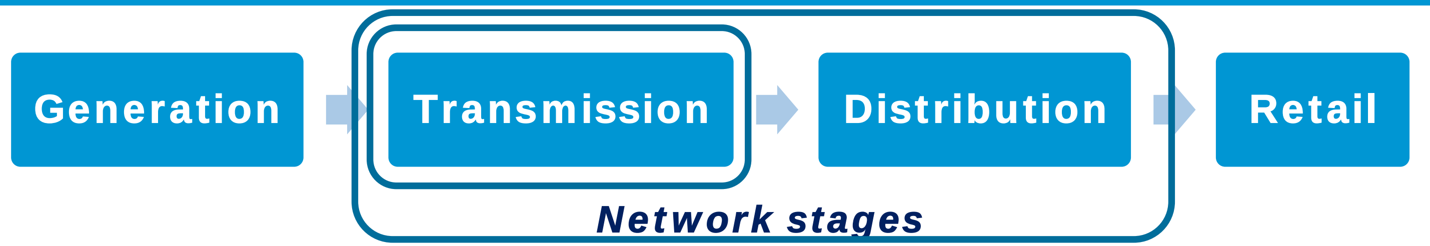
Vertical Disintegration in the European Electricity Sector: Empirical Evidence on Lost Synergies

Klaus Gugler, Mario Liebensteiner*, Stephan Schmitt

*Contact: mario.liebensteiner@wu.ac.at

CGNI Workshop, October 29, 2015

Background on unbundling



- Traditionally: vertically integrated utilities
  - Cost savings due to vertical synergies (e.g. coordination advantages)
- Unbundling of network may foster competition in generation
- EU: Unbundling of transmission grid
  - Each country must choose between: Ownership Unbundling, ISO or ITO (EU directive 2009/72/EC)
    → Ownership unbundling is predominant form
  - Pro: Promotion of competition & prevention of anti-competitive effects
  - Contra: Loss of Economies of Vertical Integration (EVI)
- Study's focus on EVI between **GEN & TRANS**:
  - Greatest cost synergies between G & T → lost with **ownership unbundling**

Sources of EVI

- Concept of **Economies of Vertical Integration (EVI)**:
  - Producing two outputs in one firm is cost beneficial over separate production
- Vertical supply stages are highly interlinked
  - technological interdependency of the operational stages
- Hence, **cost savings** arise from ...
  - ... Coordination advantages
  - ... Efficient planning of investments
  - ... Sharing of information among stages
  - ... Sharing of staff, buildings, software, inputs
  - ... Protection against uncertainty and financial risk
  - ... Coordinating dispatches of utilities according to the actual merit order
- Such cost savings cannot be easily realized by unbundled firms (Jara-Díaz et al., 2004; Meyer, 2012)
- Vertical integration: more efficient organizational form compared to leaving the coordination of the vertical supply to the market (Arocena et al., 2012)

Research question & motivation

- Research question:
  - **How large are the Economies of Vertical Integration (EVI) between generation and transmission?**

- Relevance of topic:
  - Policy debate on unbundling neglects costs of unbundling, especially OU
  - Potential cost savings from vertical integration question transmission ownership unbundling
  - Benefits of increased competition may be (partly) offset by higher costs from transmission unbundling
  - Transmission unbundling has already been put into practice in Europe
  - Regulatory authorities & politicians may rely on ineffective regulatory measures → Important for policy-makers, companies, tax payers, …
  - Need for evidence on Europe

Literature

- Cost synergies between **GEN & TRANS:**
  - Under-researched – Only one study for US (2001-2008, rather small utilities): EVI of 4% at mean (Meyer, 2012, J Regul Econ)
  - **no evidence on Europe** – Why? Data availability (!)
- Cost synergies between GEN & DIST:
  - **US:** Previous studies find substantial cost savings: ~40% at mean (Kwoka, 2002 IJIO; Greer, 2008, Energy Econ)
  - Recently: 8.1% (Arocena, Coelli, Saal, 2012, J Ind Econ), 4.4% (Triebs et al., 2012)
  - **Europe:** Single countries: Modest cost savings
Spain: 6.5% (Budría et al., 2003), Italy: 3% (Fraquelli et al., 2005, J Reg Econ), 6% (Piacenza and Vannoni, 2004, Econ Letters)
- Large disparity among results
  - EVI of 0% to >40% at mean depending on sample, estimation strategy, period, …
- Our study fills a gap in the literature:
  - Focus on transmission ownership unbundling of European utilities

