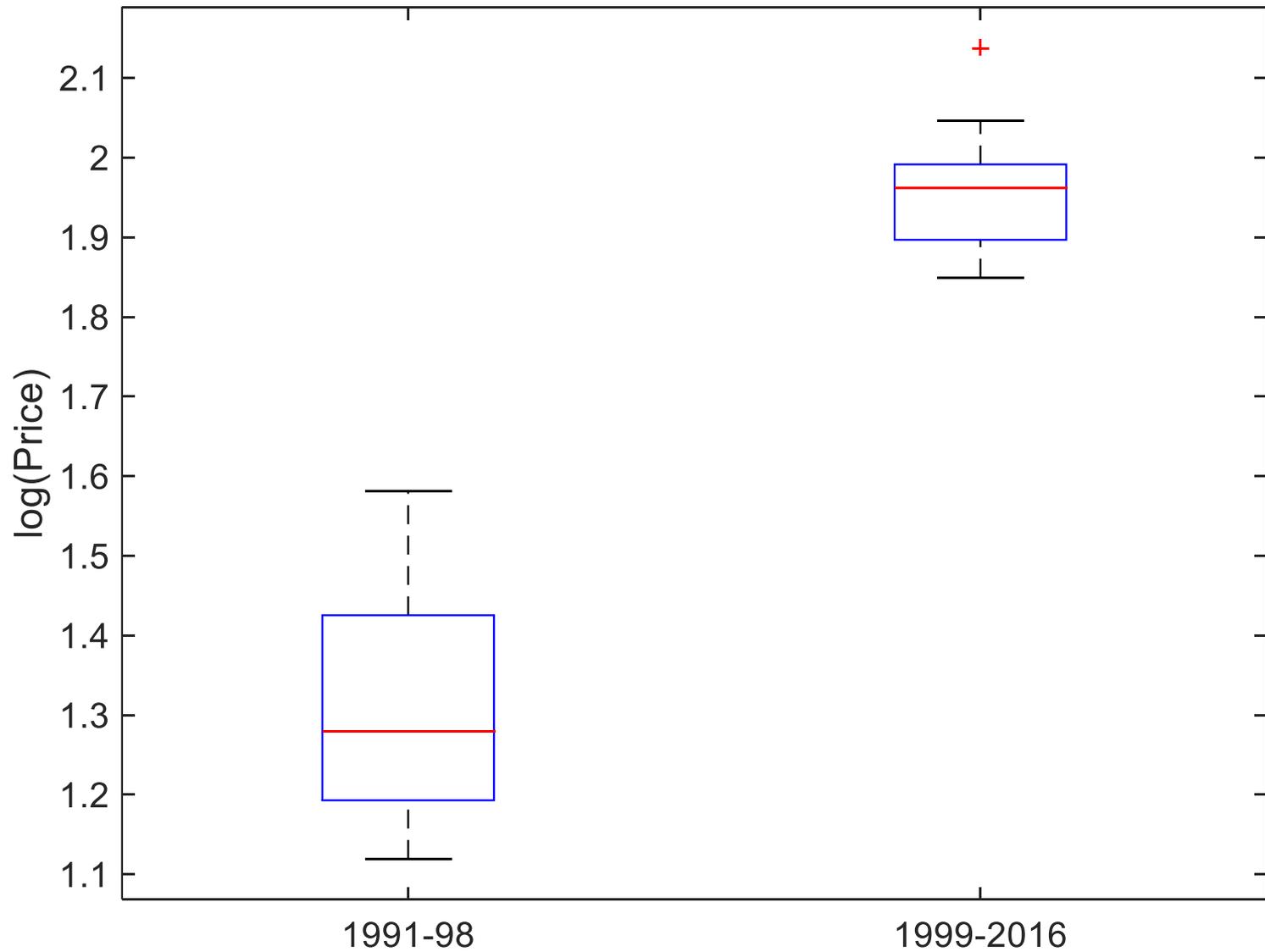
Natural gas price: 1991:H1 – 2016:H2



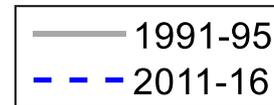
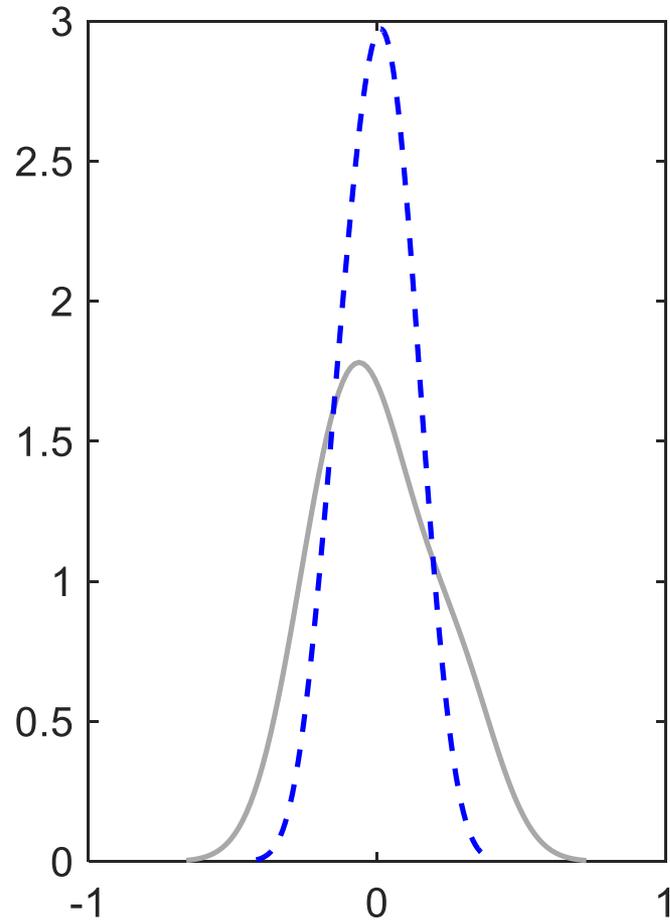
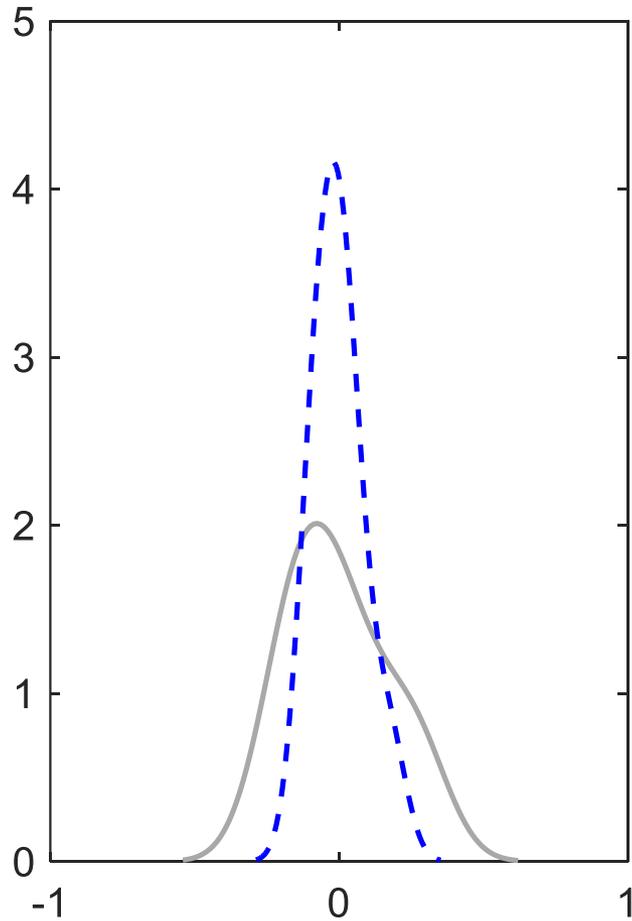
σ -convergence?



