Energy Endowments and the Location of Manufacturing Firms

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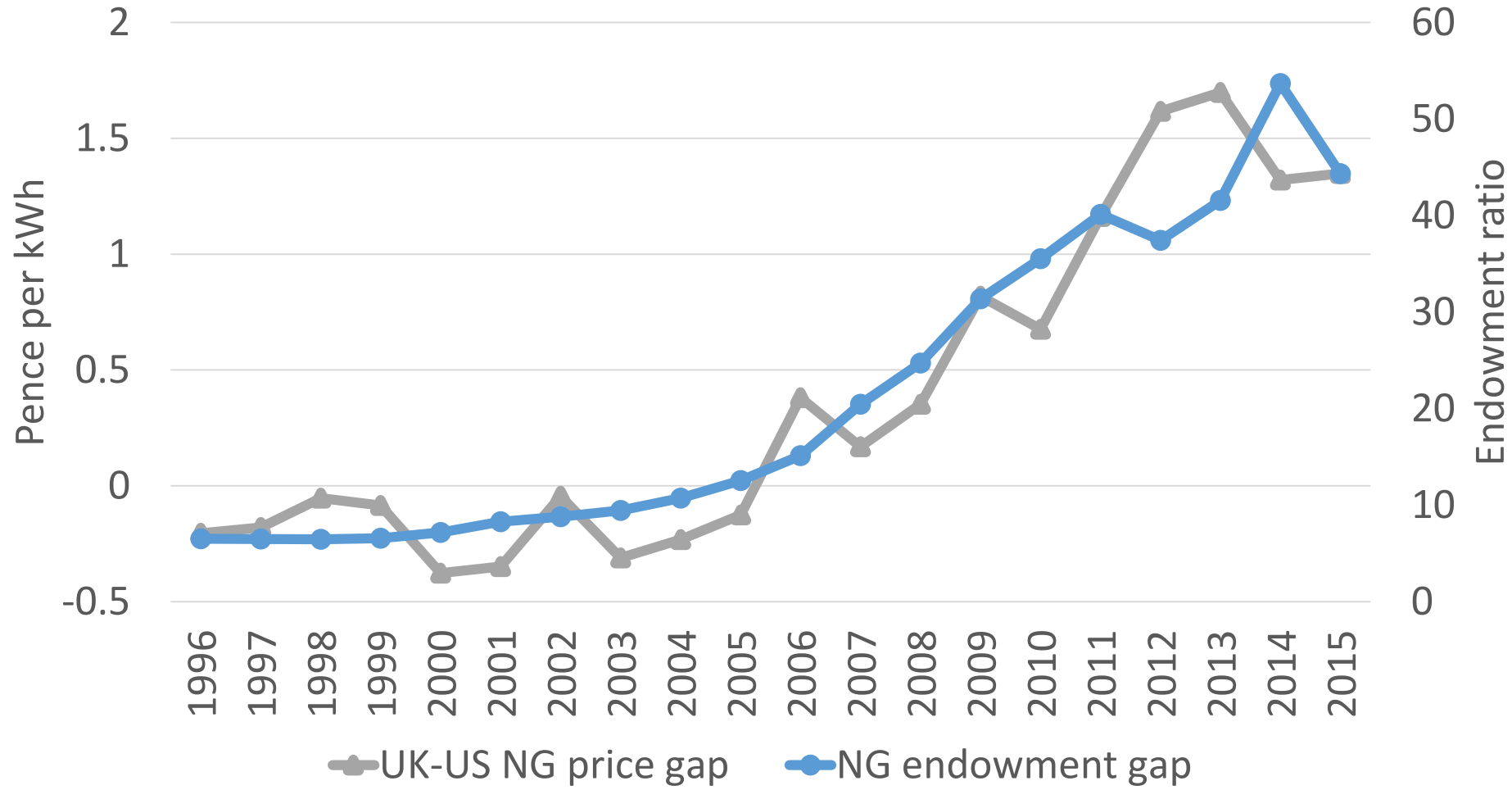
1. Motivation

- Over recent years, trends in energy prices and energy independence have diverged between the US and Europe

- In the US the shale gas revolution has dramatically increased US production of natural gas and petroleum products, decreasing energy prices

- In contrast, European countries are increasingly reliant on imported fuels

UK-US natural gas endowment gap and price gap



Implications for European competitiveness?