Methodology & estimation strategy

- Economies of vertical integration:

$$C(Y_G,0)+C(0,Y_T)-C(Y_G,Y_T)>0 \longrightarrow EVI=\frac{C(Y_G,0)+C(0,Y_T)-C(Y_G,Y_T)}{C(Y_G,0)+C(0,Y_T)}$$

- Full specification of cost function:

$$C_{it}=\alpha_0+\alpha_G+\alpha_T+\sum_j \beta_j Y_{it}^j+0.5\sum_j\sum_k \beta_{jk} Y_{it}^j Y_{it}^k+\sum_l \gamma_l w_{it}^l+0.5\sum_l\sum_m \gamma_{lm} w_{it}^l w_{it}^m+\sum_j\sum_l \delta_{jl} Y_{it}^j w_{it}^l+\rho' Z_{it}+\varepsilon_{it}$$

Y … Outputs, j={G,T}, i.e. generation, transmission
w … Input prices , l={l, c, f}, i.e. labor, capital, fuel
α_0 *… Joint fixed costs of vertically integrated utility*
α_G *… Fixed costs of stand-alone generation*
α_T *… Fixed costs of stand-alone transmission*
Z … Control variables

EVI exist if $\beta_{GT}<0$

β_{GT} measures the impact of operating at both output stages (Gen & Trans) within one utility on the total costs

Methodology & estimation strategy

- Shepard's Lemma: Estimation of cost function together with input shares to enhance performance

$$\frac{\partial C_{it}}{\partial w_{it}^{l}} = x_l = \gamma_l + \sum_m \gamma_{lm} w_{it}^{m} + \sum_j \delta_{jl} Y_{it}^{j} + \varepsilon_{it}^{l}$$

- Additional standard assumptions:
  - Linear homogeneity in input prices
    - Division of cost function by arbitrarily chosen input price
    - → Non-linear estimation (NLSUR)
  - Symmetry for β, γ, δ parameters
    - Impose restrictions on the model (e.g. $\gamma_{lc} = \gamma_{cl}$)
  - Cost minimization
    - Just assumption, not possible to impose

Data

- 28 European electricity utilities
  - Comprising 16 European countries
  - Sample utilities cover 74% in total load of their respective countries
  - Various organizational forms: Vertically integrated and specialized firms
  - Period 2000–2010, unbalanced panel
  - Total observations: 242

- Sources
  - Annual Reports – output measures for G and T
  - Worldscope & Orbis – financial data (costs & input prices), patents
  - OECD – price of natural gas
  - Platts PowerVision – capacities by fuel source
  - Eurostat – countries' shares of RES production

Descriptive Evidence

Table 1. Sample statistics

Description	Variable	Obs.	Mean	S.D.	Min.	Max.
TOTEX excl. purchased power (bnEUR)	C	242	7.36	11.88	0.12	57.90
Generation (TWh)	Y_G	242	74.80	136.85	0.00	669.00
Transmission (tKm)	Y_T	242	9.80	21.65	0.00	100.69
Price of labor (tEUR/empl.)	w_L	242	57.69	21.53	12.07	141.01
Price of natural gas (tEUR/GWh)	w_F	242	26.03	8.55	9.75	44.78
Price of capital (%)	w_C	242	7.05	3.77	0.68	30.32
Hydro Capacity (%)	hyd	242	28.28	26.63	0.00	100.00
Nuclear Capacity (%)	nuc	242	11.77	17.10	0.00	61.46
Binary indicator: generation only	α_G	242	0.43	0.50	0.00	1.00
Binary indicator: transmission only	α_T	242	0.12	0.33	0.00	1.00
Binary indicator: registered patents	$d\_patents$	242	0.44	0.50	0.00	1.00
Yearly time trend	$trend$	242	5.74	3.01	0.00	10.00
Concentration index: 1-HHI	$1 - HHI$	242	0.97	0.04	0.69	0.99
Share of renewable energy supply	$rnwbl$	224	0.11	0.10	0.01	0.46

Notes: Obs. is observations, S.D. is standard deviation, Min. is minimum, Max. is maximum, tEUR is thousand EUR, bnEUR is billion (10^9) EUR, tKM is thousand Km, TWh is thousand GWh.

