The impact of structural reforms on the performance of European transmission network operators

What lessons can be learned for designing the regulatory framework of hydrogen markets?

(Preliminary results)

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Outline

1. Introduction
   - Background, motivation and research question
   - Literature review
2. Method
   - Theory
   - Data
   - Model specification
3. Results
4. Conclusions (preliminary)

1. Introduction: Background

- Discussion:
    - What market design (regulatory framework) will be applied to hydrogen markets?

- Recently, the EC proposed a review and revision of the Gas Directive (2009) (part of the Hydrogen and Decarbonized gas package)
    - Compared to gas and electricity sectors, more strict unbundling rules the hydrogen sector:
    - Independent Transmission Operator (ITO) model with integrated network operators will be forbidden.
    - Ownership unbundling (OU) model is imposed from 2030 onwards.

- How does the regulatory design affect the development of a hydrogen network?

- Learn from the experiences with models of structural reforms in European electricity markets
    - Vertical unbundling (separating commercial from network activities)
    - Privatization (transfer of publicly held shares to private sector)
    - Entry liberalization (TPA, liberalized wholesale markets, retail supplier choice)
    - Type of tariff regulation (cost-based, incentive-based)

1. Introduction: Research question and scope

- – **Research question:** What is the impact of structural market reforms on the performance of European electricity transmission network operators?

- – **Scope:** 25 EU countries 1990-2018

1. Introduction: Literature review

- What do we know already?

  - **Alesina (2005)** shows evidence of positive impact of structural reforms on gross investments (electricity, gas and water utilities aggregated) for 1975-1998 in 21 OECD countries.

  - **Nagayama (2010):** reforms incease generation capacity and reduce T&D losses between 1985-2006.

  - **Nardi (2012):** legal unbundling (LU) and OU increase investments in the transmission network, while OU deteriorates the network quality for 14 UCTE countries between 2001 and 2010.

  - **Gugler et al. (2013):** For 16 EU countries between 1998 and 2008, structural unbundling decreases investment in electricity sector's aggregate capital stock, while entry regulation increases investments.

  - **Sugimoto (2021):** finds that OU does not outperform the ITO model in promoting renewable energy investments.

2. Method: Theory

- How to measure the impact of structural reforms?

- The basic model for the empirical evaluation of policy reforms can generally be formulated as follows:

- $Y = f(R, Z)$

- Y: the outcome variable (performance indicators)

- R: the regulatory indicators (e.g., vertical unbundling, privatization, entry liberalization, incentive regulation)

- Z: control variables (e.g., country's structural characteristics)

2. Method: Theory

- How do we measure performance?

- The main roles of the transmission network operator (Balmert and Brunekreeft, 2010)
  - Operation of grid: real time matching of supply and demand
  - Development of the grid: servicing, maintenance, new network connections
  - Coordination with neighboring TSOs (cross-border interconnections)

- To what extent is the TSO able to perform its' main activities in a cost-effective and reliable way?

- **Performance indicators**:
  - Investment: transmission network length (220kv and 400kv)
  - Quality of service: reliability (SAIDI and SAIFI)
 - Cost-effectiveness: transmission losses

2. Method: Theory

- What measures have been taken and what are their expected effects?

- Electricity Directives (1996; 2003; 2009)

1. **Vertical unbundling** (e.g. see Pollitt, 2008; Mulder and Shestalova; 2005)
   - Prevents strategic investment withholding and creates synergy and focus effects
   - Unbundling may lead to coordination failures, loss of vertical synergies, and a higher cost of capital
   - Different degrees of separation: VIU, AU, LU, ITO, ISO, OU
2. **Privatization** (e.g. see Florio and Fiorio, 2013; Florio, 2017)
   - Different objectives and corporate government mechanisms
   - *Incentive effect*: Public owners of the network tend to maximize consumer welfare rather than profit: more extensive and reliable network.
   - *Efficiency effect*: X-inefficiency for public firms: less extensive network with more losses
3. **Entry liberalization** (TPA, wholesale markets, minimum consumption thresholds)
   - Increases the need for investments to connect new entrants
4. **Independent regulator** (to enforce the above reforms)
   - *Incentive regulation*: the conventional view is that cost-based regulated TSOs tend to "gold-plate" their networks and overinvest in capital (Averch and Johnson, 1963).

