The long-term effect of renewable electricity on UK employment

Theodoros Arvanitopoulos and Paolo Agnolucci

UCL

28 August 2019

Overview

- Literature assesses **employment impact of renewable** technologies using complex/data-intensive or simplistic methods → contradicting results

- Contribution → introduce a **transparent** and **easily reproducible econometric** methodology using aggregated and widely available data

- Results indicate that **renewables**:
  - generate the most sustainable jobs in the long-term period
  - stimulate **6 times more jobs** in relation to nuclear

- What is the employment effect of the **UKERC decarbonisation scenarios**?

Contents

1. Introduction
2. Literature review
3. UK electricity supply
4. Methodological Approach
5. Results
6. Policy implications
7. Conclusions

Introduction

Introduction

- Increasing maturity of renewables and rising number of jobs created
- Are jobs created **sustainable in the long run?**
- Impact of **renewables** on net employment:
  - Literature focuses on specific technologies, location and plants
  - Complicated methods (CGE and IO) or very simple methods (employment factors)
  - Scarcity of data
  - Importance of country specific characteristics $\rightarrow$ cannot export employment factors from one country to another
- Proposing a simple and robust econometric method form **aggregated data**
- UK electricity generation sector annual data from 1990 to 2016 $\rightarrow$ can be **easily applied to other OECD countries**

Literature review

Literature review

- Cameron and Zwaan (2015) identify 70 publications since early 2000:
  - studies producing forecast or simulations based on theoretical models
  - literature reviews
  - input-output and employment factors
- But all of them focusing **solely on renewable electricity**
- Employment effect of wind energy $\rightarrow$ **no consensus over the long-run**

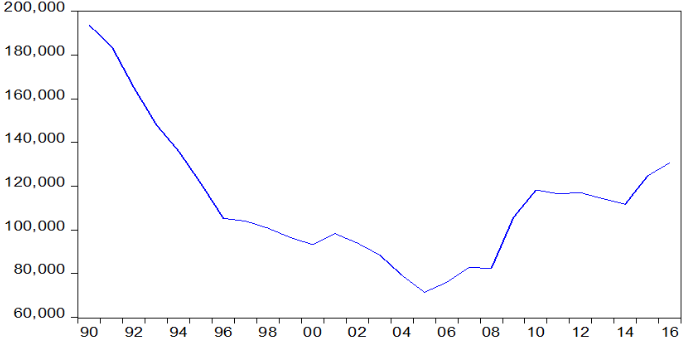
$\therefore$ Lack of robust empirical analyses comparing the macroeconomic net employment effect of conventional thermal power generation and renewable technologies

UK electricity supply

UK electricity supply

Employment

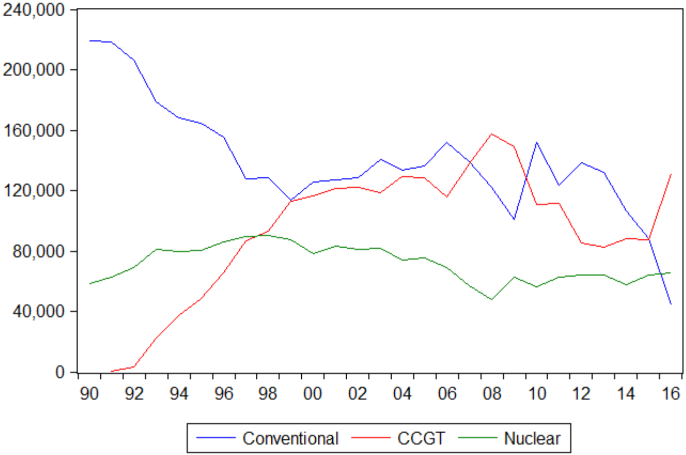
Employment in power generation sector (thousands jobs)



- UK electricity market **privatised in 1990** → a competitive bidding system lowered energy prices (DUKES 2017)

UK electricity supply

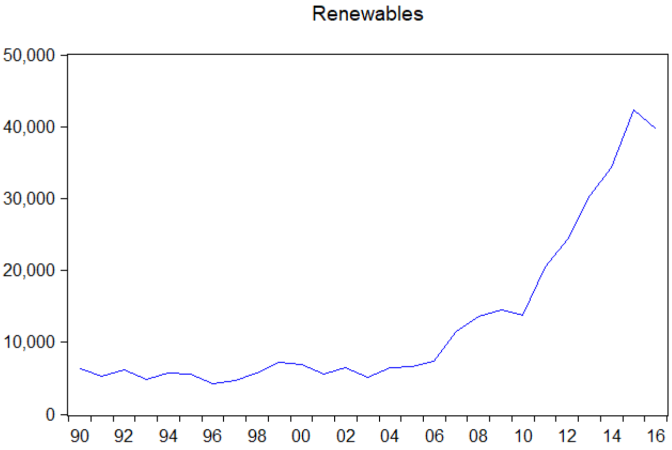
Electricity supply per technology (GWhs)