The International Energy Agency suggests that the energy price gap with the US will hurt Europe's competitiveness for "at least 20 years"

"There is no near-term cure for Europe's energy price gap with the US...Companies will continue to move overseas as a result" "The price difference is unnerving some companies and deciding their investments." Johannes Teyssen, Chief Executive of Eon

→Vertical FDI motive

Effect on location decisions of UK manufacturing firms

- In this paper we analyse whether UK manufacturing firms have relocated energy intensive production from the UK to the US in response to the endowment-driven energy price gap
- We consider two extensive margins of adjustment by UK firms:

(1) Whether energy intensive UK firms establish new affiliates in the US in response to the shale gas shock

(2) Whether the energy price gap between the US and UK increases the propensity for firms that have US operations to shut down their energy intensive UK plants

2. Data

- **Annual Inquiry into Foreign Direct Investment** (AFDI): contains a registry of the entire population of UK based firms engaging in outward FDI, and the destination country of each firm's foreign affiliates (i.e. subsidiaries or associates) and branches

- **Annual Respondents Database** (ARD): business micro-data for UK collected by the ONS

- Contains basic information for the population of plants

- More detailed information are available on inputs and outputs for a sample of reporting units from the ARD annual production survey

3. Empirical Model for Investment in US

- First approach: Model cumulative effect of all decisions by manufacturing firms to establish new foreign affiliates in the US in the period the US has an energy price advantage (2007-2015)
- Collapse time series information down to two observations for each firm (2006, 2015)
- Estimate a long interval which compares the propensity for energy intensive firms to operate US affiliates in 2006 to 2015

3. Empirical Model for investment in US

- For long interval between 2006 and 2015 we estimate:

$$USFDI_{kt}^{j} = a_k + \pi_1 Post_t * EnergyIntensity_k + d_{j,t} + \varepsilon_{kt}$$

where *USFDI* = 1 if UK firm *k* (in sector *j*) has a foreign affiliate in the US in time period *t* (and 0 otherwise)

- We estimate in first differences:

$$\Delta USFDI_{k}^{j} = \pi_1 EnergyIntensity_k + d_j + \Delta\varepsilon_k$$

Measuring energy intensity of firm

- Following other studies (Martin et al. 2012; Martin et al. 2014) we consider two measures of energy intensity:

(i) Energy Expenditure / Gross Output

(ii) Energy Expenditure / Variable Costs

- Use a time-invariant measure of energy intensity to mitigate potential endogeneity
- We calculate energy intensity for reporting units on average over beginning of sample period (2005-2008)
- We then aggregate from the reporting unit level to the firm level in two ways:

(i) use the firm's most energy intensive reporting unit

(ii) use the overall energy intensity of the firm

4. Results

Results for first difference model of US FDI over 2006 to 2015 long interval

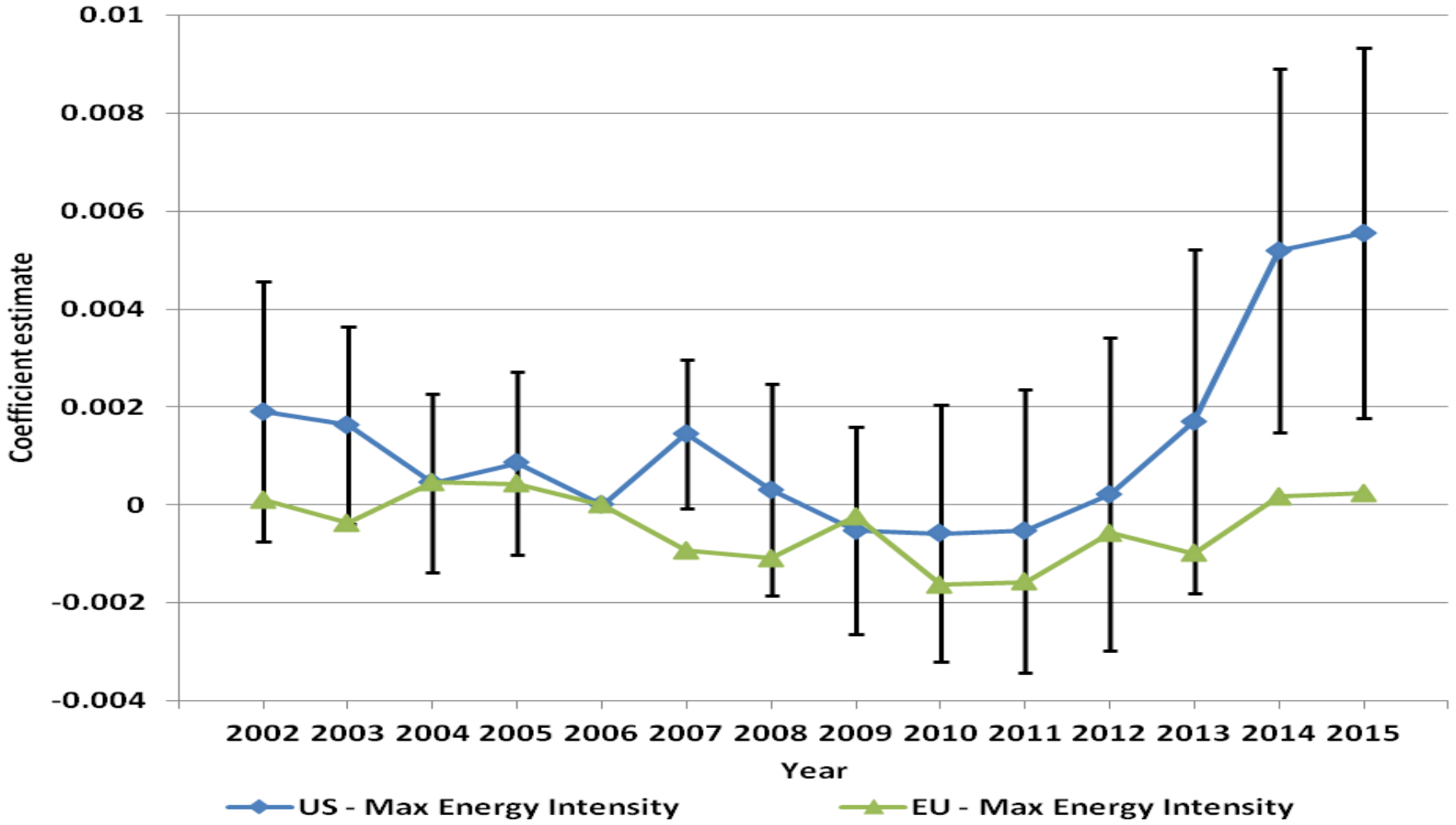
	(1) ΔUSFDI	(2) ΔUSFDI	(3) ΔUSFDI	(4) ΔUSFDI	(5) ΔUSFDI	(6) ΔUSFDI	(7) ΔUSFDI	(8) ΔUSFDI
ln(Energy Exp/Output)_k	0.005***		0.006***		0.002		0.004**	
	(0.002)		(0.002)		(0.002)		(0.002)	
ln(Energy Exp/Costs)_k		0.006***		0.008***		0.002		0.003*
		(0.002)		(0.002)		(0.002)		(0.002)
Observations	6061	6061	6061	6061	6061	6061	6061	6061
R^2	0.002	0.002	0.012	0.012	0.000	0.000	0.010	0.010
Mean USFDI in 2015	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Energy Intensity	Max	Max	Max	Max	Overall	Overall	Overall	Overall
2-digit sector dummies	NO	NO	YES	YES	NO	NO	YES	YES