2. Method: Data

- **Annual growth in transmission network length** for 25 countries from 1990 to 2018 (in %). Source: ENTSO-E (2020)
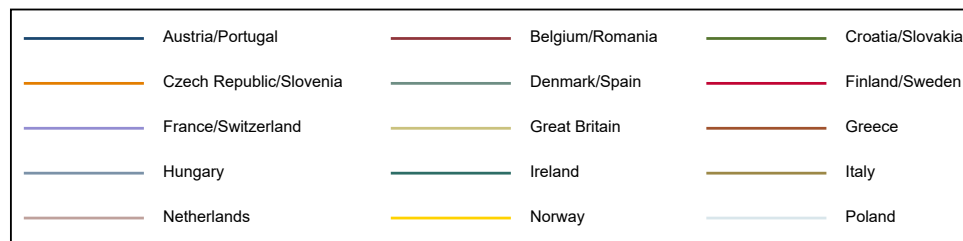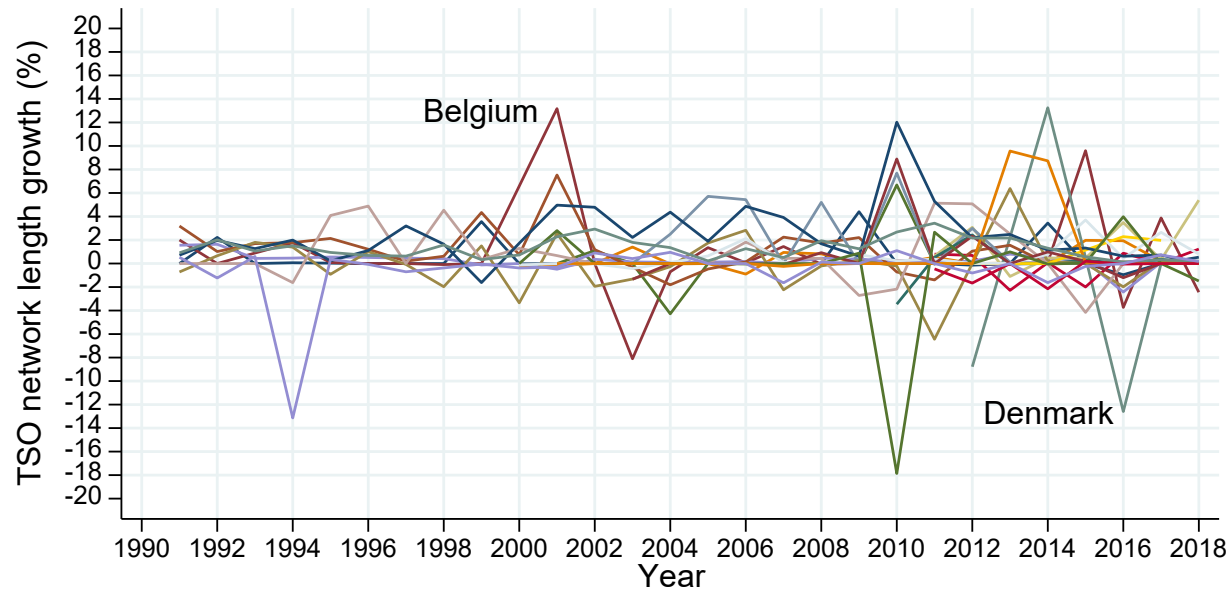
2. Method: Data

- **Reliability index** for the high voltage (HV) and extra-high voltage (EHV) network for 14 EU countries from 2002-2018. Source: CEER (2020)