- ”Dash for gas” → massive transition from coal to gas in the 90s

UK electricity supply

Electricity supply - Renewables (GWhs)



- Renewable electricity has been steadily increasing in the late 2000s
- UK has the largest global capacity in off-shore wind energy (BEIS, 2018)

UK electricity supply
Variables and data sources

- **Number of jobs** is measured by ”workforce jobs”, with data sourced from employer surveys like the ONS Labour Force Survey

- **GVA** for the industrial sector incorporating all Major Power Producers (MPPs)

- **Electricity supply** (DUKES, 2017) generated by:
  - conventional thermal
  - CCGT
  - nuclear
  - renewables

- Electricity supply is equal to the level of electricity supplied to end users in the UK generated by MPPs

- **Timespan**: 1990-2016

Methodological Approach

Methodological Approach

Theoretical modelling I

- UK electricity system is driven by demand (DUKES 2017) $\rightarrow$ **supply** is completely **elastic**

- **Adaptive expectations** (Nerlove, 1958) $\rightarrow$ representative firm chooses labour inputs L_t based on the previous period's expectations about electricity supply in t

$$L_t = f(E_{t-1}[e_t|I_{t-1}]) \tag{1}$$

- Firm's expectations about e_t can be further distinguished in 4 subcategories: conventional thermal, CCGT, nuclear and renewable electricity

$$\begin{aligned} E_{t-1}[e_t|I_{t-1}] = {} & E_{t-1}[con_t|I_{t-1}] + E_{t-1}[ccgt_t|I_{t-1}] \\ & + E_{t-1}[nuc_t|I_{t-1}] + E_{t-1}[ren_t|I_{t-1}] \end{aligned} \tag{2}$$

Methodological Approach
Theoretical modelling II

▶ Representative firm forms expectations at t by considering demand for electricity observed at $t-1$ and all past years j

$$E_{t-1}[e_t|I_{t-1}] = \beta(\sum_{j=0}^{\infty}(1-\beta_1)^j e_j), \tag{3}$$

where error-adjustment term β takes values between 0 an 1 and reflects deviations between expectations and reality

∴ expectation of higher $e_t \rightarrow$ **increase in production inputs** and thus **workforce**.

▶ Nevertheless, a positive employment effect in time t might not only be the outcome of higher electricity consumption but also of higher economic activity

∴ We also **control** for **gross value added** (GVA) in the electricity generation sector

Methodological Approach

Econometric modelling I

- Unit root (DFGLS and Zivot and Andrews 1992) and cointegration (Johansen 1998, 1991) testing $\rightarrow$ variables integrated of order I(1) and cointegrated

- Cointegration analysis using a VAR approach (Johansen 1988, 1991), and estimate a Vector Error Correction (VECM) model of order p, where all variables are treated as endogenous

$$\Delta x_t = \Gamma_0 + \Pi x_{t-1} + \sum_{i=1}^{p} \Gamma_i X_{t-1}, \tag{4}$$

where x_t is a 6 x 1 vector containing the logarithms of employment, GVA, and electricity generated by 1) conventional thermal, 2) CCGT, 3) nuclear and 4) renewable technologies, Π and Γ_i are 6 x 6 coefficient matrices and Γ_0 contains the deterministic terms

Methodological Approach
Econometric modelling II

- **Impulse response functions** (IRFs)

- We examine the **long-term response of employment** to 1 GWh shock applied to each type of electricity supply independently and then we compare the employment effects

- **Generalised** impulse response function (Koop et al, 1996) which is **invariant to the ordering of the variables** in the VAR and "fully takes into account the historical patterns of the correlation observed amongst the different shocks" (Pesaran and Smith, 1998)

Results

Results

VECM I

▶ **Table 1**. Cointegrating vectors β from the VECM specifications VECM 1 and VECM 2

	Jobs	GVA	Conventional	CCGT	Nuclear	Renewables	Trend	Constant
VECM 1								
β_1	1	-0.96					-0.35	2.8
β_2			1	0.31			0.89	-28.27
β_3			1		1.36		-0.12	-25.34
β_4					1	0.22	-1.02	1.58
VECM 2								
	Jobs	GVA	Conventional	CCGT	Nuclear	Renewables	Trend	Constant
β_1	1	**-1.0**					0.06	-2.32
β_2			1	**0.46**	**0.76**	**0.3**	-0.001	-28.25

