Interdependencies Between Countries in the Provision of Energy

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Motivation

A current challenge: *Granting the security of supply* in the provision of electricity while *decarbonizing the energy system*.

The coal-fuelled Cottam power station generates electricity in November 2009 in Nottinghamshire. The plant closed this week after 50 years © Getty

The Big Read Coal + Add to myFT

How Britain ended its coal addiction

The shift in the UK is an important victory for environmentalists in their fight against fossil fuels

Nathalie Thomas in Edinburgh, **Leslie Hook** in the Vale of Glamorgan and **Chris Tighe** in Newcastle OCTOBER 1 2019

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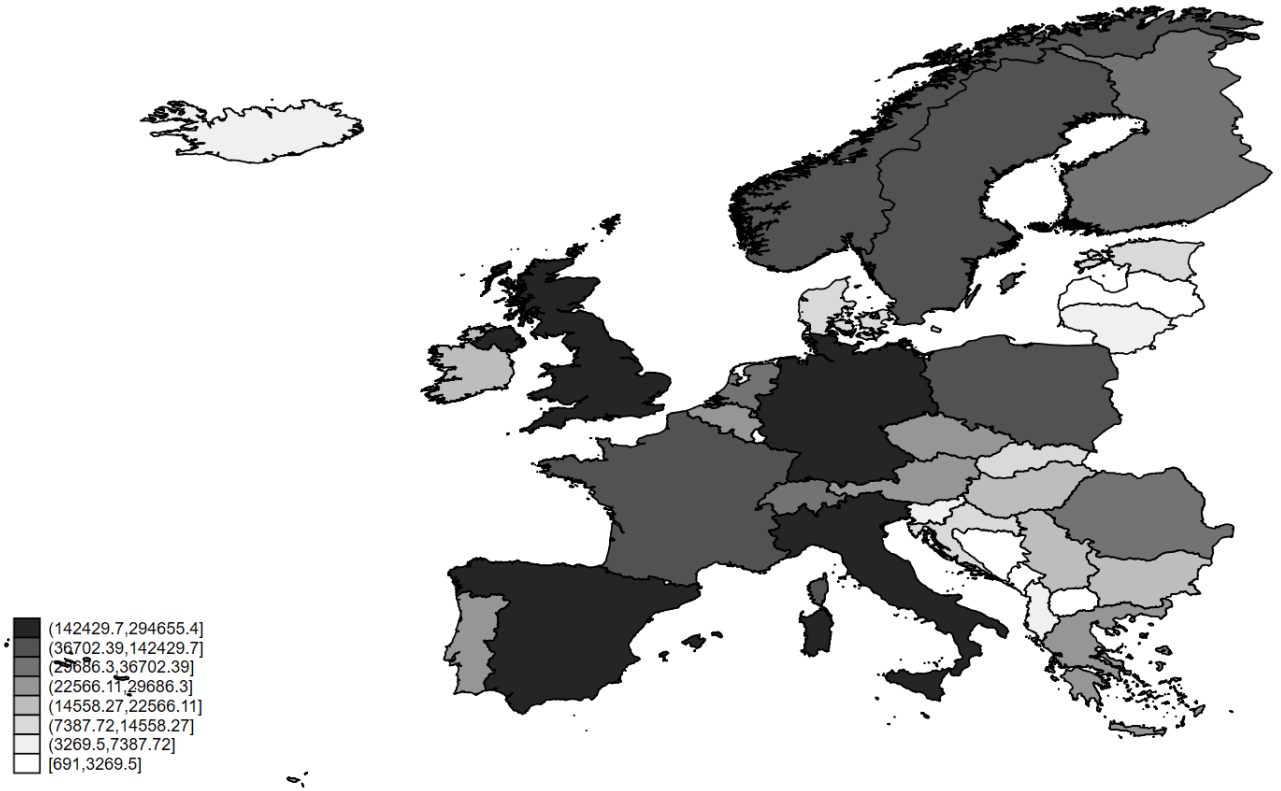
Yet even when Britain quits coal power generation, heavy industry will still need the fossil fuel to manufacture products including steel and cement. The majority of that demand is met from imports. In the first three months of 2019, the UK imported 2.6m tonnes of coal; the biggest single source was Russia. Indigenous production was just 592,000 tonnes.