Table A1. Electricity utilities in the sample

utility	Country	Obs.	Period	Organizational structure
A2A	Italy	7	2004-2010	G
Acea	Italy	11	2000-2010	G&T until 2005, then G
BKW	Switzerland	11	2000-2010	G&T
CEZ Group	Czech Rep.	11	2000-2010	G&T until 2002, then G
Drax Group	United Kingdom	8	2003-2010	G
EDF	France	11	2000-2010	G&T
EDP	Portugal	10	2001-2010	G&T
ENBW	Germany	10	2001-2010	G&T
EVN	Austria	11	2000-2010	G
Endesa	Spain	11	2000-2010	G
Enea	Poland	3	2008-2010	G
Enel	Italy	6	2005-2010	G
Energiedienst	Switzerland	7	2004-2010	G&T
Fortum	Finland	10	2001-2010	G
IREN	Italy	11	2000-2010	G&T
Iberdrola	Spain	9	2002-2010	G
Latvenergo	Latvia	5	2006-2010	G&T
Magyar Villamos	Hungary	7	2003-2010	G&T
National Grid	United Kingdom	11	2000-2010	T
PGE Polska Grupa	Poland	3	2008-2010	G
Public Power Corp.	Greece	11	2000-2010	G&T
RWE	Germany	11	2000-2010	G&T
Red Electrica	Spain	8	2003-2010	T
Statkraft	Norway	5	2006-2010	G
Terna	Italy	10	2001-2010	T
Vattenfall	Sweden	10	2001-2010	G&T until 2009, then G
Verbund	Austria	11	2000-2010	G&T
Wiener Stadtwerke	Austria	3	2008-2010	G
Total		*242*		

Notes: Obs. Is observations; G&T represents an integrated utility, G is stand-alone generation, T is stand-alone transmission.

Data issues

- Dependent Variable: Total costs minus purchased electricity
  - Avoids double-counting of purchased electricity
  - Purchased electricity difficult to measure
- Multi-product firms (e.g. electricity & gas)
  - Data at firm level – not product level
  - → Study's focus on electricity
  - Financial variables adjusted by *share of revenues from electricity*
    Information from Worldscope / Orbis / annual reports / other company infos
- Outputs measured at European level
  - Firm level data – incl. overseas operations (few firms)
  - → Study's focus on Europe
  - Financial variables adjusted by *share of revenues generated within Europe*

Table 2. Non-linear regression (NLSUR) estimates of the cost function

	(i) Basic model			(ii) Time FE			(iii) Country FE			(iv) Time & Country FE		
α_0	0.5852	(0.003)	***	0.9311	(0.002)	***	1.0088	(0.022)	**	0.8026	(0.109)	
α_G	-0.1055	(0.591)		0.0385	(0.856)		-0.2736	(0.127)		-0.0071	(0.977)	
α_T	2.2536	(0.000)	***	2.2903	(0.000)	***	3.3830	(0.000)	***	3.2382	(0.000)	***
β_G	0.0351	(0.000)	***	0.0333	(0.000)	***	0.0596	(0.000)	***	0.0585	(0.000)	***
β_T	-0.1502	(0.000)	***	-0.1427	(0.000)	***	-0.1318	(0.001)	***	-0.1066	(0.011)	**
β_{GG}	0.0001	(0.070)	*	0.0002	(0.032)	**	0.0000	(0.926)		0.0000	(0.974)	
β_{TT}	0.0041	(0.001)	***	0.0038	(0.001)	***	0.0021	(0.064)	*	0.0014	(0.219)	
β_{GT}	-0.0006	(0.008)	***	-0.0007	(0.003)	***	-0.0007	(0.078)	*	-0.0008	(0.054)	*
γ_l	0.1789	(0.000)	***	0.1858	(0.000)	***	0.1679	(0.000)	***	0.1760	(0.000)	***
γ_c	0.3116	(0.000)	***	0.3230	(0.000)	***	0.3092	(0.000)	***	0.3189	(0.000)	***
γ_{ll}	-0.0078	(0.359)		-0.0110	(0.212)		-0.0045	(0.592)		-0.0085	(0.334)	
γ_{cc}	-0.1309	(0.000)	***	-0.1308	(0.000)	***	-0.1407	(0.000)	***	-0.1354	(0.000)	***
γ_{lc}	-0.0161	(0.001)	***	-0.0211	(0.000)	***	-0.0140	(0.007)	**	-0.0191	(0.000)	***
δ_{Gl}	0.0000	(0.745)		0.0000	(0.757)		0.0000	(0.630)		0.0000	(0.598)	
δ_{Gc}	-0.0007	(0.000)	***	-0.0007	(0.000)	***	-0.0006	(0.000)	***	-0.0006	(0.000)	***
δ_{Tl}	0.0006	(0.153)		0.0006	(0.161)		0.0006	(0.138)		0.0005	(0.152)	
δ_{Tc}	0.0042	(0.000)	***	0.0042	(0.000)	***	0.0041	(0.000)	***	0.0042	(0.000)	***
hyd	-0.0080	(0.002)	***	-0.0067	(0.016)	**	-0.0147	(0.037)	**	-0.0100	(0.182)	
nuc	-0.0063	(0.213)		-0.0053	(0.304)		0.0260	(0.189)		0.0252	(0.194)	
Time FE	no			yes			no			yes		
Country FE	no			no			yes			yes		
Obs.	242			242			242			242		
Overall R^2	0.883			0.891			0.928			0.936		