σ -convergence?



σ -convergence?



Related Literature/1

- **Only a few papers have specifically tested for natural gas market integration.** Most of the academic papers primarily focused on the deregulation of natural gas markets in North America. Only afterwards tackled the issue of gas market integration for the EU.
- North America. *King and Cuc (1996)* apply time-varying parameter (Kalman Filter) analysis to measure the degree of price convergence in North American natural gas spot markets. *Serletis (1997)* investigates the nature of the observed east-west split for the natural gas traded on organized exchanges using cointegration methodologies. *Park et al. (2008)* analyze daily prices on 8 natural gas spot markets in North America for the period 1998-2007. *Cuddington and Wang (2006)* use daily data on 76 pricing points in the U.S. wholesale spot markets over the period 1993-1997 to understand whether the FERC's regulatory reforms have succeeded in creating a single national market for natural gas or it can still be considered as a segmented market.
- European Union.

Related Literature/2

European Union.

- *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.
- *Growitsch et 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.
- *Silverstovs et al. (2005)*: natural gas market integration across North-America, Europe and Japan over the period 1990-2004 using both principal component and Johansen cointegration analysis
- *Li et al. (2014)* integration and convergence of gas prices for Henry Hub (U.S.), National Balancing Point (U.K.), and LNG price for Japan, South Korea and Taiwan

Related Literature/3

Remarks on existing literature.

- By and large literature consisted of econometric testing of the *Law of One Price* (LOP), using methodologies originally adopted in applied Trade and Industrial Organization Economics.
- Under *market integration* (MI), each pair of price series (assumed to individually have a unit root) must be cointegrated, i.e. there must be a stationary linear combination between the two prices. The LOP then holds if the coefficient of the cointegrating relationship is equal to one, which is the null hypothesis of the test.
- Problem: LOP/MI may be rejected *while the process of market integration is under way*. Solution: Kalman filter. Coefficient of the cointegrating relationship evolves stochastically and its estimation is revised as updated information is added. Track evolution of coefficient toward unity.

Problems with current practice.

- Track process of market integration looking at evolution of estimated coefficient, rather than prices themselves
- Look at each price pairs, not at all prices taken together

Research Question

Research questions:

- Are European natural gas markets characterized by an increasing degree of integration? Are we making substantial progress toward a Single European Market (SEM) for gas?
- Can we identify the main factors driving this process of integration of European gas markets?

Our contribution:

- Study Market Integration using convergence analysis
- Extend the dataset to the latest available data and to ten EU Member States for which we have complete time series
- Focus on industrial medium-sized consumers but extend study to other categories of consumers
- Study the impact of OECD's Energy, Transport and Communications Regulation (ETCR) scores to analyze the factors driving the market integration process

Data

- Before tax data on prices (Euro per GJ) paid by industrial consumers (medium consumption band: 1000 to 10000 GJ per year)
- 10 EU countries: Austria, Belgium, France, Germany, Hungary Italy, Netherlands, Slovenia, Spain and UK.
- Each of the chosen markets is interconnected with at least one of the other country
- Sampling frequency: half-yearly prices
- Time-span: 1991:h1 – 2016h1
- Source: Eurostat.

Interesting classifications

1) Hub maturity

- Trading hubs: British NBP, Dutch TTF
- Transit hubs: Belgian Zeebrugge, Austrian CEGH
- Transition hubs: German GPL and NCG, French PEGSs, Italian PSV, Hungary, Slovenia, Spain.
- Definition and classification following Heather (2012), “Continental European gas hubs: are they fit for purpose”, OIES Working paper, NG 63.

Interesting classifications

2) Geography

- Baltic: Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Sweden.
- North West: *Belgium*, Denmark, France, Germany, Ireland, Luxembourg, *Netherlands*, Sweden, *United Kingdom*.
- Central Eastern: *Austria*, Bulgaria, Croatia, Czech Rep., Germany, Hungary, Poland, Romania, Slovakia, *Slovenia*.
- South: *France*, Portugal, *Spain*.
- Southern Corridor: *Austria*, Bulgaria, Croatia, Cyprus, *Hungary*, Greece, *Italy*, Romania, Slovakia, Slovenia.