FINANCIAL TIMES

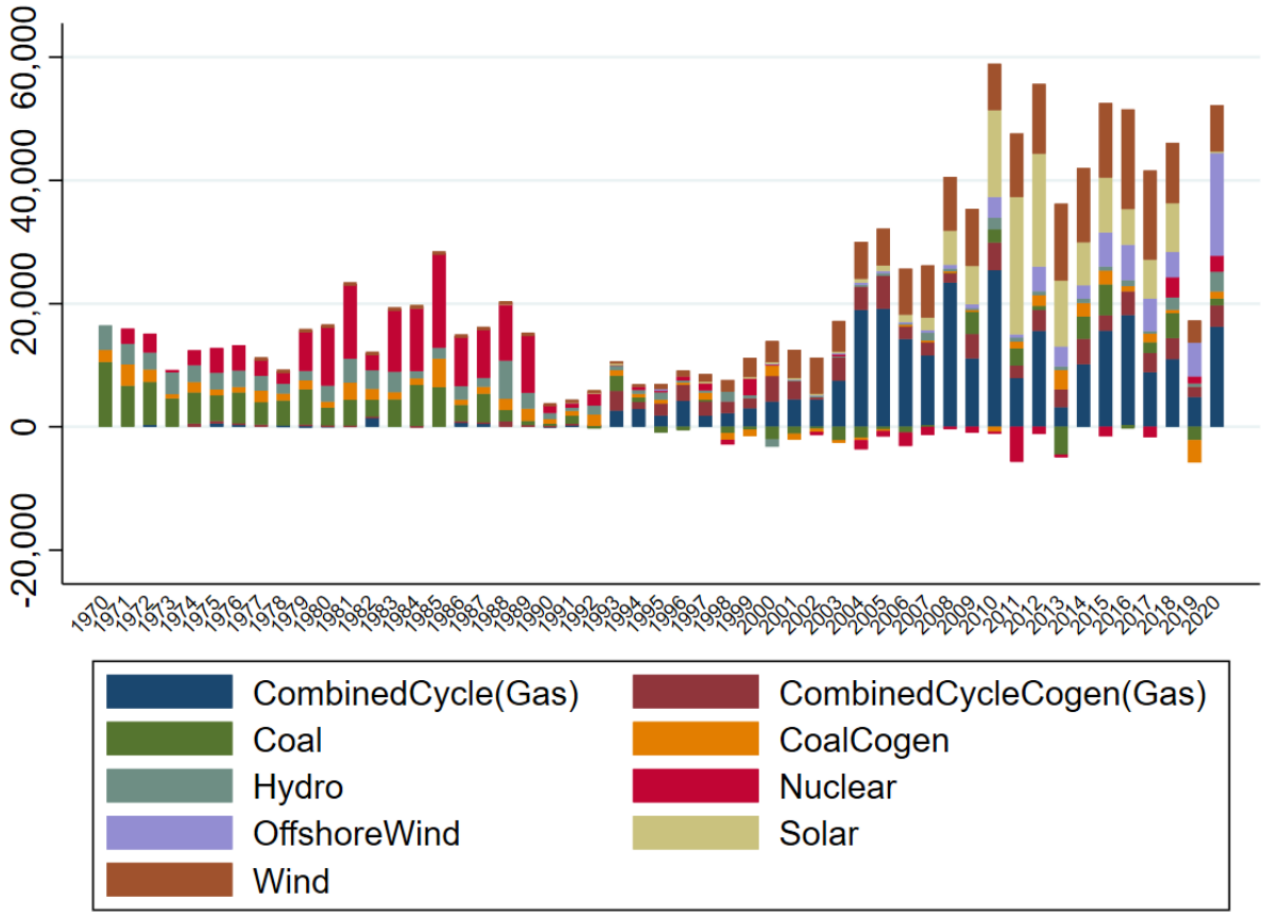
Source: Financial Times, October 1, 2019, https://www.ft.com/content/a05d1dd4-dddd-11e9-9743-db5a370481bc

Electricity production capacities in European countries (in MW)