- Unreliability $= \left(\frac{SAIDI_{t,i}}{SAIDI_{0,i}}\right) * 0.5 + \left(\frac{SAIFI_{t,i}}{SAIFI_{0,i}}\right) * 0.5$ (Florio, 2017)
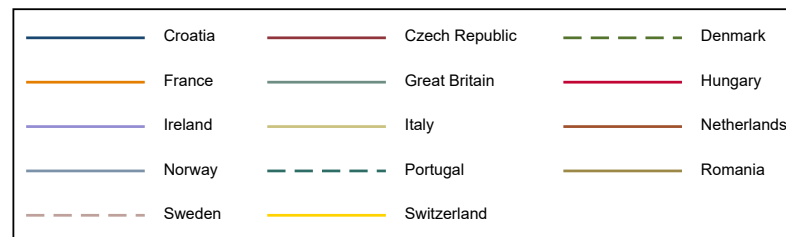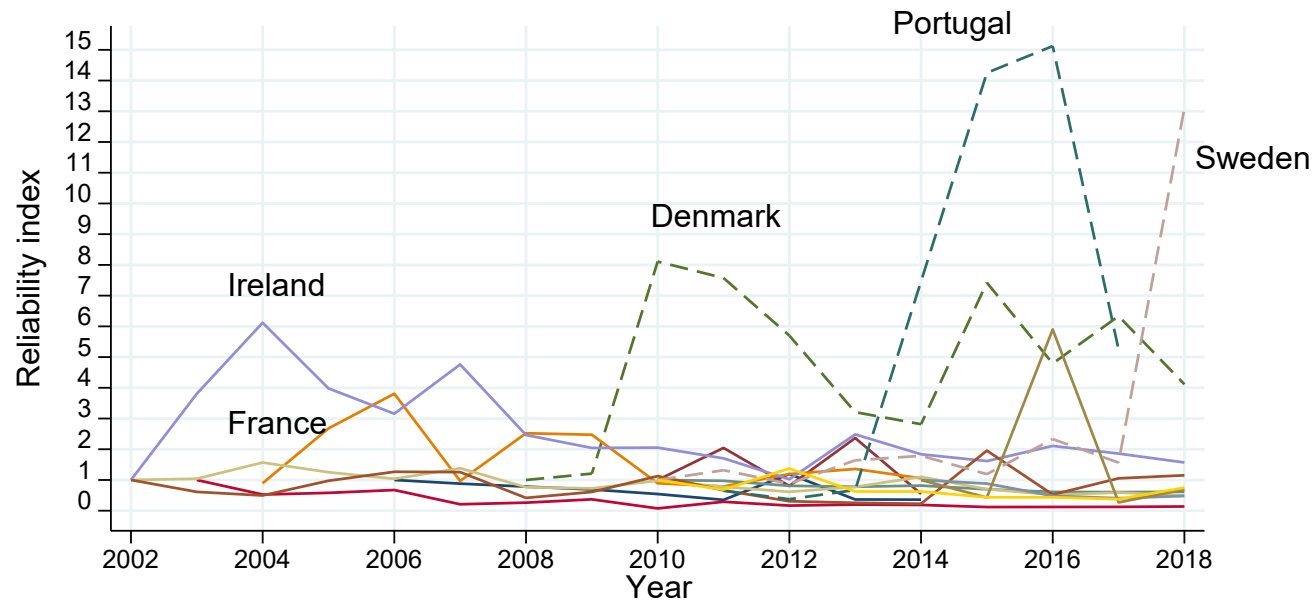