Robustness

- Results are robust to a range of alternative approaches:

- Models of entry (exit) decision into (out of) US FDI using OLS and probit specifications
- Firm energy intensity averaged over an earlier period (2002-2005)
- Falsification test for EU FDI decision
- Control for other factor intensities (physical capital intensity, labour intensity) in first difference specification
- Alternative choices for comparison years?

Effect of firm energy intensity on the propensity to invest in the US and EU by year



Decision by US investors to exit energy intensive UK plants

- We use the natural gas price gap between the US and UK as a measure of the US energy endowment shock

- Interact natural gas price gap with energy intensity of plant and US FDI dummy (triple interaction)
- US FDI dummy = 0 for a control group of multinational firms that invest abroad but not in the US

- Estimate hazard model (cloglog) and linear probability model

	(1)	(2)	(3)	(4)	(5)	(6)
	Cloglog	OLS	Firm FEs	Firm FEs	Firm FEs	Firm FEs
PriceGap_t*ln(Energyintensity)_j	0.077	0.005	-0.017**	-0.021**		
	(0.100)	(0.007)	(0.007)	(0.010)		
USFDI_kt	-0.132**	-0.011**	-0.007	-0.007	-0.008	-0.009
	(0.054)	(0.005)	(0.008)	(0.008)	(0.009)	(0.010)
USFDI_kt*ln(Energyintensity)_j	-0.298***	-0.030***	-0.026***	-0.032***	-0.039***	-0.040***
	(0.068)	(0.007)	(0.009)	(0.009)	(0.011)	(0.010)
USFDI_kt*PriceGap_t	0.064	0.007	0.011	0.009	0.014	0.014*
	(0.090)	(0.006)	(0.007)	(0.008)	(0.009)	(0.008)
USFDI_kt*PriceGap_t*	0.008	0.007	0.031***	0.032***	0.042***	0.042***
ln(Energyintensity)_j	(0.114)	(0.009)	(0.009)	(0.010)	(0.012)	(0.010)
Observations	48101	48101	48101	48101	47818	56903
R^2	-	0.050	0.146	0.154	0.201	0.184
Number of 5 digit industries	240	240	240	240	240	263
Region fixed effects	YES	YES	YES	YES	YES	YES
5 digit industry effects	YES	YES	YES	YES	NO	NO
Year fixed effects	YES	YES	YES	NO	NO	NO
Firm fixed effects	NO	NO	YES	YES	YES	YES
2 digit sector-year effects	NO	NO	NO	YES	NO	NO
5 digit industry-year effects	NO	NO	NO	NO	YES	YES
Foreign owned firms in sample	NO	NO	NO	NO	NO	YES