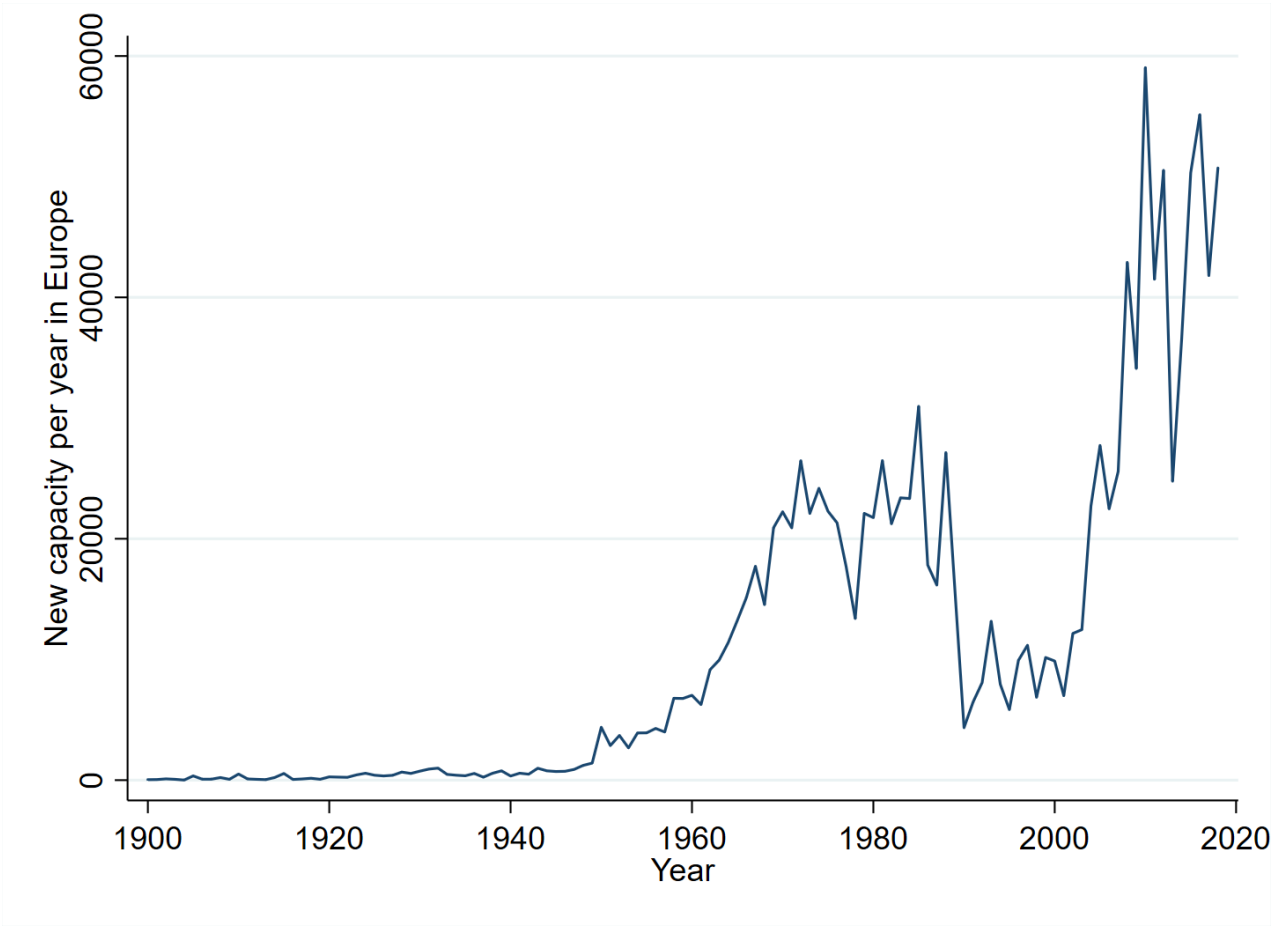
Own illustration using data from Standard&Poor's Power Plant Database. The map depicts the overall invested capacity in these European countries in MW.

New capacities by fuel type between 1970 and 2020



Own illustration using data from Standard&Poor's Power Plant Database. The figure shows the new capacities by fuel type between 1990 and 2020 in Europe in MW

Additional energy capacities by year in Europe (in MW)



Own illustration using data from Standard&Poor's Power Plant Database. The figure graphs the additional energy capacities by year in MW.

Research questions

- Do there exist interdependencies between economies in the provision of energy?
- Are countries substituting domestic energy production using fossil resources with energy imports based on fossil resources?

Literature

Spillover models

- Brueckner (2003)
- Murdoch and Sandler (1984) (defense spending); Murdoch and Sandler (1997) (environmental regulation); Solé-Ollé (2006) (governmental spending)

Investment decisions in energy capacities

- Tietjen, Pahle and Fuss (2016); European Commission (2015)
- Joskow (2019); Joskow and Tirole (2007)

Carbon leakage effect

- Carbone and Rivers (2017); Dechezleprêtre and Sato (2017), Aichele and Felbermayr (2015)
- EU ETS: Koch and Basse Mama (2016); Naegele and Zaklan (2019)

Empirical analysis - Spatial interdependencies in capacity investments

Hypothesis

Investment in electric power plants in jurisdiction i in year t also depends on the investment decision of neighboring countries, as well as on domestic factors.

Estimator

Spatial econometric analysis, more specifically, the Spatial Durbin Model (SDM).

Empirical analysis - Energy production and import patterns

Hypothesis

Countries substitute domestic fossil energy production with energy imports based on fossil raw materials.

Estimator

Fixed effects and instrumental variable estimators.

Empirical analysis - Event study

Event

Implementation of the EU ETS in 2003.

Idea

Introduction of emission trading with fixed caps has led to stricter requirements and higher costs for the EU electricity supply sector, making domestic fossil energy production less attractive compared to imports.