2. Method: Data
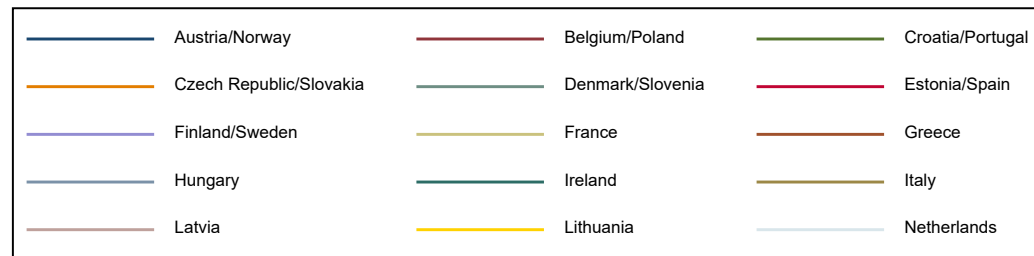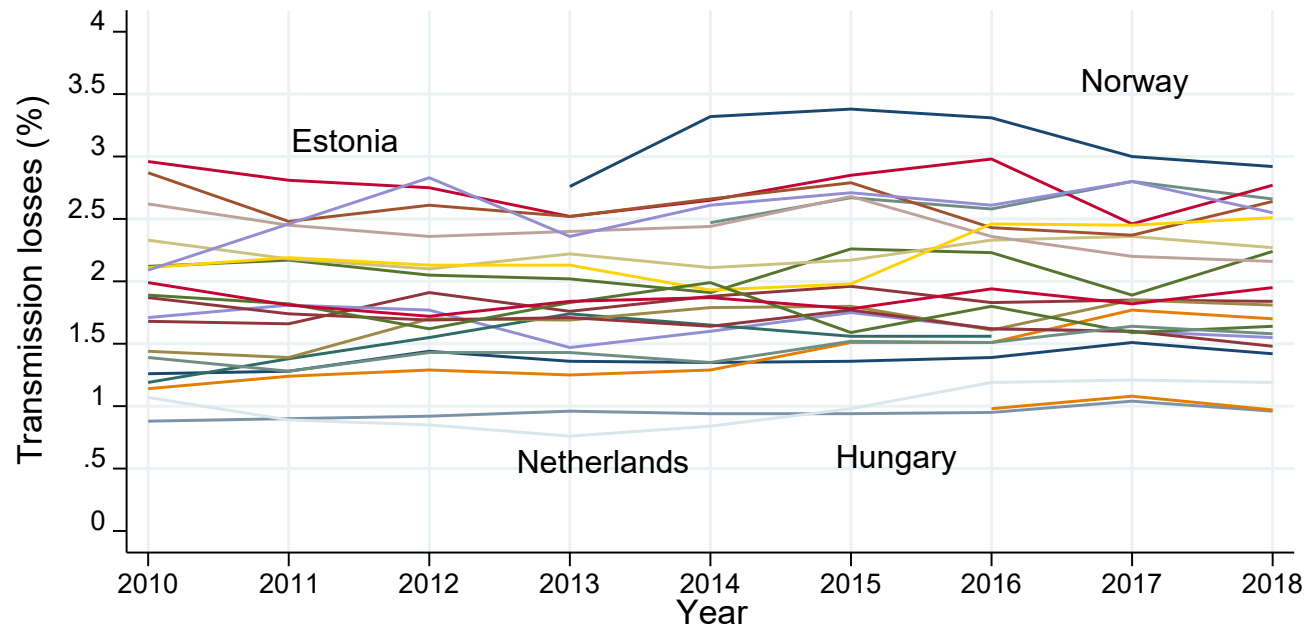
- **Transmission losses** for 22 countries from 2010 to 2018 (in %). Source: CEER (2020)