6. Conclusions

- Evidence is consistent with the vertical FDI motive for UK firms

- Energy intensive UK firms are investing in the US in response to the endowment driven energy price gap between UK and US

- Firms investing in the US are more likely to shut down their energy intensive UK production in response to the energy price gap

- These results support the concern that firms are relocating their production

Thank you

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Data citations

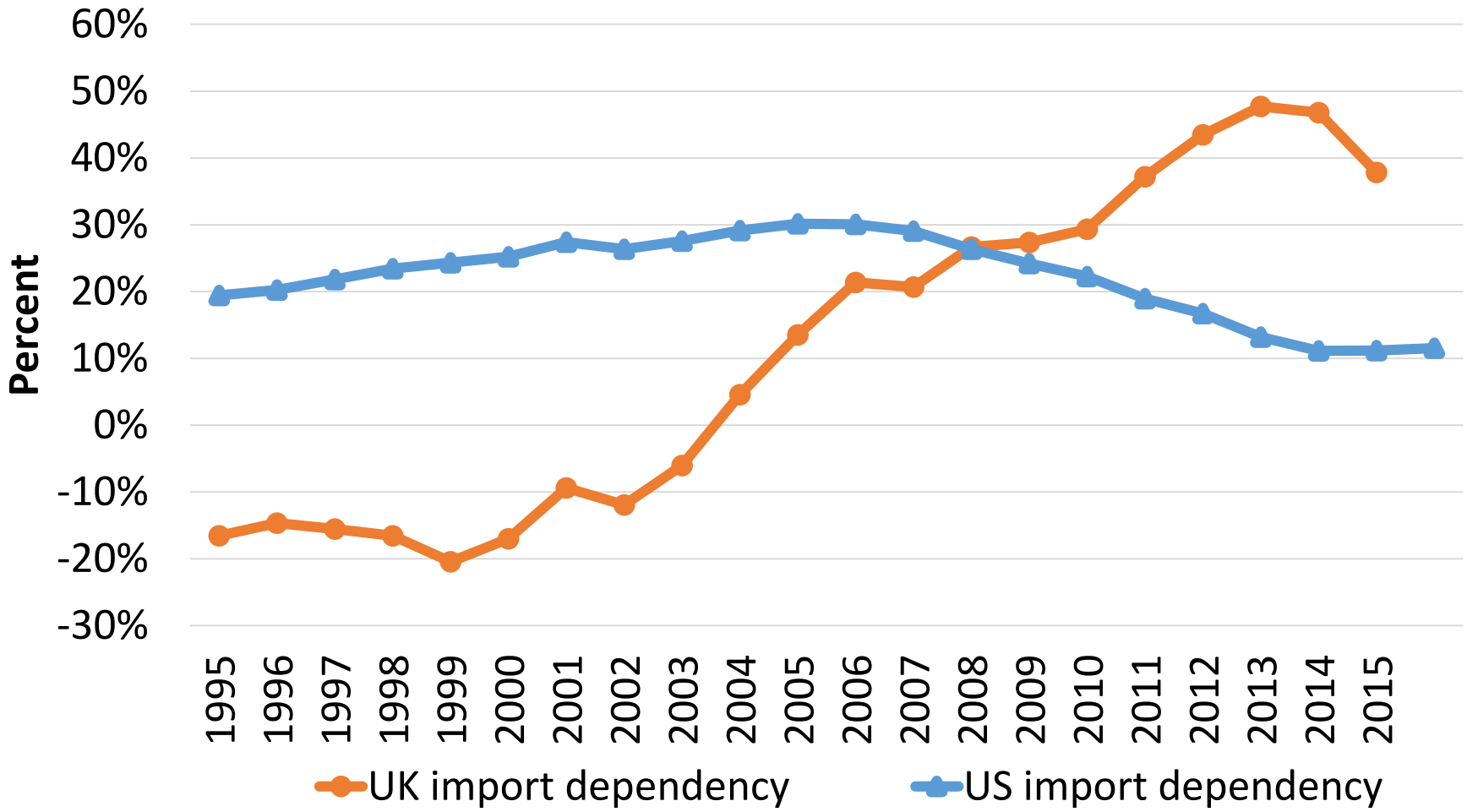
- Office for National Statistics. (2012). *Annual Respondents Database, 1973-2008: Secure Access*. [data collection]. *3rd Edition.* UK Data Service. SN: 6644, http://doi.org/10.5255/UKDA-SN-6644-5

- Office for National Statistics. (2017). *Annual Inquiry into Foreign Direct Investment, 1996-2015: Secure Access*. [data collection]. *5th Edition.* UK Data Service. SN: 6664, http://doi.org/10.5255/UKDA-SN-6664-5