Data

- Standard&Poor's Power Plant Database: Data on new power plant capacities for 17 European economies, 1978-2017.
- IEA: energy imports and exports, final consumption, population, GDP.
- Eurostat: Number of heating and cooling degree days.
- BP Statistical Review of World Energy: Data on oil-, coal- and natural gas-reserves.

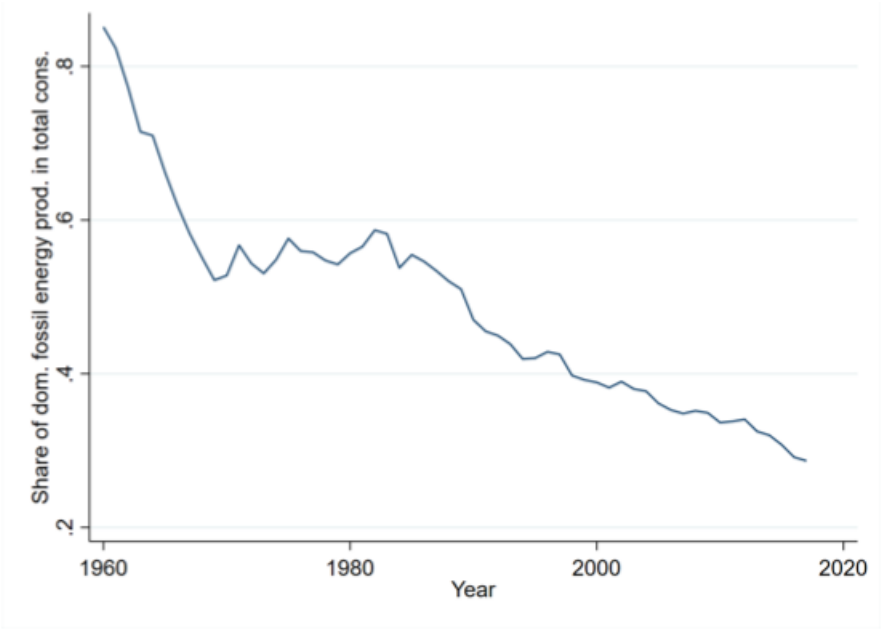
Results - Spatial interdependencies in capacity investments

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GDP (in USD ppp) per capita	0.005	0.255	-0.012	0.135	0.010	0.013	-0.006	0.002
	(0.01)	(0.17)	(0.01)	(0.19)	(0.01)	(0.02)	(0.01)	(0.01)
Electricity imports	0.003	-0.015*	0.005	-0.021***	-0.004	-0.003	0.001	-0.006**
	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
Electricity exports	0.001	0.014*	0.003	0.006	0.015*	0.013	0.020***	0.019***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Delta electricity final cons.	0.011*	0.007	0.010	0.008	0.011*	0.012**	0.009	0.005
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Electricity price	-0.090	-22.887***	-0.064	-0.453	0.653	0.380	0.201	-6.008
	(2.53)	(5.97)	(2.44)	(13.97)	(2.24)	(2.31)	(1.14)	(6.19)
Interest rate	0.157	-643.012***	-19.712	-693.693***	-38.777	-33.545	-7.490	3.131
	(30.77)	(183.29)	(30.09)	(157.65)	(42.32)	(41.47)	(17.98)	(15.05)
Price volatility		-98.399***		-96.210***				
		(30.11)		(29.12)				
GDP (in USD ppp) per capita	-0.058	-0.608	-0.120**	-1.255**	0.150	0.206	0.014	-0.062
	(0.04)	(0.43)	(0.05)	(0.61)	(0.13)	(0.15)	(0.06)	(0.05)
Electricity imports	0.004	-0.050	0.046	-0.067	0.014	0.001	0.012	-0.006
	(0.02)	(0.03)	(0.04)	(0.05)	(0.03)	(0.04)	(0.04)	(0.01)
Electricity exports	0.009	0.011	0.043	-0.051	0.014	0.019	0.022	-0.013
	(0.01)	(0.04)	(0.04)	(0.04)	(0.01)	(0.02)	(0.02)	(0.01)
Delta electricity final cons.	-0.012	0.006	-0.016	-0.002	-0.005	-0.003	-0.009	0.000
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Electricity price	5.389	-13.580	-2.742	-4.924	-5.145	-0.466	5.737	-5.331
	(6.81)	(31.38)	(5.12)	(43.32)	(9.12)	(3.57)	(4.54)	(9.85)
Interest rate	-180.874	-1145.565***	-441.497**	-1318.425	-377.248	-271.278	-136.883	-71.791
	(154.00)	(424.67)	(224.63)	(887.32)	(249.19)	(262.55)	(146.81)	(114.78)
Price volatility		-27.843		-194.459*				
		(73.26)		(109.46)				
Rho	-0.483***	-0.201	-1.039***	-0.723**	-0.260**	-0.363**	-0.615***	-0.572***
	(0.14)	(0.23)	(0.27)	(0.36)	(0.11)	(0.14)	(0.15)	(0.14)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of countries	17	9	17	9	17	17	17	17
Number of years	40	13	40	13	40	40	29	25
N Obs	680	117	680	117	680	680	493	425
R^2	0.086	0.418	0.007	0.070	0.013	0.134	0.015	0.071

