The Political Economy of Energy Innovation

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1. Introduction

- IPCC AR5: It will take unprecedented levels of improvement in institutional quality to limit temperature rise below 2° C
- Critical to examine the determinants of energy innovation
- Impact of environmental and R&D policies, governance quality, political orientation, and lobbying on innovation
- Two indicators of energy innovation
  - Industrial energy R&D - innovation inputs
  - Energy patents - innovation outputs

2.

Gaps in the Literature

- Inducement effect of institutions and political economy factors have not been studied jointly
- Role of governance quality, government political orientation, and lobbying have only received marginal attention

3. Measuring Energy Innovation: R&D Expenditure

- R&D in the electricity, water, and gas distribution industry
  - Downstream sector for energy production (power R&D)
- R&D expenditures from Electricity, water, and gas distribution industry, and Mining
  - Upstream and downstream for energy supply sector (energy R&D)
- Represent a lower-bound of energy-related innovation

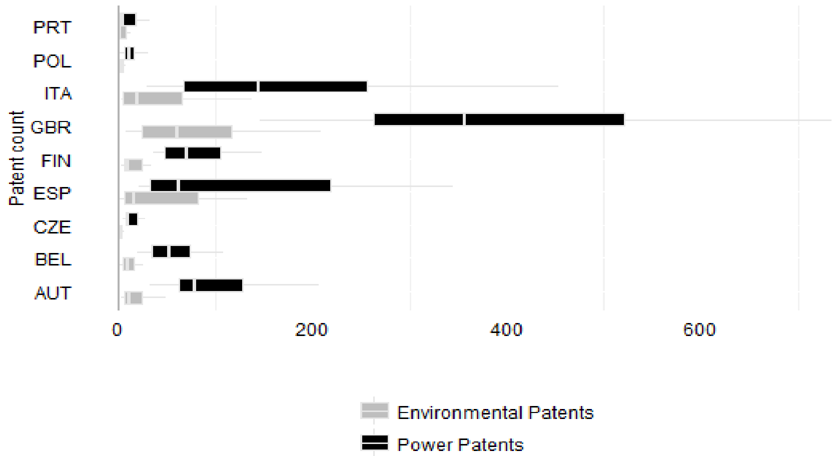
3.1. Measuring Energy Innovation: Patents

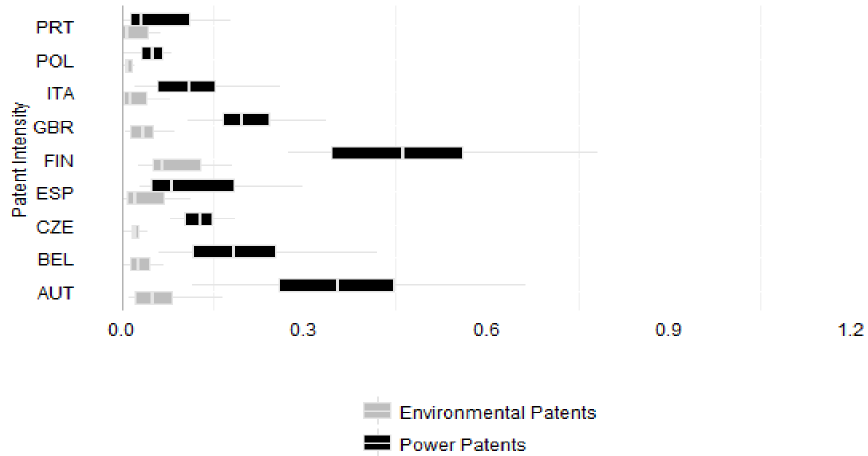
- Power Patents: related to energy generation
  - Energy generations from renewable and non-fossil sources
  - Technologies improving efficiency of fossil fuels
- Green Patents: power patents and patents related to
  - General environmental management
  - Climate change mitigation
  - Energy efficiency in buildings and lighting
  - Emissions mitigation and abatement
  - Fuel efficiency in transportation
- Environmental patents: sum of power and green patents
- We scale all innovation proxies relative to the total value added to account for the heterogeneity among countries

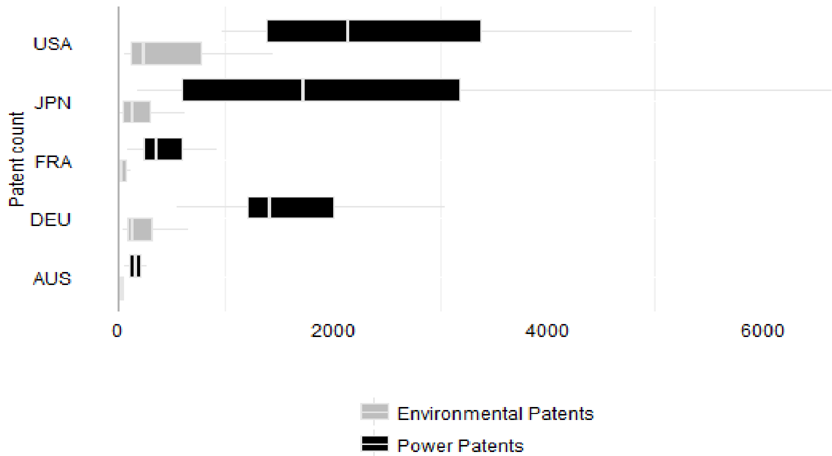
3.2. Measuring Energy Innovation: Sources