*Notes: Dependent variable is total expenditures excluding purchased power; Robust p-values in parentheses; ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.*

***Recall:* EVI exist if $\beta_{GT} < 0$**

Magnitude of Economies of Vertical Integration

Table 3. Magnitude of economies of vertical integration (EVI)

Generation	Transmission GWh \ Km	50th %ile: 658		60th %ile: 3,657		70th %ile: 6,713		80th %ile: 11,000		90th %ile: 33,580
20th %ile:	2,569	17.7%	***	20.5%	***	23.9%	***	30.0%	***	
30th %ile:	6,503	17.0%	***	19.8%	***	23.2%	***	29.3%	***	
40th %ile:	12,869	16.0%	***	18.8%	***	22.2%	***	28.2%	***	
50th %ile:	29,885	13.8%	***	16.6%	***	20.0%	***	25.8%	***	
60th %ile:	52,100	11.6%	***	14.5%	***	17.9%	***	23.5%	***	
70th %ile:	62,126	10.8%	***	13.7%	***	17.1%	***	22.7%	***	
80th %ile:	90,785	8.9%	***	11.9%	***	15.3%	***	20.7%	***	
90th %ile:	179,000									

*Notes: Calculation of EVI is based on parameter estimates from Model i. ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively. Values below the 20th percentile of generation and 50th percentile of transmission are not reported because outputs have values of zero. Cells in grey indicate output combinations at equal percentiles.*

Magnitude of EVI

- Median firm obtains cost savings of around 14%
- **Substantial cost savings** from vertical integration between GEN & TRANS at higher output levels
  → Higher cost synergies for large operators (even 20% seem plausible)
- Very large output combinations (90^{th} %ile) should be viewed with caution:
  - Quadratic cost function = Taylor approximation of unknown true function
  - Hence, estimates are not reliable at corners
  - Only one utility (i.e. EDF) exists in this scope
- Non-linear significance test of EVIs based on Delta-method (large N)
  - → Additional linear test:
  - Linear test of $\beta_{GT}Y_GY_T<0$ yields robust significance levels
- Robustness: Similar magnitude and significance levels of EVI from other specifications
  - Time and country fixed-effects / linear SUR / reduced sample from earlier version

Sources of EVI

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

- We investigate two potential sources of EVI:
  - Presence of **asset specificity**
  - Coordination requirements from high **market complexity**
- Inclusion of output interaction term multiplied by additional variable of interest: $\theta * Y_G Y_T X$
  - *X* captures either asset specificity or market complexity
    - **Patents** as proxy for technological intensity (e.g. Acemoglu et al., 2010)
    - **Time trend** may capture increased complexity over time
    - Share of countries' **renewable energy**
    - **concentration of power plants** (1-HHI)

$$HHI = \sum_{p=1}^{N} {a_p}^2, \ a_p = \frac{capacity_p}{\sum_{q=1}^{N} capacity_q}$$