Estimation of firm decision to enter US investment and exit from US investment

	(1) ENTRY OLS	(2) ENTRY OLS	(3) ENTRY PROBIT	(4) ENTRY PROBIT	(5) EXIT OLS	(6) EXIT OLS	(7) EXIT PROBIT	(8) EXIT PROBIT
ln(Energy Exp/Output)_k	0.006***		0.007***		-0.062**		-0.056*	
	(0.002)		(0.002)		(0.028)		(0.032)	
ln(Energy Exp/Costs)_k		0.007***		0.008***		-0.063**		-0.062*
		(0.002)		(0.002)		(0.031)		(0.036)
Observations	5,936	5,936	5,936	5,936	125	125	125	125
R^2	0.018	0.018	-	-	0.242	0.238	-	-
Pseudo R^2	-	-	0.080	0.078	-	-	0.090	0.087
Mean ENTRY / EXIT	0.011	0.011	0.011	0.011	0.112	0.112	0.112	0.112
Energy Intensity	Max	Max	Max	Max	Max	Max	Max	Max
2-digit sector dummies	YES	YES	YES	YES	YES	YES	YES	YES

UK and US dependency on energy imports



	Coal	Natural gas	Electricity	Petroleum	Other	Total	Gas + Electricity / Total
2000	1,228	15,773	9,812	6,039	2,654	35,506	0.72
2001	1,195	15,464	9,573	6,611	2,600	35,443	0.71
2002	1,186	14,202	9,473	6,248	2,656	33,764	0.70
2003	1,248	14,292	9,396	6,899	2,239	34,074	0.70
2004	1,235	13,238	9,584	6,918	1,937	32,912	0.69
2005	1,180	13,022	9,976	6,282	1,843	32,303	0.71
2006	1,164	12,428	9,879	6,099	1,872	31,442	0.71
2007	1,268	11,466	9,699	6,095	2,011	30,540	0.69
2008	1,296	9,863	9,815	5,895	2,183	29,053	0.68
2009	1,152	7,847	8,576	5,152	1,662	24,389	0.67
2010	1,311	9,395	8,989	5,482	1,833	27,011	0.68
2011	1,194	9,007	8,806	4,500	1,747	25,254	0.71
2012	1,212	8,821	8,466	4,669	1,707	24,876	0.69
2013	1,555	9,030	8,339	4,056	1,910	24,889	0.70
2014	1,627	8,653	7,997	4,238	1,787	24,302	0.69
2015	1,380	8,418	7,989	4,212	2,064	24,063	0.68

A note on definitions: Internationalisation, outsourcing and offshoring (Molnar et al. 2007)

- **Outsourcing**: the purchase of goods and services from third parties that were previously produced in-house.
- The third party can be located inside (**domestic outsourcing**) or outside (**international outsourcing**) the country of the sourcing company.

- **Offshoring**: the purchase from abroad goods and services previously produced in-house.
- Includes not only **international outsourcing**, but also **international insourcing** (where the foreign affiliates of domestic parent companies export to their parents).

- **Internationalisation of production:** the establishment of affiliates abroad by parent companies in the home country.
- These affiliates may export back to the parent company (**international insourcing**), or provide goods and services to home and foreign markets. The goods and services produced by affiliates need not have been previously produced inside the parent company.

Related Literature

- Arezki et al. (2017) investigate the impact on production and trade patterns of US manufacturing industries of the US shale gas revolution.

- Ratti et al. (2011) and Panhans et al. (2017) look at relationship between energy prices and the location decisions of European firms.

- Literature on the effect of outward investment on the home-country operations of multinational firms ((Braconier and Ekholm, 2000; Head and Ries, 2002; Muendler and Becker, 2010; Harrison and McMillan, 2011; Simpson, 2012)).