- All variables I(1) and Johansen test indicates at least 4 coint relationships
- **Positive scale effect** between output and employment
- **Substitution effect** between conventional thermal and rest of technologies
- Concerns about 4 vectors → try 2 vectors

Results

VECM II

▶ **Table 2**. P-values of the Likelihood Ratio tests for the coefficients in the cointegrating vectors presented in Table 1

	GVA	CCGT	NUC	REN	Trend β_1	Trend β_2	Trend β_3	Trend β_4	All trends
VECM 1	0	0	0	0	0.04	0.31	0.15	0.07	0
VECM 2	0	0	0	0	0	0.86			0

▶ **Table 3**. Diagnostic tests for the residuals of the VECMs cointegrating vectors presented in Table 1

	Lags	Serial correlation	Heteroskedasticity
VECM 1	1	0.04	0.31
VECM 2	1	0.17	0.4

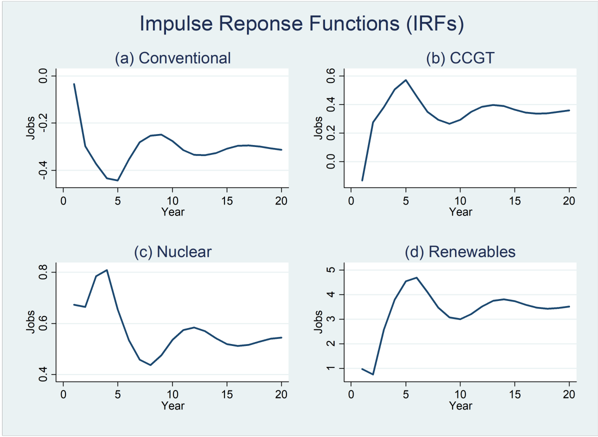
- long-term coefficients are all strongly statistically
- VECM 1 residuals serially correlated
- VECM 2 no heteroskedasticity and serial correlation in the residuals

Results
VECM III

- 4 cointegrating vectors:
  - unexpectedly high values of the trend in β_3 and β_4
  - residuals **serially correlated**
  - restricting one coefficient implies considerable **instability** in the other β coefficients
  - plenty of indication about **spurious** results
- 2 cointegrating vectors:
  - restricting one coefficient does **not** affect the other β coefficients
  - failure to detect heteroskedasticity and serial correlation in the residuals
  - restricting one coefficient does **not** affect the stability of the model
  - VECM 1 and VECM 2 have coefficients of the **same sign and similar value** $\rightarrow$ proves the overall **stability of the model**

Results
IRFs

▶ Employment response to 1 GWh electricity supply permanent increase



▶ 1GWh permanent increase in renewable electricity supply creates **3.5 jobs in the long run → 6 times more than nuclear**

Policy implications

Policy Implications

▶ Employment effect for the **UKERC energy security scenarios** (Watson et al, 2018)

Scenario	CCGT	Nuclear	Renewables	Net employment	Gross employment
1) Energy island	-21,492	19,303	-10,219	-12,408	118,432
2) Slow decarbonisation	-9,278	-19,089	60,034	31,668	162,418
3) Low carbon	4,499	-19,089	53,549	38,960	169,024
4) Low carbon (no BECCS)	14,956	-19,089	16,124	11,992	142,742
5) Technology optimism	-17,886	-19,089	75,136	38,162	168,912

- We use the long-run employment effect estimates on the 2030 UK decarbonisation scenarios for the UK energy generation sector
- Energy island which is "inward-looking" and potentially related to no-deal BREXIT $\rightarrow$ reduction in employment ($-12,000$ jobs)
- Low carbon UK meets climate change goals $\rightarrow$ highest level of employment ($+39,000$ jobs)

$\therefore$ Scenarios based overwhelmingly on renewable electricity result in a **significant net employment effect**

Conclusions

Conclusions

- 1 GWh permanent increase in renewable electricity supply creates 3.5 jobs in the long-term, i.e. about **six times the number of jobs created by an equally sized increase in nuclear generation**.

- Jobs created by the deployment of **renewable technologies** are the **most sustainable in the long-term period**

- UKTM scenarios for electricity generation in 2030 → scenarios based on renewables can generate net effect of 39.000 jobs

∴ Policy-makers should **incentivise and support the deployment of renewable electricity technologies**

References

References

BEIS (2018) *The clean growth strategy.* Department for Business, Energy and Industrial Strategy.