Theory: *negative and significant θ → vertical integration is cost-beneficial compared to stand-alone operations in order to deal with either asset specificity or market complexity.*

EFMD EQUIS ACCREDITED

Table 4. Non-linear regression (NLSUR) estimates of the cost function including a double interaction term

	(i) d_patents			(ii) trend			(iv) rnwbl			(iii) (1-HHI)		
α_0	0.5609	(0.004)	***	0.8214	(0.000)	***	0.7674	(0.000)	***	0.7940	(0.000)	***
α_G	-0.0184	(0.930)		-0.3022	(0.099)	*	-0.6082	(0.001)	***	-0.2780	(0.132)	
α_T	3.0887	(0.000)	***	2.5536	(0.000)	***	2.8827	(0.000)	***	2.5771	(0.000)	***
β_G	0.0303	(0.000)	***	0.0402	(0.000)	***	0.0517	(0.000)	***	0.0392	(0.000)	***
β_T	-0.1931	(0.000)	***	-0.1770	(0.000)	***	-0.1998	(0.000)	***	-0.1758	(0.000)	***
β_{GG}	0.0002	(0.015)	**	0.0001	(0.259)		-0.0000	(0.708)		0.0001	(0.156)	
β_{TT}	0.0053	(0.001)	***	0.0051	(0.000)	***	0.0057	(0.000)	***	0.0050	(0.000)	***
β_{GT}	0.0026	(0.003)	***	-0.0004	(0.067)	*	0.0001	(0.659)		0.0134	(0.030)	**
θ	-0.0034	(0.001)	***	-9.94E-06	(0.020)	**	-0.0057	(0.001)	***	-0.0142	(0.024)	**
γ_l	0.1693	(0.000)	***	0.1703	(0.000)	***	0.1674	(0.000)	***	0.1699	(0.000)	***
γ_c	0.2715	(0.000)	***	0.2742	(0.000)	***	0.2950	(0.000)	***	0.2729	(0.000)	***
γ_{ll}	-0.1044	(0.164)		-0.1089	(0.147)		-0.1071	(0.178)		-0.1076	(0.152)	
γ_{cc}	-1.2488	(0.027)	**	-1.2398	(0.029)	**	-1.5730	(0.008)	***	-1.2384	(0.029)	**
γ_{lc}	-0.1598	(0.192)		-0.1840	(0.129)		-0.1958	(0.116)		-0.1736	(0.152)	
δ_{Gl}	-0.0000	(0.464)		-0.0000	(0.453)		-0.0000	(0.530)		-0.0000	(0.457)	
δ_{Gc}	-0.0007	(0.000)	***	-0.0007	(0.000)	***	-0.0007	(0.000)	***	-0.0007	(0.000)	***
δ_{Tl}	0.0007	(0.066)	*	0.0007	(0.066)	*	0.0007	(0.060)	*	0.0007	(0.066)	*
δ_{Tc}	0.0043	(0.000)	***	0.0044	(0.000)	***	0.0043	(0.000)	***	0.0043	(0.000)	***
hyd	-0.0052	(0.062)	*	-0.0069	(0.011)	**	-0.0043	(0.299)		-0.0068	(0.010)	***
nuc	0.0031	(0.618)		-0.0081	(0.157)		-0.0126	(0.022)	**	-0.0079	(0.170)	
Obs.	242			242			224			242		
Overall R2	0.887			0.887			0.894			0.889		

*Notes: Dependent variable is total expenditures excluding purchased power; Robust p-values in parentheses; ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.*

Indication for vast potential for cost savings from vertical integration in the presence of either asset specificity or market complexity.

Conclusions

- Empirical findings:
  - Economies of vertical integration (EVI) ≈14%
  - Unbundling comes at a cost: (full) loss of EVI
  - Non-negligible hurdle for successful unbundling regime
- Policy implications:
  - Findings put practical application of transmission unbundling in Europe into perspective
  - Policies allowing for internalization of externalities from asset specificity and/or market complexity are desirable
  - Institutions to meet coordination needs / Policies for lowering hold-up risk of sunk costs
- Study's limitations:
  - Data requirements – first attempt to provide evidence on Europe
  - Static focus: Dynamic aspects of ownership unbundling not part of analysis
  - Limited sample: transmission companies are underrepresented