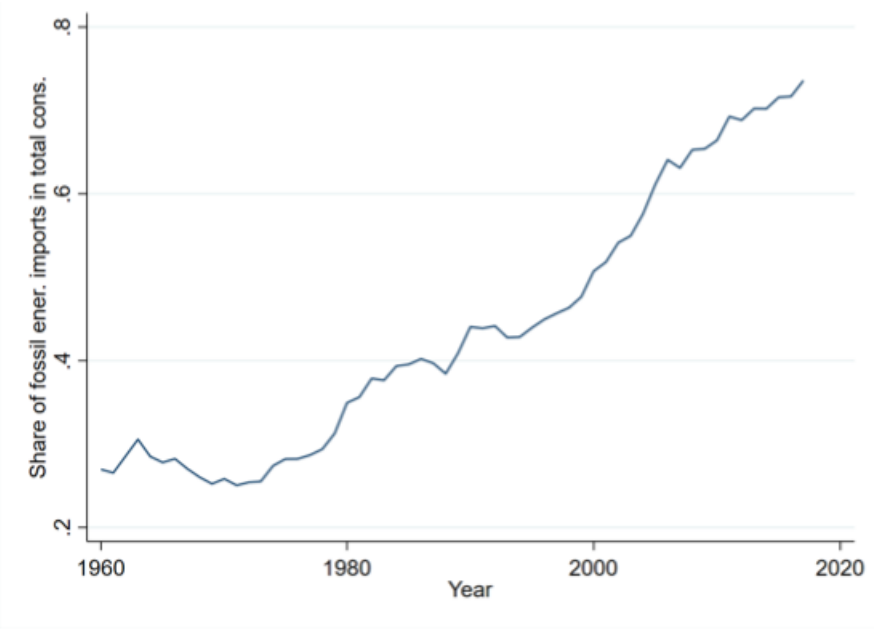
Note: Columns (1) and (2) report the results using the contiguity matrix and columns (3) and (4) using the inverse distance matrix. Column (5) reports the results using the matrix with information on the number of bilateral transmission lines, in column (6) the weighting matrix accounts for information on the total bilateral electricity transmission capacity. Columns (7) and (8) report results for the years before 2007 and 2003, respectively, using the matrix with information on the total bilateral transmission capacity. The dependent variable is the new electricity capacity invested in country i in year t in MW. Clustered standard errors in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Fossil energy production and imports as a share of total energy consumption between 1960 and 2019

Production



Imports



Source: Own illustration using data from the IEA World Energy Balances database.

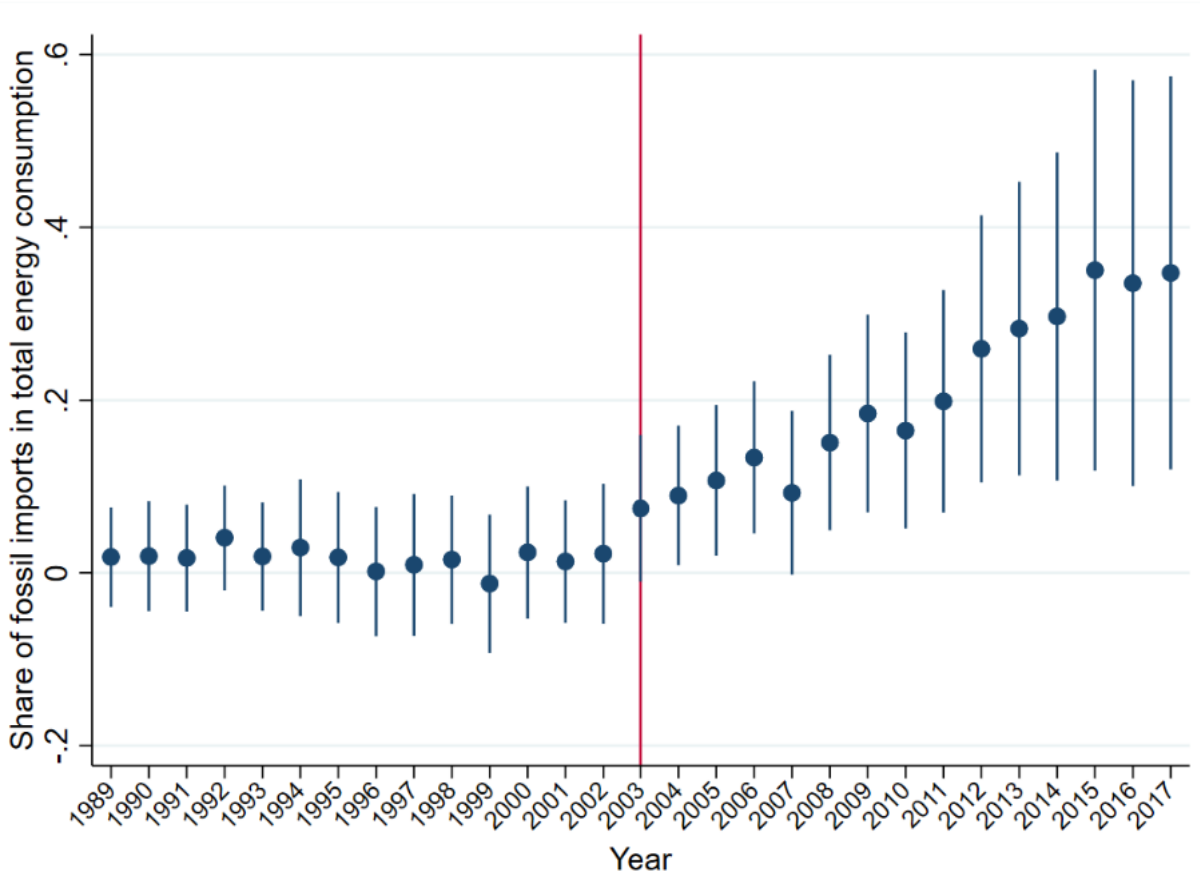
Fossil energy domestic production and imports