Natural gas prices in levels

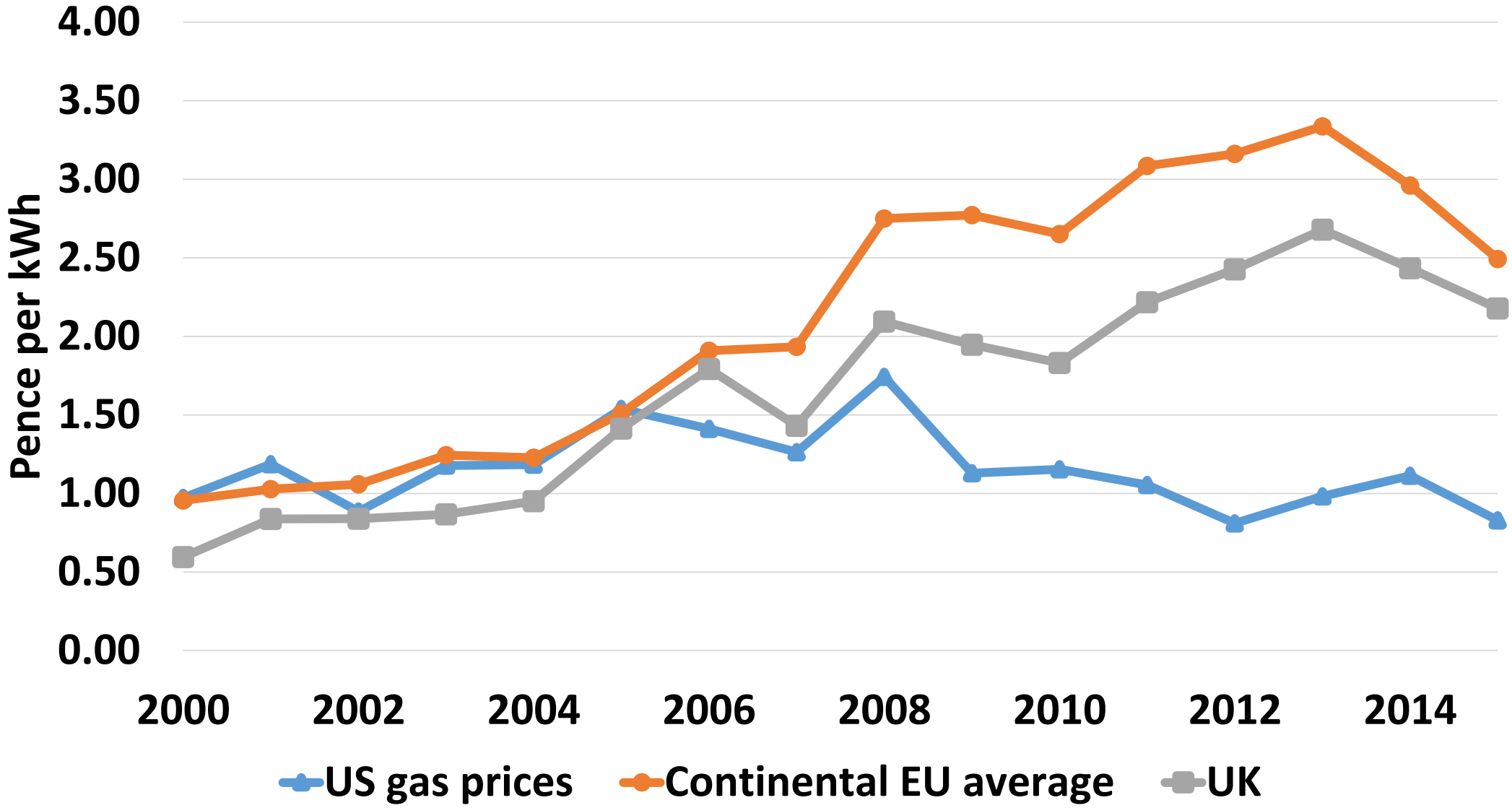