Source: ENTSOG (the European Network of Transmission System Operators for Gas)

Method: Convergence analysis

- Path-breaking contributions by Barro (1991), Barro and Sala-i-Martin (1992), and Islam (1995), convergence in per capita GDP central in the empirical growth literature.
- Convergence transposed to energy and environmental economics - energy consumption levels, energy intensities, and carbon dioxide emissions or emission intensities.
- Convergence of energy price co-movements has been investigated by a few authors, notably Bentzen (2003), Li et al. (2010, 2014), Apergis et al. (2017).
- The literature has suggested different notions of convergence: σ -convergence, β -convergence, stochastic convergence (Carlino and Mills, 1993)
- Stochastic convergence exploits the time series properties of data. Convergence requires that shocks to price relative to the mean are temporary, implying that the (logged) price series is stationary. On the contrary, the existence of a unit root in the series implies that shocks are not temporary but permanent, so that price is not converging over time.
- Several unit root tests are available and alternative ways of testing for stochastic convergence have been proposed, including Bernard and Durlauf (1995, 1996) and Phillips and Sul (2007)

Methods

- *Pairwise convergence tests à la Bernard and Durlauf (BD, 1996)*
- *Phillips-Sul test (PS, 2009), joint test of relative convergence.*
- Advantages of PS over BD:
 - Less restrictive assumptions: does not require trend stationarity or cointegration.
 - Non-parametric trend estimation: can have structural breaks.
 - PS allows for a wide range of transition paths
 - PS allows for transitional divergence (i.e. the series can temporarily diverge from the general convergence path)

Pairwise BD convergence test

- BD propose two definitions of convergence:

1) Convergence as catching-up, if $p_{it} > p_{at}$:

$$E(p_{it+T} - p_{at+T} \mid W_t) < p_{it} - p_{at}$$

where P_{at} = cross-country average, $p = \log(P)$ and W_t = information set

2) Convergence of long-term forecasts:

$$\lim_{h \rightarrow \infty} E(p_{it+h} - p_{at+h} \mid W_t) = 0$$

- These definitions are violated in the presence of persistent shocks to the price differential.
- BD test boils down to an Augmented Dickey-Fuller (ADF) of the price differential
- If $(p_{it} - p_{at})$ has a unit root, there is evidence against the convergence of price i to the cross-country average.

Convergence to the mean? Pairwise test

Pairwise test of convergence to the average price

country	ADF	Const	Trend	$\pi_0 > \text{avg}(p_0)$
Austria	0.1258	2.3401*	-2.2626*	yes
Belgium	0.5441	1.5667***	-2.0308*	yes
France	0.0068***	-3.3879	3.5738	no
Germany	0.0376**	3.5612	-2.7612	yes
Hungary	0.1101	-2.6296	2.6027	no
Italy	0.5233	0.9797***	-0.9232***	no
Netherlands	0.5525	-0.2888***	-0.6623***	no
Slovenia	0.5234	0.0554***	0.4625***	no
Spain	0.0197**	-3.5438	3.0207	no
UK	0.2711	-1.2572***	0.3137***	yes

Notes: columns 2-4 shows p-values with asterisks denoting rejection of the null hypothesis (H_0) at the 0.1 (*), 0.05 (**), 0.01 (***) significance level. In column 2, H_0 : no convergence (unit root); in column 3 and 4 H_0 is const = 0 and trend = 0, respectively. The last column shows whether the price in the first period was above the average price.

Phillips and Sul test

- Relative convergence defined as:

$$\lim_{s \rightarrow \infty} (p_{it} / p_{jt}) = 1 \quad \text{for all } i \text{ and } j$$

- A test of *relative convergence* relies on:

$$\log(H_1 / H_t) - 2 \log(\log(t)) = a + g \log t + u_t$$

where:

- H_1 is the cross-sectional variance in the first time period ($t = 1$)
- $H_t = N^{-1} \sum_i (h_{it} - 1)^2$ is (up to a scale factor) equivalent to the cross sectional variance of prices
- $h_{it} = p_{it} / (N^{-1} \sum_i p_{it})$ captures the transition path of a country with respect to the group average

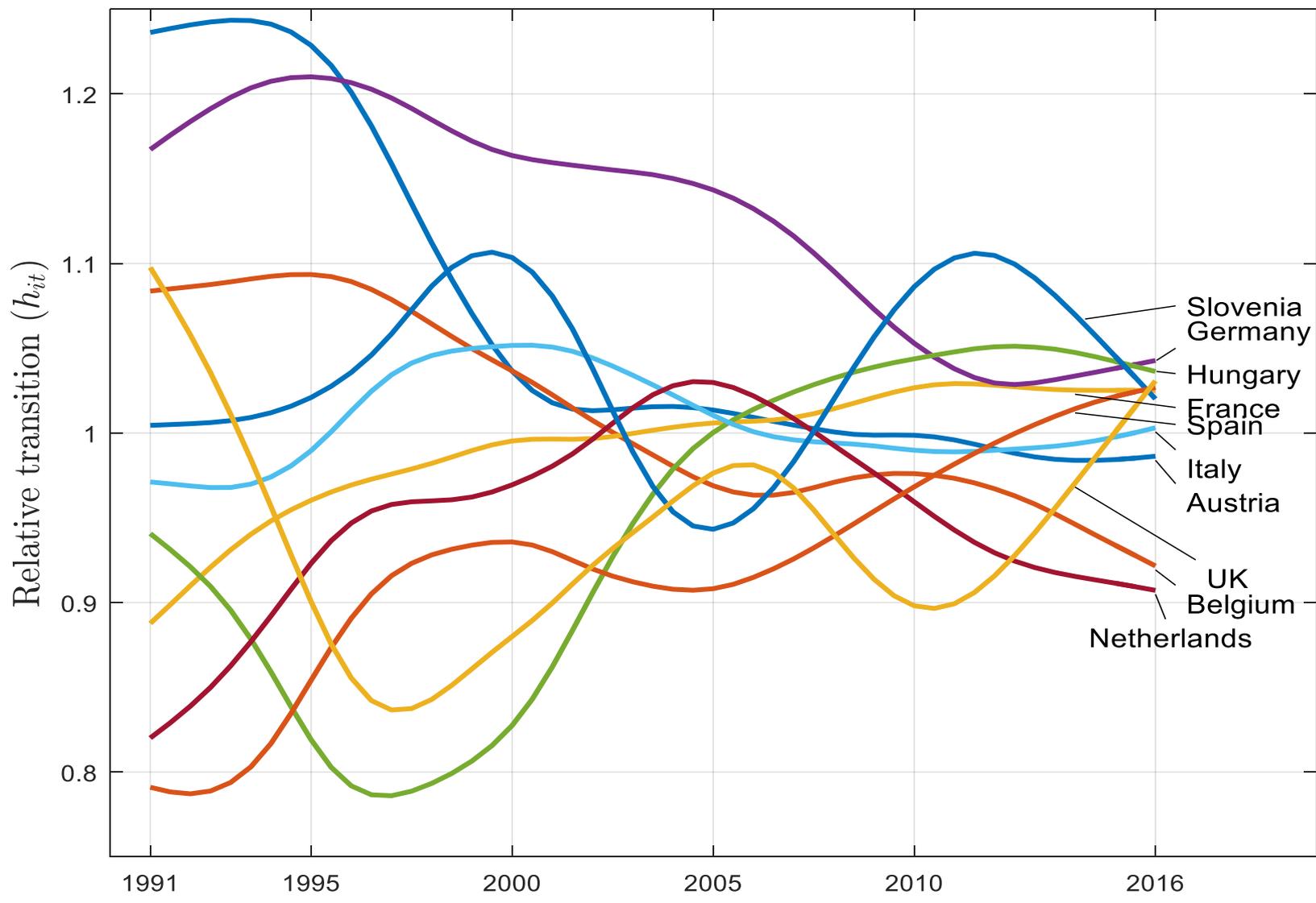
- PS rely on a one-sided t-test of $H_0: g \geq 0$, against the alternative $g < 0$.
- H_0 : relative convergence is rejected at the 5% significance level if $t_g < -1.65$.
- Rejection of the null implies either divergence or club convergence.