Variables	(1)	(2)	(3)	(4)
Share of domestic fossil energy production in total final cons.	-0.080**	-0.983***	-0.075***	-0.992***
	(0.03)	(0.01)	(0.01)	(0.01)
Share of domestic renewable energy production in total final cons.	-1.036	-0.908	-0.980***	-0.988***
	(0.63)	(0.64)	(0.15)	(0.15)
Share of domestic nuclear energy production in total final cons.	-0.711*	-0.622*	-0.891***	-0.733***
	(0.37)	(0.34)	(0.16)	(0.15)
Number of heating degree days	-0.000	-0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Number of cooling degree days	0.001	0.001	0.001***	0.001**
	(0.00)	(0.00)	(0.00)	(0.00)
GDP in USD ppp	-0.000	-0.000	0.000	-0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
Population	-0.013	-0.005	-0.018***	-0.008*
	(0.01)	(0.01)	(0.01)	(0.00)
Ratio of industrial energy consumption to total energy cons.	1.545*	1.321	1.487***	1.437***
	(0.90)	(0.92)	(0.24)	(0.24)
Ratio of residential energy consumption to total energy cons.	0.632	0.291	0.661**	0.129
	(0.52)	(0.42)	(0.30)	(0.27)
Share of fossil energy in overall energy cons.	-0.632	-1.143	-0.942**	-1.479***
	(1.05)	(0.97)	(0.41)	(0.41)
Constant	1.538	2.289**		
	(0.95)	(0.88)		
Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Number of countries	25	25	25	25
Number of years	43	43	43	43
N Obs	1,029	1,029	903	903
R^2	0.304	0.891	0.302	0.835
Cragg Donald Wald F stat.			630.8	630.8
Hansen J stat. overid.			40	18.15
Chisq P-val endog.test			0.53	0.51

Note: Columns (1) and (2) report the results of fixed effects estimations and columns (3) and (4) the second stage results of the IV estimations. The dependent variable is the share of fossil energy imports in total energy consumption in columns (1) and (3) and the share of net imports (imports-exports) in total energy consumption in columns (2) and (4). The number of observations in specifications (3) and (4) is smaller since we do not have information on coal, gas or oil reserves for all countries in the data set. Clustered standard errors for columns (1) and (2) and robust standard errors for regressions (3) and (4). *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Event study - Regression results

Share of fossil energy imports in total energy consumption before and after introduction of EU ETS



Conclusion

- Nuclear phase-out and coal plant shutdown raise concerns about the security of electricity supply.
- Pressure to decarbonize economies and CO_2 emission reduction targets $\Rightarrow$ expansion of renewables $\Rightarrow$ low and volatile electricity prices $\Rightarrow$ low return on investment in domestic power generation capacity.
- Our results show a negative relationship between investments in new electricity generation capacity between neighboring countries.
- Countries partially substitute domestic fossil energy production with fossil energy imports.
- Questions self-praise of countries regarding carbon-free domestic electricity generation.
- Economic policy implication: tax on fossil-based energy imports.