Cameron L and Zwaan B (2015) ”Employment factors for wind and solar energy technologies: A literature review.” *Renewable and Sustainable Energy Reviews* 45: 160-172.

DUKES (2017) *Digest of UK energy statistics*. Department for Business, Energy and Industrial Strategy.

Johansen S (1988) ”Statistical analysis of cointegration vectors.” *Journal of Economic Dynamics and Control* 2-3: 231-254.

Johansen S (1991) ”Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models.” *Econometrica* 59(6): 1551-1580.

Koop G, Pesaran H and Potter S (1996) ”Impulse response analysis in nonlinear multivariate models.” *Journal of Econometrics* 74(1): 119-147.

Nerlove (1958)

Pesaran H and Smith R (1998) ”Structural analysis of cointegrating VARs.” *Journal of Economic Surveys* 12(5): 471-505.

Watson J, Ketsopoulou I, Dodds P, Chaudry M, Tindemans S, Woolf M and Strab G (2018) *The security of UK energy futures.* London, UK Energy Research Centre.

Zivot E and Andrews K (1992) ”Further evidence on the great crash, the oil price shock, and the unit root hypothesis.” *Journal of business and Economic Statistics* 10(3): 251-270.

Thank you!

- Unit root test results for Major Power Producers (MPPs)

	Logs			First differences			Logs		First differences	
	DF-GLS test	lags	Determ comp	DF-GLS test	lags	Determ comp	ZA test	lags	ZA test	lags
Jobs	-1.46	1	Trend	-3.91 (*)	0	Trend				
GVA	-1.18	2	Trend	-6.43 (**)	0	Trend				
Conv. thermal	-1.43	0	Trend	-1.49	2	Trend	-1.86	2	-7.31 (**)	0
CCGT	-1.97	1	Trend	-2.81	1	Trend	-3.67	0	-4.59 (*)	1
Nuclear	-2.27	0	Trend	-1.85	3	Trend	-3.45	3	-10.19 (**)	0
Renewables	-1.57	0	Trend	-6.15 (**)	0	Trend				

(+) ,(*),(**) in the superscripts indicate significance of the test statistics of the unit root tests at 90%, 95% and 99% significance level, respectively.

- Johansen test cointegration results

	Trace				Max Eigenvalue			
	H0	H1	trace	p-value	H0	H1	max	p-value
MPPs	r = 0	r ≥ 1	0.973 (**)	0	r = 0	r = 1	0.973 (**)	0
	r ≤ 1	r ≥ 2	0.897 (**)	0	r = 1	r = 2	0.897 (**)	0
	r ≤ 2	r ≥ 3	0.827 (**)	0	r = 2	r = 3	0.827 (**)	0
	r ≤ 3	r ≥ 4	0.737 (**)	0	r = 3	r = 4	0.737 (**)	-0.01
	r ≤ 4	r ≥ 5	0.507	-0.14	r = 4	r = 5	0.507	-0.11

Appendix
VECM A

► Cointegrating vectors β from alternative VECM specifications to those presented in Table 1

VECM 1A

	Jobs	GVA	Conv	CCGT	Nuclear	Renewables	Trend	Constant
β_1	1	-0.73					0.05	-5.32
β_2			1	0.56				-18.17
β_3			1		1.3		0.03	-26.9
β_4					1	0.64	-0.02	-16.8

VECM 1B

	Jobs	GVA	Conv	CCGT	Nuclear	Renewables	Trend	Constant
β_1	1	-1.03					0.21	-4.76
β_2			1	0.35			-0.3	-11.38
β_3			1		1.15			-24.71
β_4					1	0.27	0.37	-19.09

VECM 2A

	Jobs	GVA	Conv	CCGT	Nuclear	Renewables	Trend	Constant
β_1	1	-1.06					0.06	-2.27
β_2			1	0.44	0.77	0.28		-28.19

Appendix
VECM A

- P-values of the Likelihood Ration tests for the coefficients in the coint vectors β

	GVA	CCGT	NUC	REN	Trend β_1	Trend β_2	Trend β_3	Trend β_4	All trends
VECM 1A	0	0	0	0	0.01		0	0.4	0
VECM 1B	0	0	0	0	0.02	0		0	0
VECM 2A	0	0	0	0	0				

- Diagnostic tests for the residuals of the VECMs cointegrating vectors

	Lags	Serial correlation	Heteroskedasticity
VECM 1A	1	0.37	0.32
VECM 1B	1	0.03	0.32
VECM 2A	1	0.2	0.38

Appendix

Variables