Convergence to the mean price?

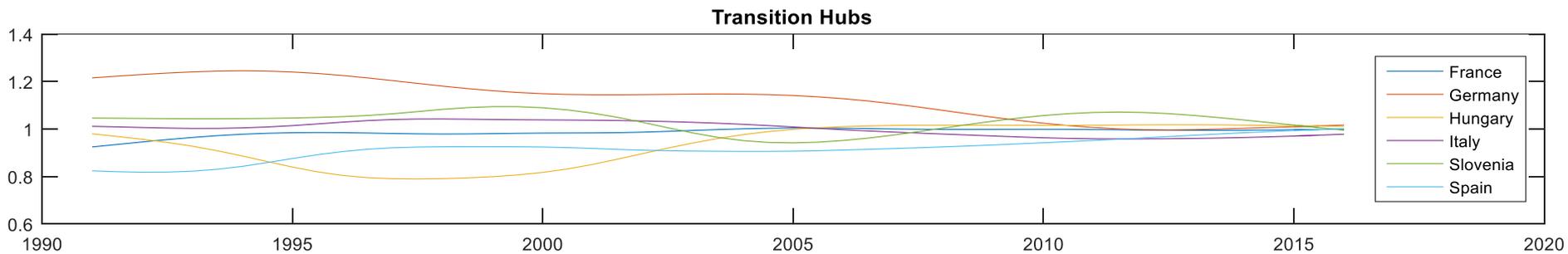
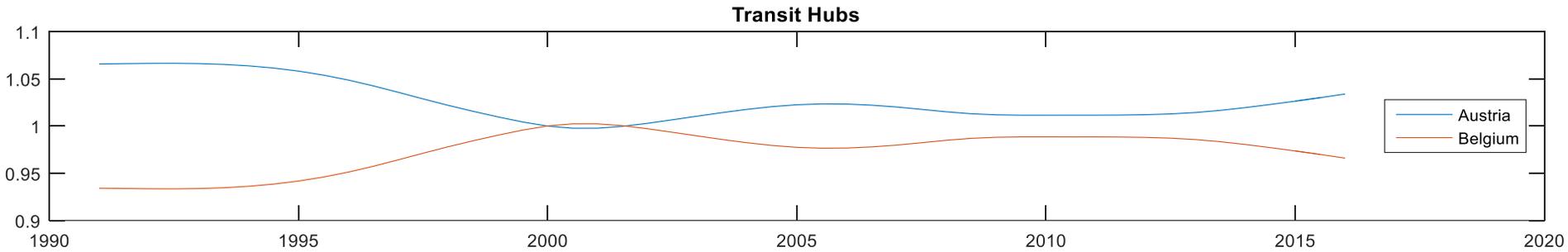
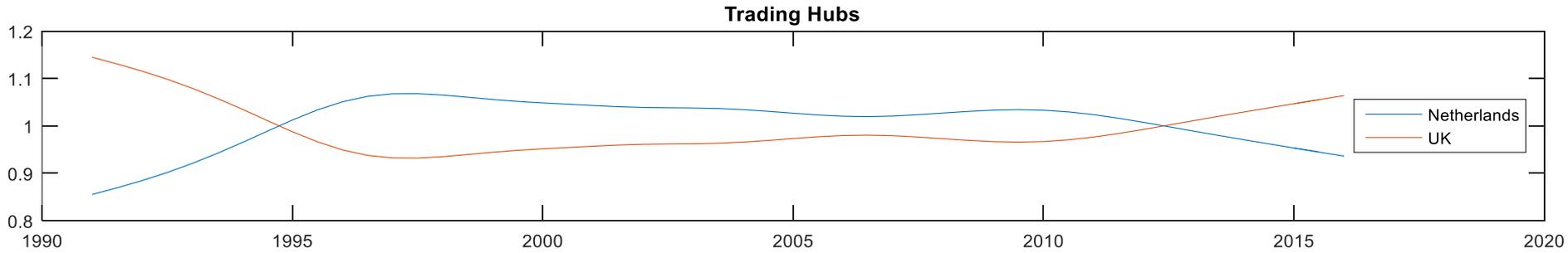
Phillips-Sul test				
Group	γ estimate	std. Err.	t-stat	
All	0.7859	0.1960	4.0103	***
Trading hubs	0.8776	1.1521	0.7618	***
Trasit Hubs	-6.0439	1.6044	-3.7670	
Transition hubs	3.0732	0.4953	6.2041	***
H0: convergence				

Note: as suggested by PS, log prices have been HP filtered

Convergence to the mean price?



Convergence by hub maturity?



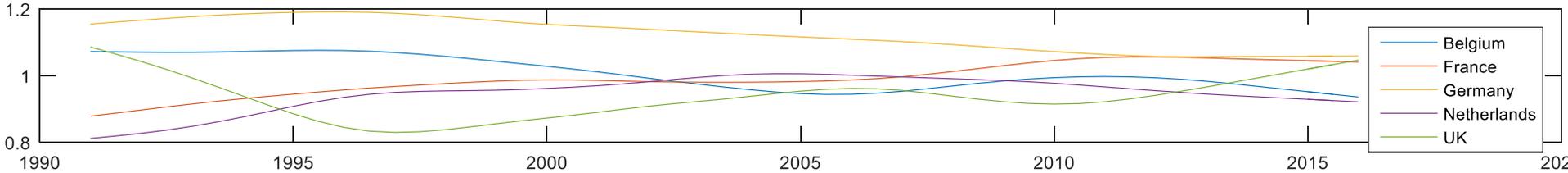
Convergence by geography?