Backup

Summary statistics I

	N Obs	Mean	Std Dev	5th Perc	Median	95th Perc
New Capacity (in MW)	680	822.81	1,641.7	-322.6	300.5	4,261.05
GDP (in USD ppp) per capita	680	35,109.5	12,953.5	19,085.3	33,143	58,715.4
Electricity imports (in TJ)	680	44,456.8	43,209.9	1,087	29,401	145,860
Electricity exports (in TJ)	680	-41,773.5	60,955.4	-209,387	-17,251	-63
Delta electricity final cons. (in TJ)	680	6,395.01	17,279.3	-12,096	3,918.5	37,190
Electricity price (in USD p. MWh)	680	79.72	40.16	34.84	75.47	138.41
Interest rate	680	7	4.47	.94	5.71	15.7

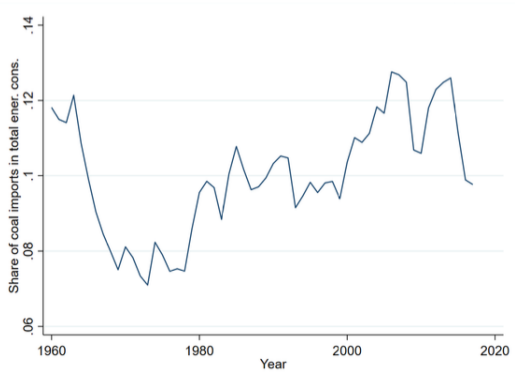
Summary statistics II

	N Obs	Mean	Std Dev	5th Perc	Median	95th Perc
Fossil imports/Total ener. cons.	903	1.11	.78	.31	.97	2.26
(Fossil imp-exp)/Total ener. cons.	903	.57	1.74	-.27	.79	1.32
Domestic fossil ener. prod./Total ener. cons.	903	.65	1.56	0	.18	1.65
Renewable ener. prod./Total ener. cons.	903	.2	.28	0	.1	.63
Nuclear ener. prod./Total ener. cons.	903	.13	.18	0	.02	.53
Fossil ener. cons./Total ener. cons.	903	.67	.14	.39	.69	.85
Nb. cooling days	903	87.88247	147.904	0	14.33	447.83
Nb. heating days	903	3,109.21	1,356.49	768.88	3,022.16	5,671.74
Industry ener.cons./Total ener. cons.	903	.2849126	.1080933	.1385905	.271814	.5031729
Residential ener.cons./Total ener. cons.	903	.2413329	.0638016	.1419569	.2391527	.3383448

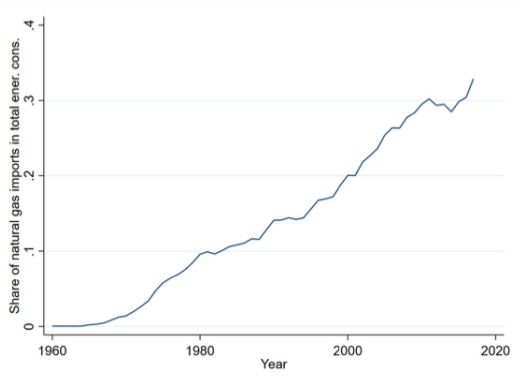
Sources: IEA World Energy Balances; S&P Power Plant Database

Backup: Fossil energy imports (divided by types) as a share of total energy consumption between 1960 and 2019

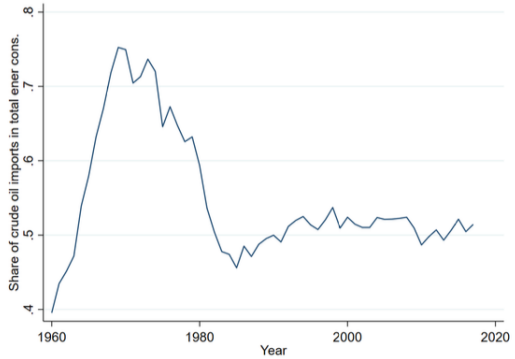
Coal



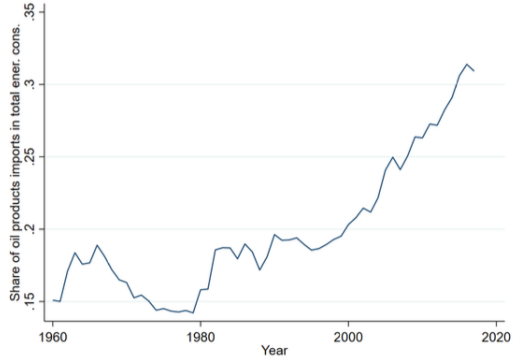
Natural gas



Crude oil, liquid gas



Oil products



Source: Own illustration using data from the IEA World Energy Balances database.