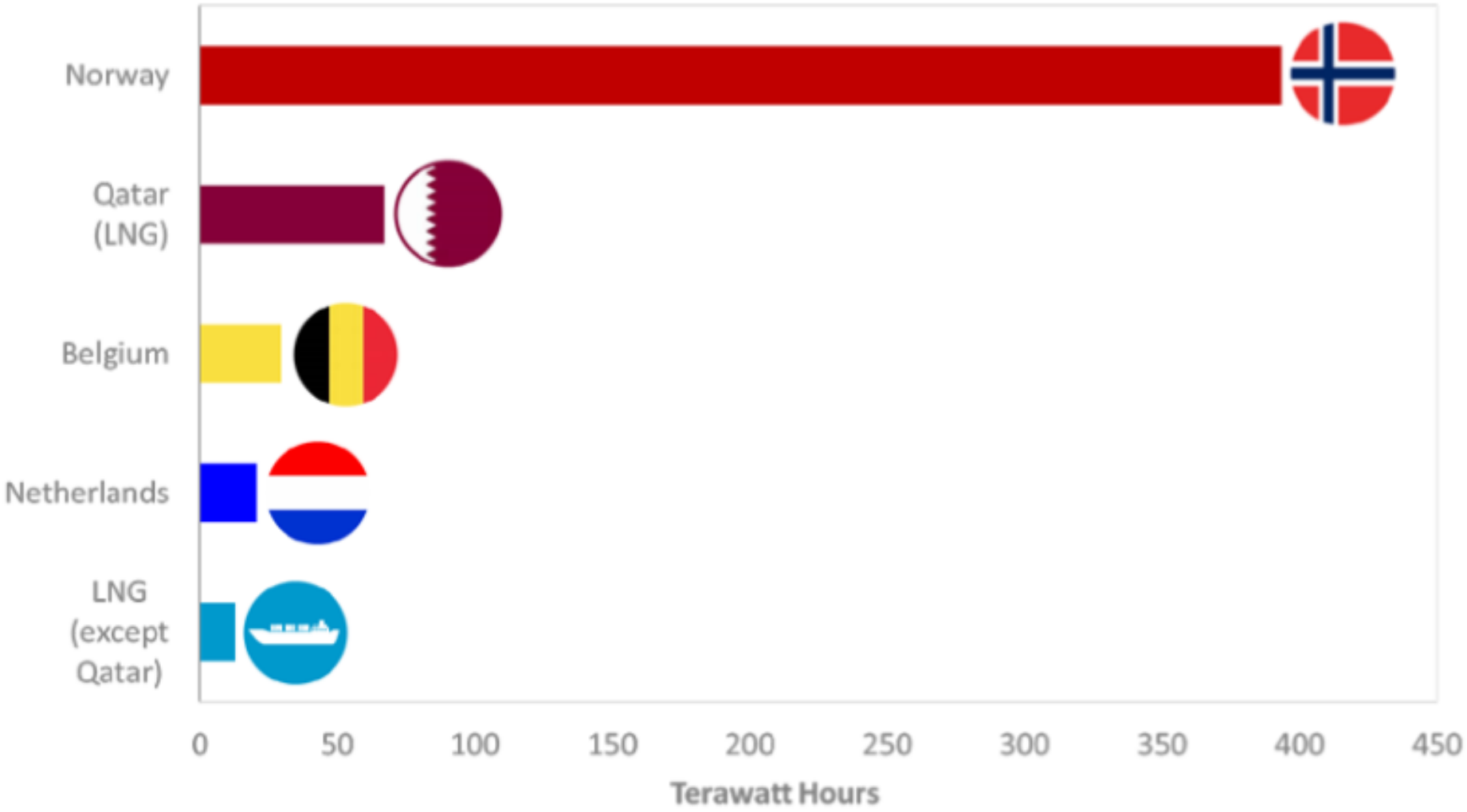
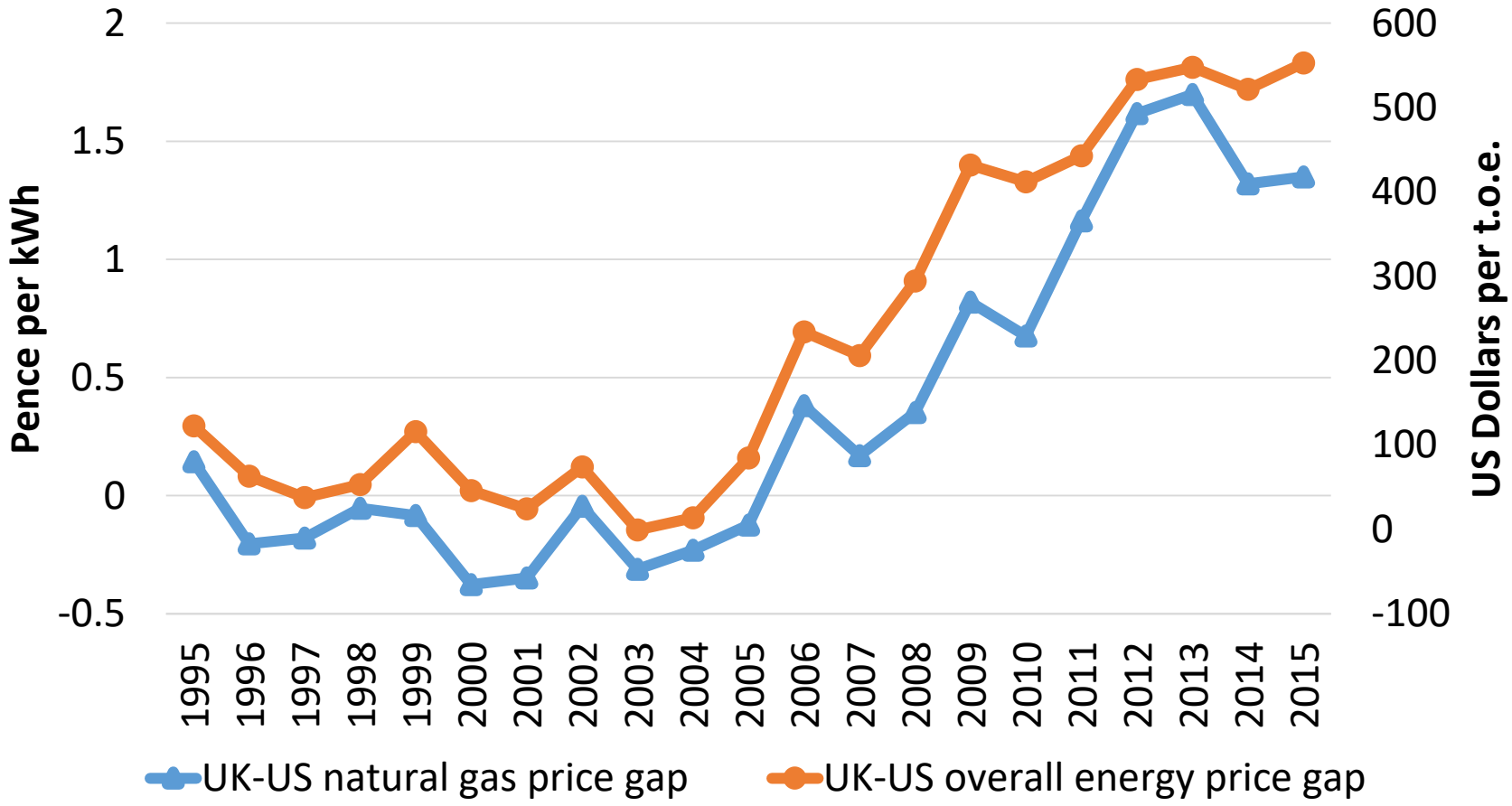