Phillips-Sul test

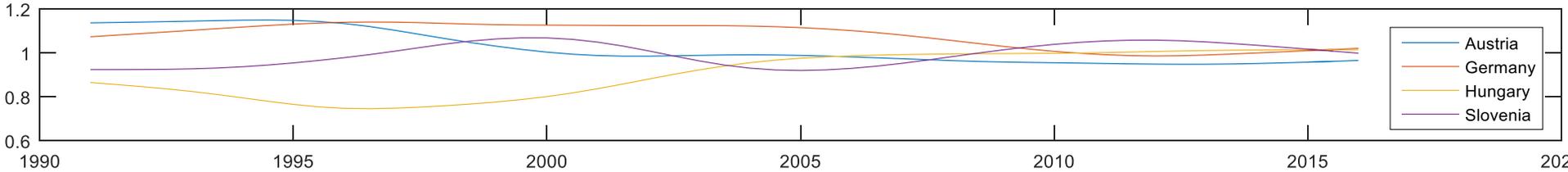
Group	γ estimate	std. Err.	t-stat	
North-west	0.6564	0.1694	3.8746	***
Central Eastern	2.7337	0.2119	12.8978	***
South	4.6414	2.1602	2.1486	***
Southern Corridor	1.2674	0.8595	1.4746	***
H0: convergence				

Convergence by geography?