2. Method: Data

Table A.1. Structural reforms per country in the period 1990-2020

| | Year of introduction | | | | | | | | | | | | | | Average |
| | General structural reforms | | | | | Vertical unbundling models | | | | | Incentive schemes | | | | Public ownership |
Country	PRIV	TPA	LWM	MCT	IRA	VIU	AU	LU	ITO	OU	N	C	I	H	(%)
Austria	2001	1999	2002	2001	2000	1990	2000	2001	2012			1990			66.85
Belgium	1990	2000	2005	1990	1999	1990	2000	2001		2012	1990	1998	2002		43.43
Croatia	2003		2005		2004	1990		2005	2015		1990	2006			100.00
Czech Republic	2000	2000	2000	2002	2001	1990		1999		2005	1990		2006		82.14
Denmark	1999	1999	1996	1999	1999	1990		2001		2005	1990	1998			100.00
Estonia	2001			1999	2001	1990	2002	2004		2013	1990	2001			100.00
Finland	1999	1995	1996	1995	1995	1990	1995			1997	1990	1998	2016		69.81
France	2006	2000	2002	1999	2000	1990	2000	2004	2012			1990		2010	92.83
Great Britain	1990	1990	1990	1990	1990			1990		1995			1990		0.00
Greece	2002	2001	2005	2001	1999	1990	1999	2002	2012		1990	1999		2015	69.80
Hungary	1995	2002	2003	2002	1994	1990	1992	2003	2012	2005	1990			1999	99.97
Ireland	1999	2000	2007	2000	1999	1990	1993	2001		2005	1990		1999		100.00
Italy	2000	1999	2004	2000	1999	1990	1999	2001		2004		1990	1998	2010	61.47
Latvia	1993				2001	1990	1993	2002		2013	1990	2001	2021		100.00
Lithuania	2001			2003	2000	1990		2002		2013	1990		1997		98.31
Netherlands		1999	1999	1999	1998	1990		1999		1998	1990		2002		100.00
Norway	1991	1991	1991	1991	1991	1990		1992		2002	1990	1993	1997	2007	100.00
Poland	1998	2000	2000	1999	1997	1990	2003	2002		2006	1990			1997	100.00
Portugal	1990	2000	2002	1995	1995	1990	1994	2000		2003	1990	1998		2007	47.89
Romania	2000		1997	2000	2000	1990	2000	2002		2013	1990		2005		78.95
Slovakia	2004	1999	2011	2002	2001	1990		2002		2006	1990		2001		100.00
Slovenia	2001		2001			1990		2002		2005	1990		2001		100.00
Spain	1990	1999	1999	1998	1997	1990	1994	1997		2002		1990	1997	2013	32.72
Sweden		1996	1996	1996	1996	1990		1992		1996	1990		2003		100.00
Switzerland			2006		2001	1990		2007	2013		1990	2001			100.00

Note: PRIV = privatization; TPA = regulated TPA; LWM = Liberalized wholesale market; IRA = Independent regulatory agency; MCT = free choice of supplier; VIU = vertically integrated utility; AU = accounting unbundling; LU = Legal unbundling; ITO = Independent Transmission Operator; OU = ownership unbundling; I = incentive regulation; H = hybrid scheme.

2. Method: Model specification

- To evaluate TSO performance, we focus on three key indicators:
  - Annual growth transmission network capacity (y^T)
  - Unreliability of supply (y^Q)
  - Transmission losses (y^L)

- If we let i and t denote country and time, we obtain the following model:
  - $$y_{i,t} = \alpha_0 + \alpha_s y_{i,t-1} + \Sigma_{k=2}^{K}\beta_1 VS_{i,t-1} + \beta_2 OS_{i,t-1} + \Sigma_{k=2}^{K}\beta_3^k IR_{i,t-1} + \beta_4 R_{i,t-1} + \beta_5 C_{i,t-1}^{I} + \varepsilon_{i,t}$$

- $VS \in \{$VIU, AU, LU, ITO, ISO/OU$\}$
- OS: the percentage of public ownership
- $IR \in \{$C, I, H$\}$
- $R_{i,t}$: the set of additional regulatory indicators (entry liberalization, IRA)
- C: the set of control variables reflecting the main structural differences between countries and political economy variables
- Account for path-dependency: $y_{i,t-1}$
- FE/RE and dynamic panel model