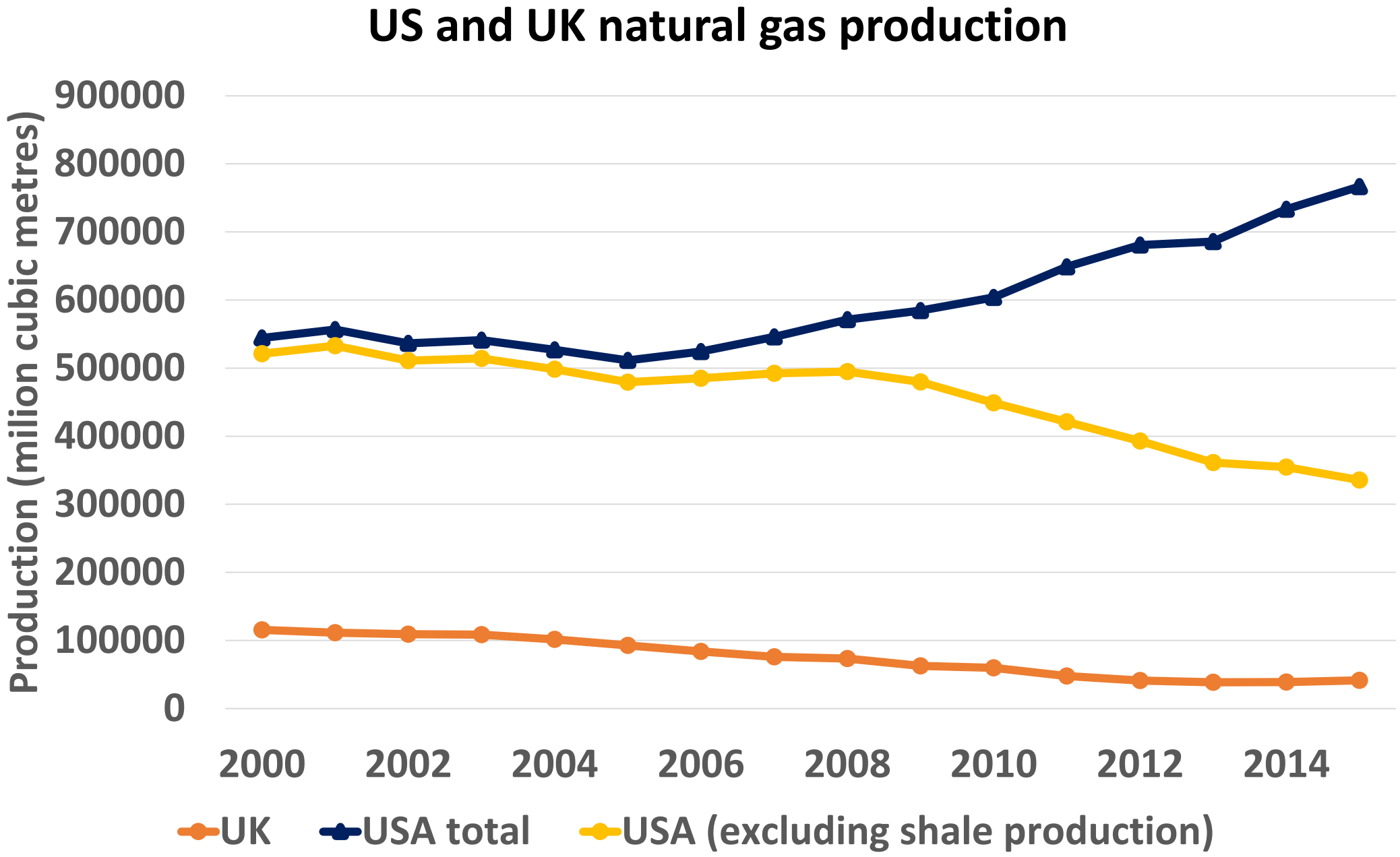
Chart 4.2: Gas imports by country 2017



Source: www.gov.uk

UK-US natural gas price gap and overall energy price gap for manufacturing




US and UK natural gas production
Production (milion cubic metres)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
2000
2002
2004
2006
2008
2010
2012
2014
UK
USA total
USA (excluding shale production)