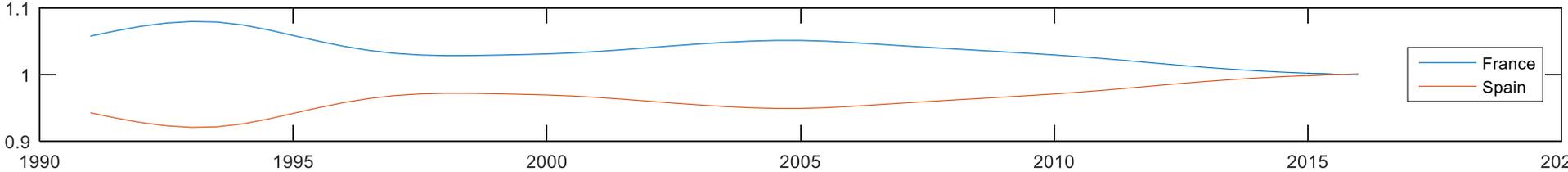
North West



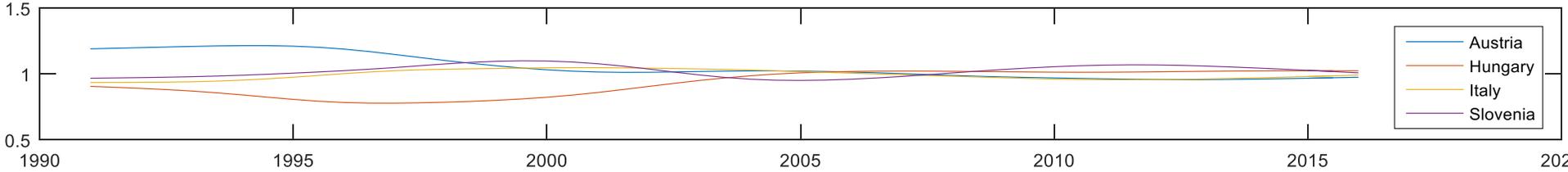
Central Eastern



South



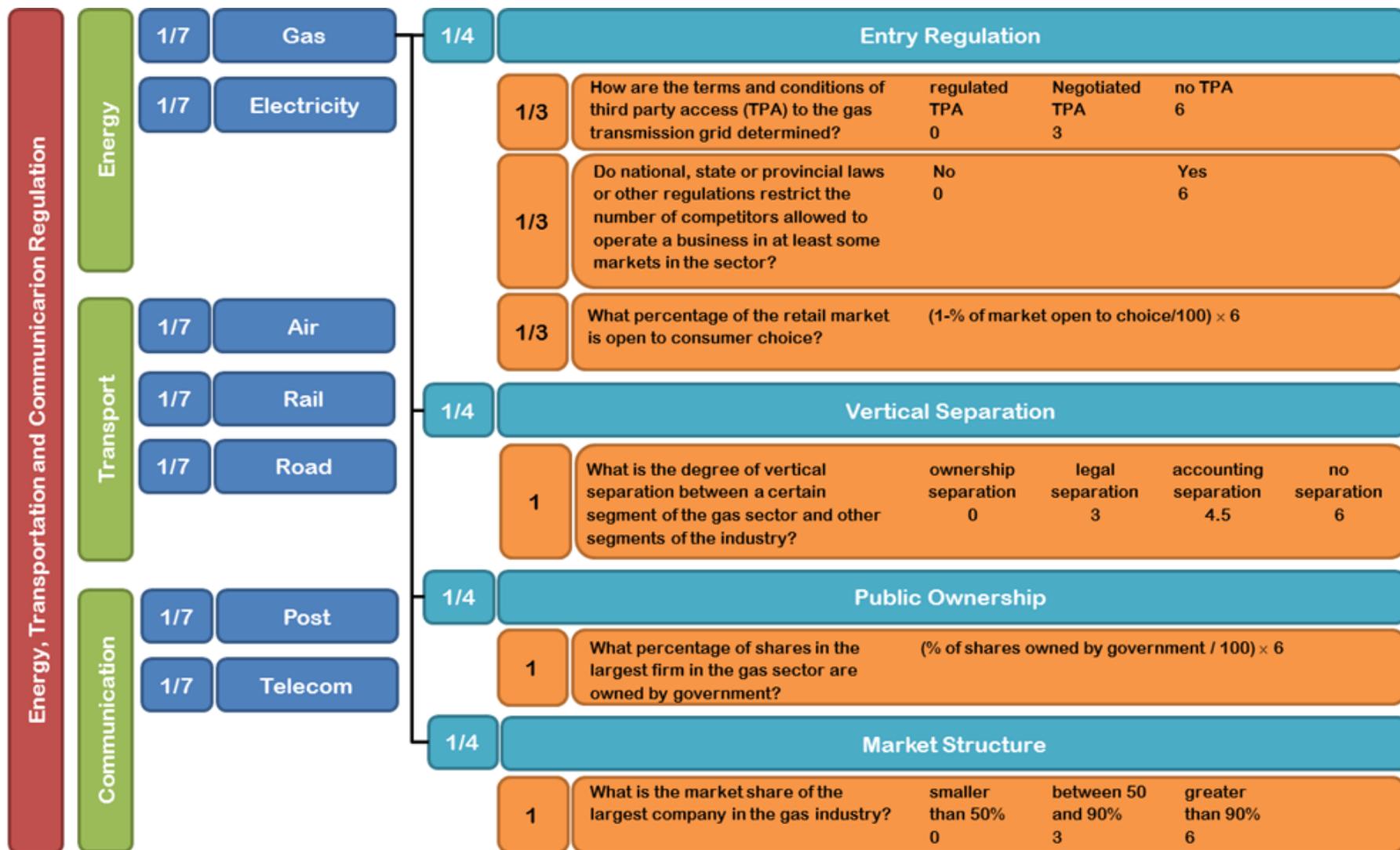
Southern corridor



Factors behind convergence

- We now study the driving factors of price convergence across EU gas markets
- we can exploit the information provided by the OECD ETCR dataset, limiting out attention to the gas network sector
- A score is attributed to the degree of market regulation ranging from zero to six, where values near zero indicate fewer restrictions to competition.
- In addition, there are four sub-indices covering different dimensions of the gas reforms: entry regulation, public ownership, vertical integration and market regulation.
- General tendency toward more competition, UK in a class by itself

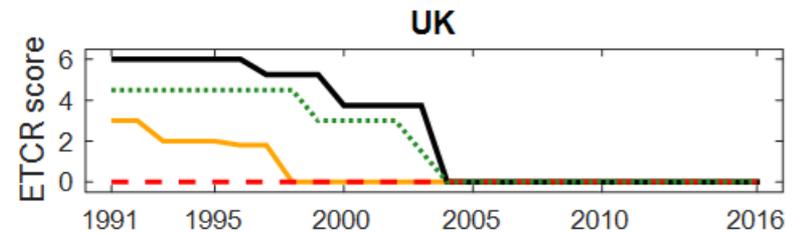
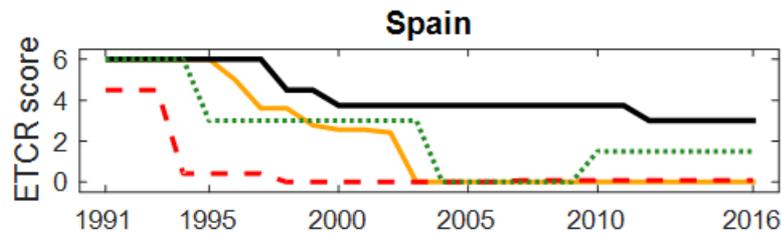
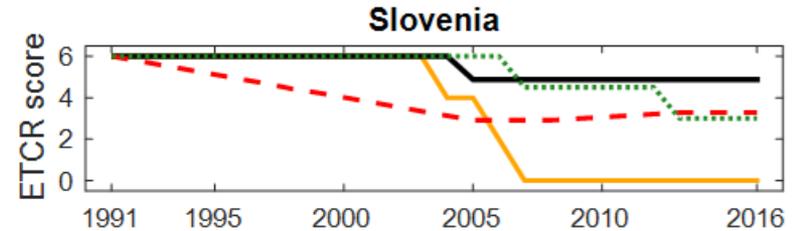
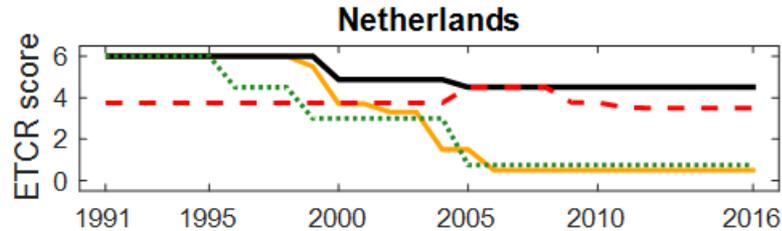
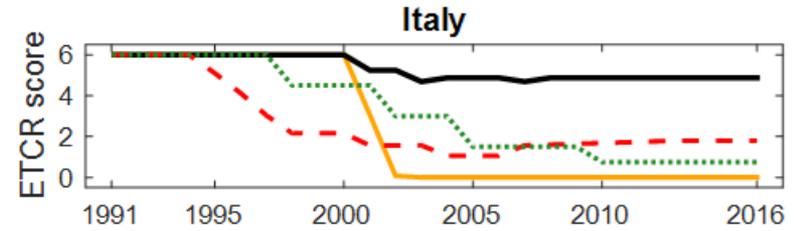
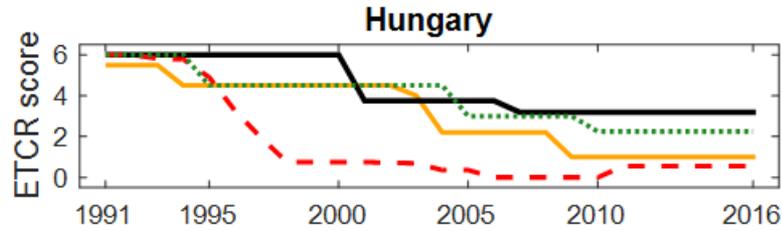
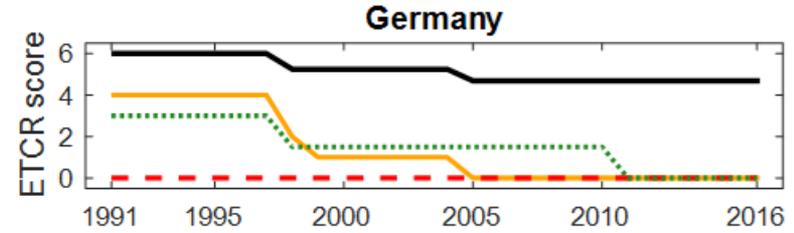
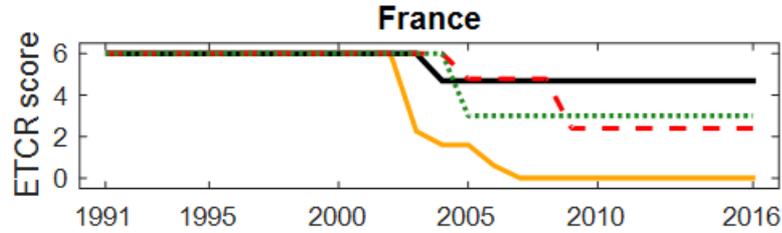
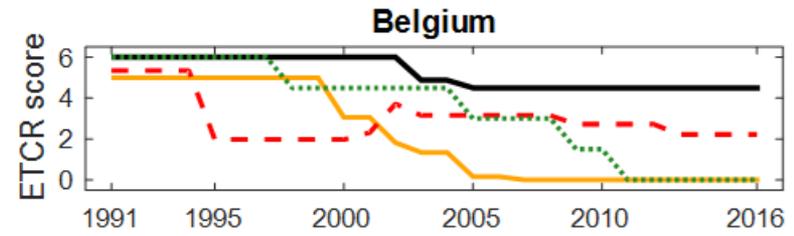
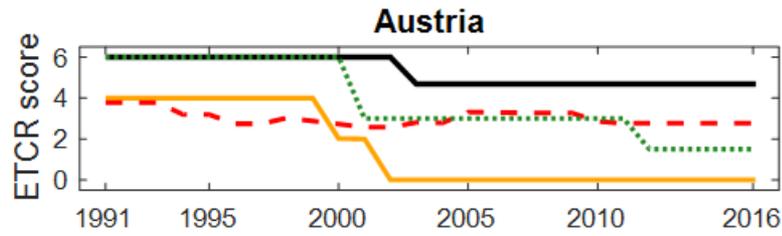
OECD's Energy, Transport and Communications Regulation (ETCR) database.