3. Results

Table 1. Regression results

Dependent variable	Annual growth in network length (1990-2018)				Unreliability of supply (2002-2018)				Transmission losses (2010-2018)			
	RE		Dynamic panel		FE		Dynamic panel		RE		Dynamic panel	
Independent variable	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.	Coeff.	Std. err.
L1.y			**-0.095**	0.051			**0.518**	0.189			**0.354**	0.158
VIU	-1.987	1.631	-2.870	1.992								
AU	-0.093	1.541	-0.457	1.698								
ITO	-0.510	1.244	-0.554	1.228	-1.343	1.059	-0.614	0.858				
OU	0.455	0.989	-0.147	1.029	-1.088	1.705	2.375	1.833	**-0.168**	0.065	**-0.686**	0.258
Public ownership	**-2.214**	1.245	**-2.592**	1.282	**-6.926**	3.771	-0.761	1.505	0.268	0.204	**-1.082**	0.399
LWM	-1.000	1.150	-1.190	1.228	0.197	1.814	-2.581	1.636				
MCT	-1.076	1.239	-0.476	1.431								
IRA	0.366	1.344	-0.966	1.548								
Incentive-based scheme	**-1.679**	0.948	-1.447	1.051	-1.832	2.530	-3.085	1.946	**-0.216**	0.087	-0.195	0.218
Hybrid scheme	-0.669	1.031	-1.067	1.095	-2.280	1.690	-0.712	0.693	**-0.200**	0.087	-0.319	0.239
Long-term interest rate	-0.044	0.145	-0.059	0.153	**-0.848**	0.207	-0.193	0.215	**-0.014**	0.007	-0.029	0.021
Electricity consumption	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	**0.000**	0.000	**0.000**	0.000
Primary energy supply	10.875	12.541	6.656	13.954	83.354	49.406	-2.863	14.133	**-3.955**	2.059	**-7.274**	3.546
Import dependency	-1.094	2.334	-1.364	2.371	0.154	4.837	-0.348	1.362	0.399	0.185	**1.366**	0.485
Manufacturing share	0.009	0.088	0.016	0.088	**-0.206**	0.119	0.021	0.057	-0.007	0.008	**-0.031**	0.018
Political orientation												
Left	0.200	0.901	-0.397	0.964	1.172	1.305	1.196	0.972	-0.002	0.043	-0.094	0.181
Right	-0.065	0.897	-0.362	0.935	0.888	1.111	1.166	1.092	-0.038	0.040	**-0.251**	0.138
Herfindahl Gov. Index	-1.144	1.461	0.004	1.508	**5.676**	2.698	2.131	1.868	-0.086	0.123	-0.343	0.360
Gov. stability	-0.074	1.030	-0.533	1.105	0.096	0.762	-1.502	1.091	0.058	0.043	0.082	0.091
Constant	6.977	3.306	7.913	3.599	6.571	8.505	2.632	2.925	**2.095**	0.399	**3.148**	0.747
Observations	411		390		143		117	183			161	
Groups	21		21		13		13		22		22	
AR(2) (Pr > z)			0.381				0.273				0.489	
Sargan test (Pr > chi_2)			0.972				0.052				0.146	

Note: reference level is Legal unbundling (LU) and cost-based scheme. VIU = vertically integrated utility; AU = accounting unbundling; ITO = Independent Transmission Operator; OU = ownership unbundling; LWM = Liberalized wholesale market; IRA = Independent regulatory agency; MCT = free choice of supplier; I = incentive regulation; H = hybrid scheme.

4. Conclusions (preliminary)

Table 2. Results matrix			
	Outcome variable		
Regulatory indicator	Annual growth in network length	Unreliability of supply	Transmission losses
Vertical unbundling	+/-	+/-	-
Public ownership	-	-	-
Entry liberalization	+/-	+/-	+/-
Incentive regulation	-	+/-	-

- **What lessons can be learned for hydrogen market design?**
  - If prioritizing investments in network: private ownership + cost-based regulation
  - If quality and cost-efficiency: VU, public ownership + incentive regulation

- **Caveats:**
  - TSO performance data is scarce, fewer observations on quality and losses
  - Also focus on natural gas markets?

- **Compared to previous literature:**
  - In contrast to Nagayama (2010), Nardi (2012) and Gugler et al. (2013), we find no clear effect of unbundling on investments
  - Vertical unbundling results in less network losses (Nagayama, 2010)
  - Consistent with (Averch and Johnson (1963) and in contrast to Cambini and Rondi (2010), we find more investments under cost-based regulation.
  - In contrast with Nagayama (2010), public ownership results in less network losses

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