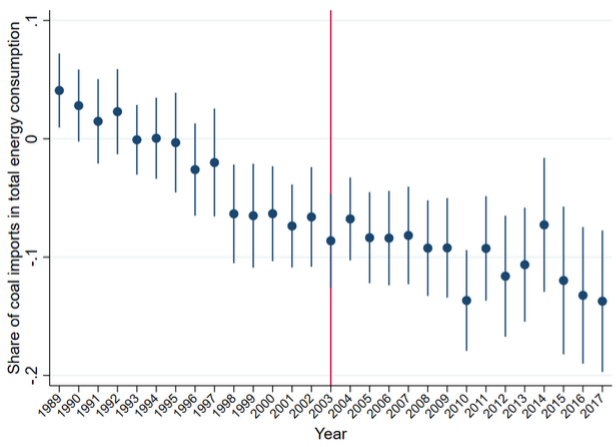
Backup: Fossil energy domestic production (divided by types) and imports

Variables	(1)	(2)	(3)
Share of domestic coal energy production in total final consumption	-0.214**		
	(0.10)		
Share of domestic natural gas energy production in total final consumption		-0.060***	
		(0.02)	
Share of domestic crude oil energy production in total final consumption			-0.033***
			(0.01)
Share of domestic renewable energy production in total final consumption	0.062	-0.146**	0.059
	(0.08)	(0.06)	(0.05)
Share of domestic nuclear energy production in total final consumption	-0.027	-0.147*	-0.022
	(0.11)	(0.08)	(0.16)
Number of heating degree days	0.000	0.000	-0.000
	(0.00)	(0.00)	(0.00)
Number of cooling degree days	-0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)
GDP in USD ppp	0.000**	0.000	0.000
	(0.00)	(0.00)	(0.00)
Population	-0.005	0.014*	-0.020***
	(0.01)	(0.01)	(0.01)
Ratio of industrial energy consumption to total energy consumption	0.357	-0.036	0.077
	(0.41)	(0.11)	(0.13)
Ratio of residential energy consumption to total energy consumption	0.245	0.063	-0.013
	(0.30)	(0.13)	(0.21)
Share of fossil energy in overall energy consumption	-0.056	-0.088	0.193
	(0.16)	(0.21)	(0.32)
Constant	0.029	-0.061	0.660**
	(0.19)	(0.21)	(0.32)
Year FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Number of countries	25	25	25
Number of years	43	43	43
N Obs	1,029	1,051	1,051
R^2	0.262	0.616	0.288

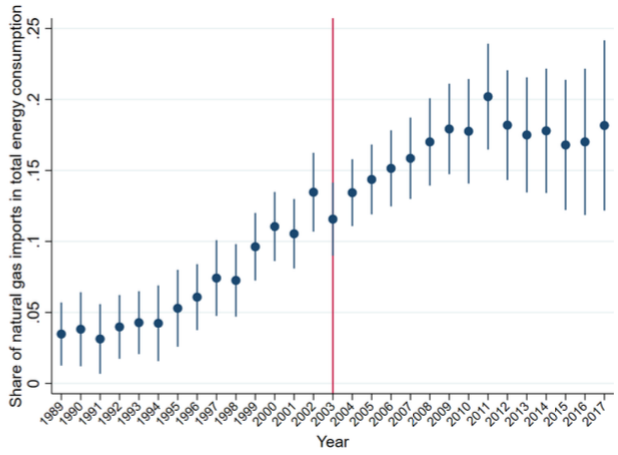
Note: Column (1)-(3) reports the results of alternative specifications of column (1) in Table 4. The dependent variable is the share of coal imports (column (1)), natural gas imports (column (2)) or crude oil imports (column(3)) in total energy consumption. Clustered standard errors in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Backup: Event study - Regression results by fuel types

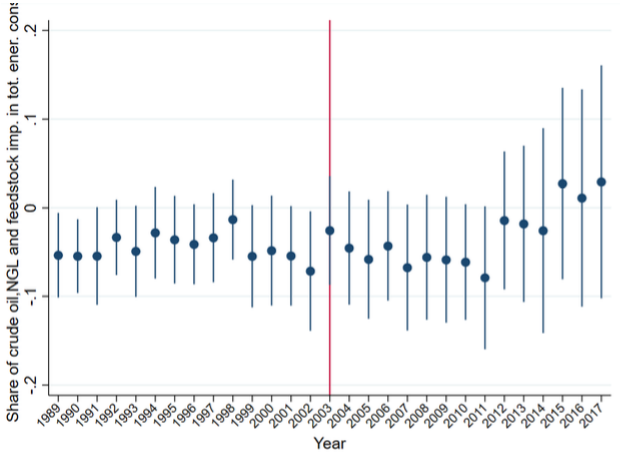
Coal



Natural gas



Crude oil, liquid gas



Oil products