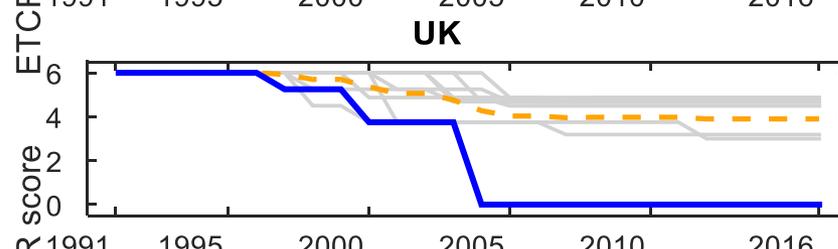
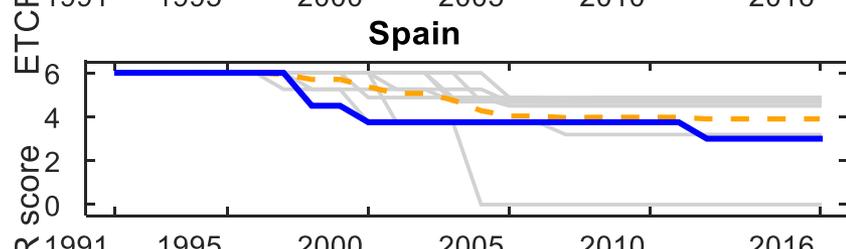
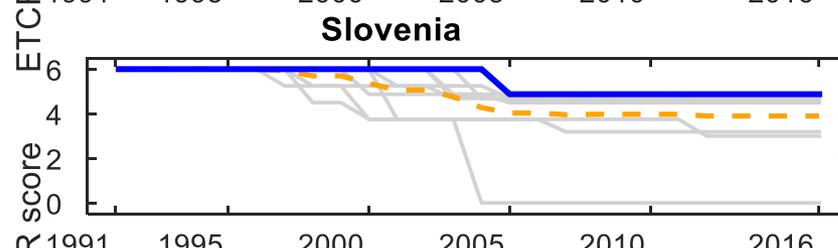
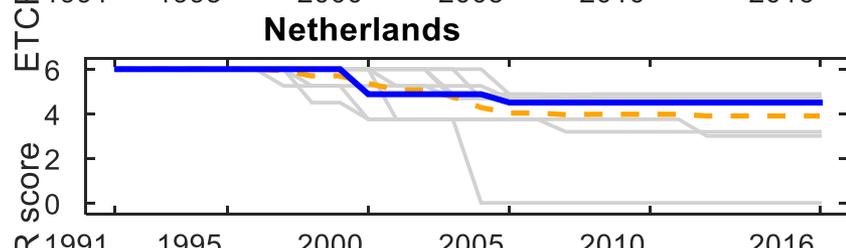
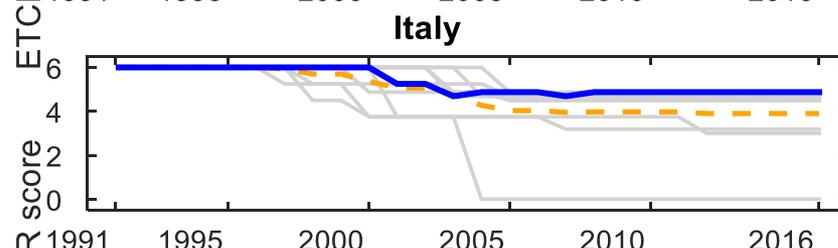
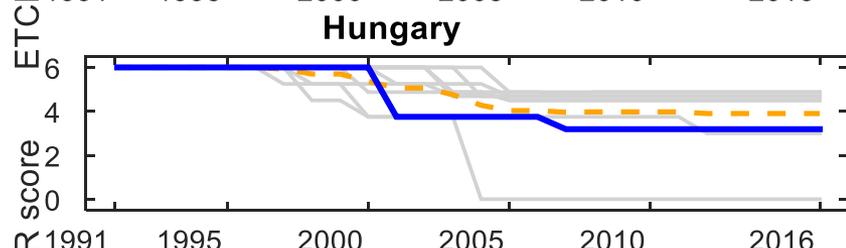
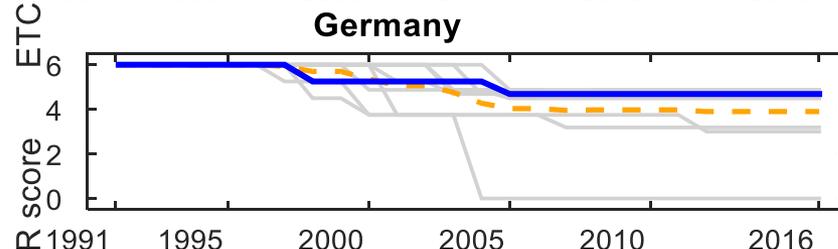
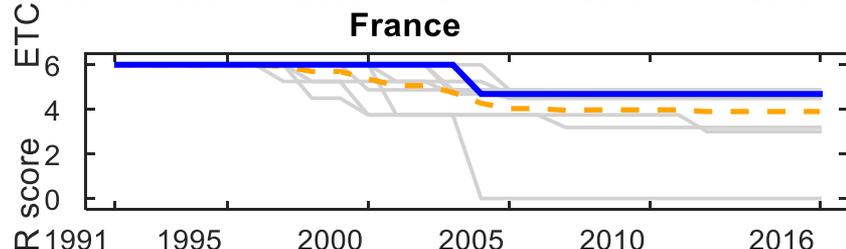
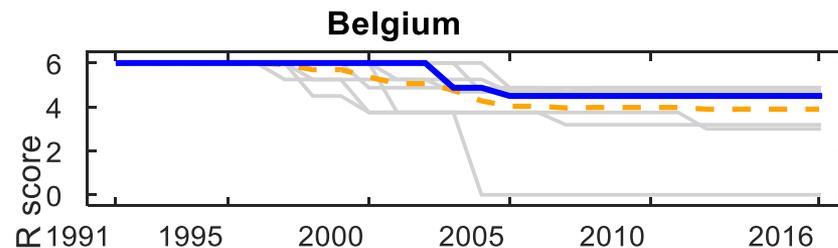
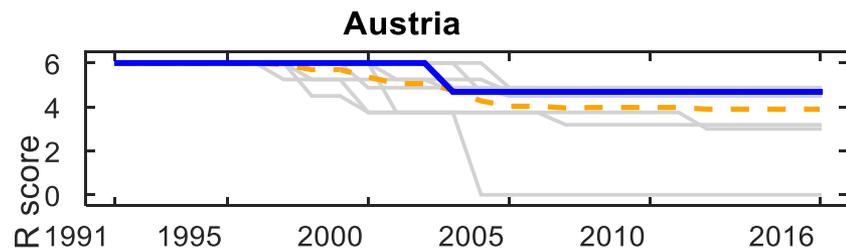
Notes: The ETCR index aggregates with equal weights indices for seven network sectors: telecom, electricity, gas, post, air transport, rail transport, and road transport. For each sector, there are up to four sub-indices that cover different dimensions of the reforms: entry regulation, public ownership, vertical integration and market regulation. We show the underlying questionnaire for the gas sector. Numbers are sector, topic and question weights used for aggregation purposes.

Source: Bastianin et al. (2017).

Structure of OECD Energy, Transport and Communications Regulation (ETCR) dataset – Natural gas sector 1991-2016



Natural gas ETCR index for market separation – 1991 – 2016



Catch-up regression

- Specification borrowed from the macroeconomic literature on productivity catch-up (see e.g. Bernard and Jones, 1996; Nicoletti and Scarpetta, 2003, Griffith, Redding, and Simpson, 2009)

$$\Delta \log P_{it} = \alpha_i + \lambda \text{gap}_{t-1} + a \text{ETCR}_{it-1} + g (\text{ETCR}_{it-1} \times \text{gap}_{t-1}) + \mathbf{x}_{it} \mathbf{d} + T_t + u_{it}$$

- $\text{gap}_{t-1} = \log (P_{it-1} / P_{it-1})$; λ = catch-up parameter
- α_i fixed-effects: time-invariant heterogeneity between countries
- T_t time dummies: common price innovations, business cycle fluctuations and other shocks that jointly affect all countries in the sample.
- ETCR_{it} regulatory activity indicator (OECD; Score: 6 (no regulation) to 0 (regulation to favour of competition)).
- \mathbf{x}_{it} other control variables that account for demand- and supply-side determinants of the price.

Catch-up regression

Catch up regression: base model

Gap, $\log(P_a/P_i)$ (t-1)	0.3678***	0.2828***	0.3167***	0.3513***	0.3665***
ETCR (t-1)	-0.0152*				
Gap*ETCR (t-1)	-0.0447*				
Entry (t-1)		-0.0021			
Gap*Entry (t-1)		-0.0276*			
Pub. Own. (t-1)			-0.0093**		
Gap*Pub. Own. (t-1)			-0.0442***		
Vert. Int. (t-1)				-0.0100	
Gap*Vert. Int. (t-1)				-0.0289	
Mkt. Share (t-1)					0.0080
Gap*Mkt. Share (t-1)					-0.0406***

Notes: fixed effects and time dummies always included.

Catch-up regression

- Alternative, more flexible formulation (see also Albrizio, Koźluk, and Zipperer, 2017)

$$\text{Dlog } P_{it} = a_i + \lambda \text{ gap}_{t-1} + b \text{ DP}_{at} + a \text{ ETCR}_{it-1} + g (\text{ETCR}_{it-1} \times \text{gap}_{t-1}) + \mathbf{x}_{it} \mathbf{d} + T_t + u_{it}$$

- Specification accounts also for the rate of growth of the average price, capturing the instantaneous effect of changes in the EU average price.
- \mathbf{x}_{it} other control variables that account for demand- and supply-side determinants of the price (to be added later on).

Catch-up regression

Catch up regression: ECM model

$\Delta pa(t)$	1.0015**	0.9926**	1.0174**	0.9964**	0.9997**
Gap = $\log(Pa/Pi)(t-1)$	0.3678***	0.2828***	0.3167***	0.3513***	0.3665***
ETCR (t-1)	-0.0152*				
Gap*ETCR (t-1)	-0.0447*				
Entry (t-1)		-0.0021			
Gap*Entry (t-1)		-0.0276*			
Pub. Own. (t-1)			-0.0093**		
Gap*Pub. Own. (t-1)			-0.0442***		
Vert. Int. (t-1)				-0.0100	
Gap*Vert. Int. (t-1)				-0.0289	
Mkt. Share (t-1)					0.0080
Gap*Mkt. Share (t-1)					-0.0406***

Notes: fixed effects and time dummies always included.

Further steps

- Rather than the cross sectional average of gas prices formulate analysis using the lowest price among our ten EU countries. Convergence to the mean could be considered a sort of “weak convergence”, whereas convergence to the lowest price could be thought of as “strong convergence”. We plan to pursue this extension in the future.
- Extension to small and large industrial consumers and perhaps to residential ones as well.
- Complete analysis of driving factors of price convergence
- Especially, relate our evidence to I.O. analysis of gas market structure