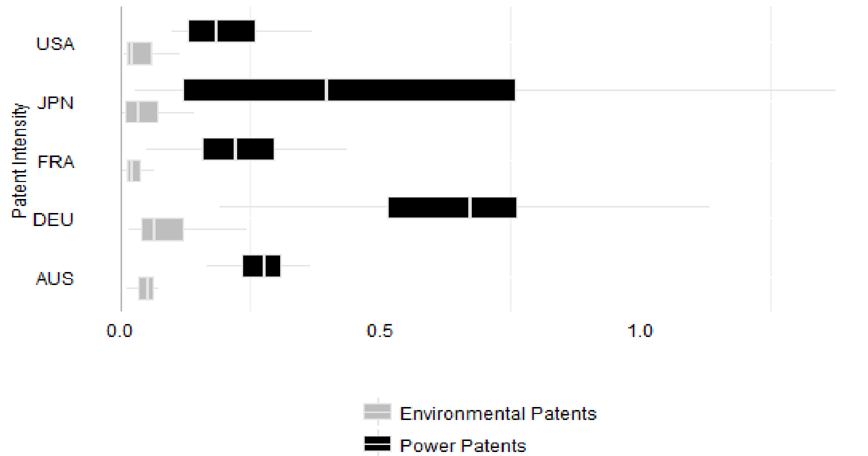
- Energy innovation: ANBERD (OECD)
  - Sectoral information for 30 countries' 1990 - 2013
- Patents: OECD Patent Statistics Database and Patent Cooperation Treaty (PCT)

3.3. Counts and Patent Intensity: 1995–2010









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4. Research Hypotheses

1. Environmental policy stringency results in dynamic efficiency gains and stringent regulations provide long-term incentives for energy-saving and pollution-reducing technologies

2. Institutional quality, measured in terms of government quality, increases the incentives to invest in energy-related innovation

4.1. Research Hypotheses

3. Political orientation of government influences investments in energy innovation but it's impact can be ambiguous

4. Higher share of energy intensive sectors induces market-size effect and increases lobbying power but also increases coordination costs. Impact of resource distribution on innovation is not clear *a priori*

5. Econometric Approach

$$y_{it} = \alpha_i + \gamma_t + \boldsymbol{\pi}_{it}\beta_1 + \beta_2\varphi_{it} + \beta_3\rho_{it} + \beta_4\theta_{it} + \boldsymbol{Z}_{it}\omega + \varepsilon_{it}$$

y_{it}: energy innovation intensity of the economy
$\boldsymbol{\pi}_{\mathbf{it}}$: vector of policy stringency measures
φ_{it}: institutional quality
ρ_{it}: political orientation of the government
θ_{it}: distribution of resources to the energy sector
$\mathbf{Z}_{\mathbf{it}}$: vector of other control variables, including industrial energy prices and trade openness
α_i and γ_t: country and year fixed effects

- Unbalanced panel: 20 countries for the years 1995 – 2010
- 1 - 2 year lag structure

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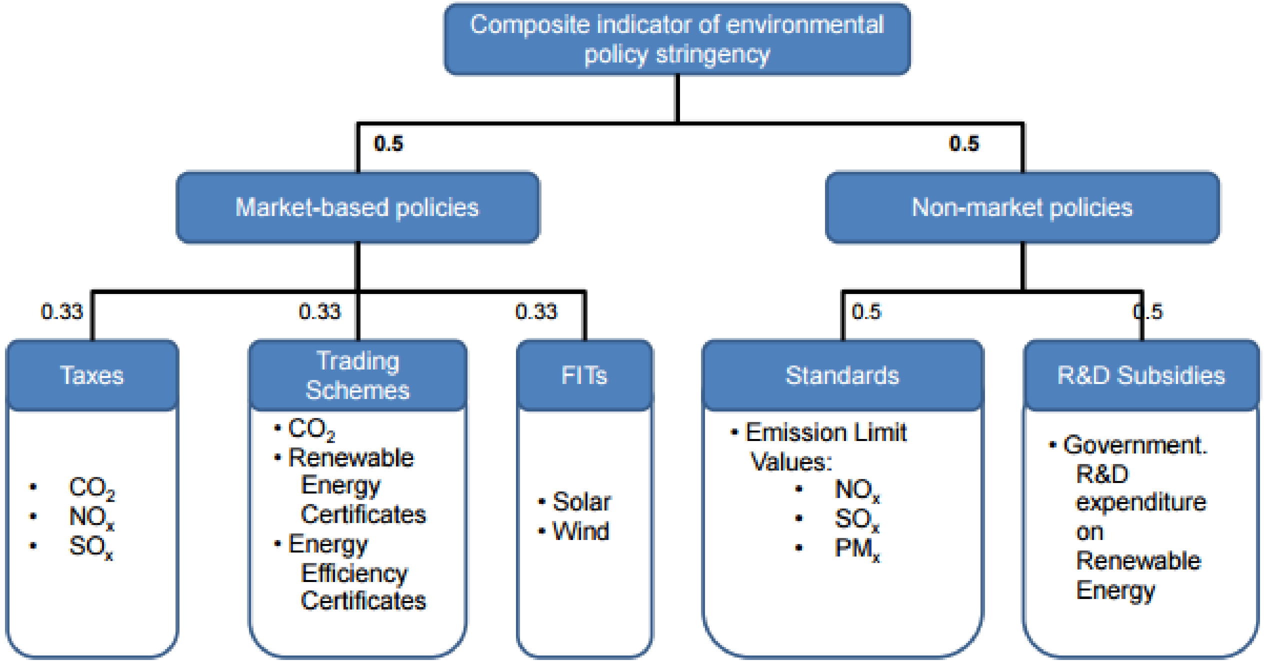
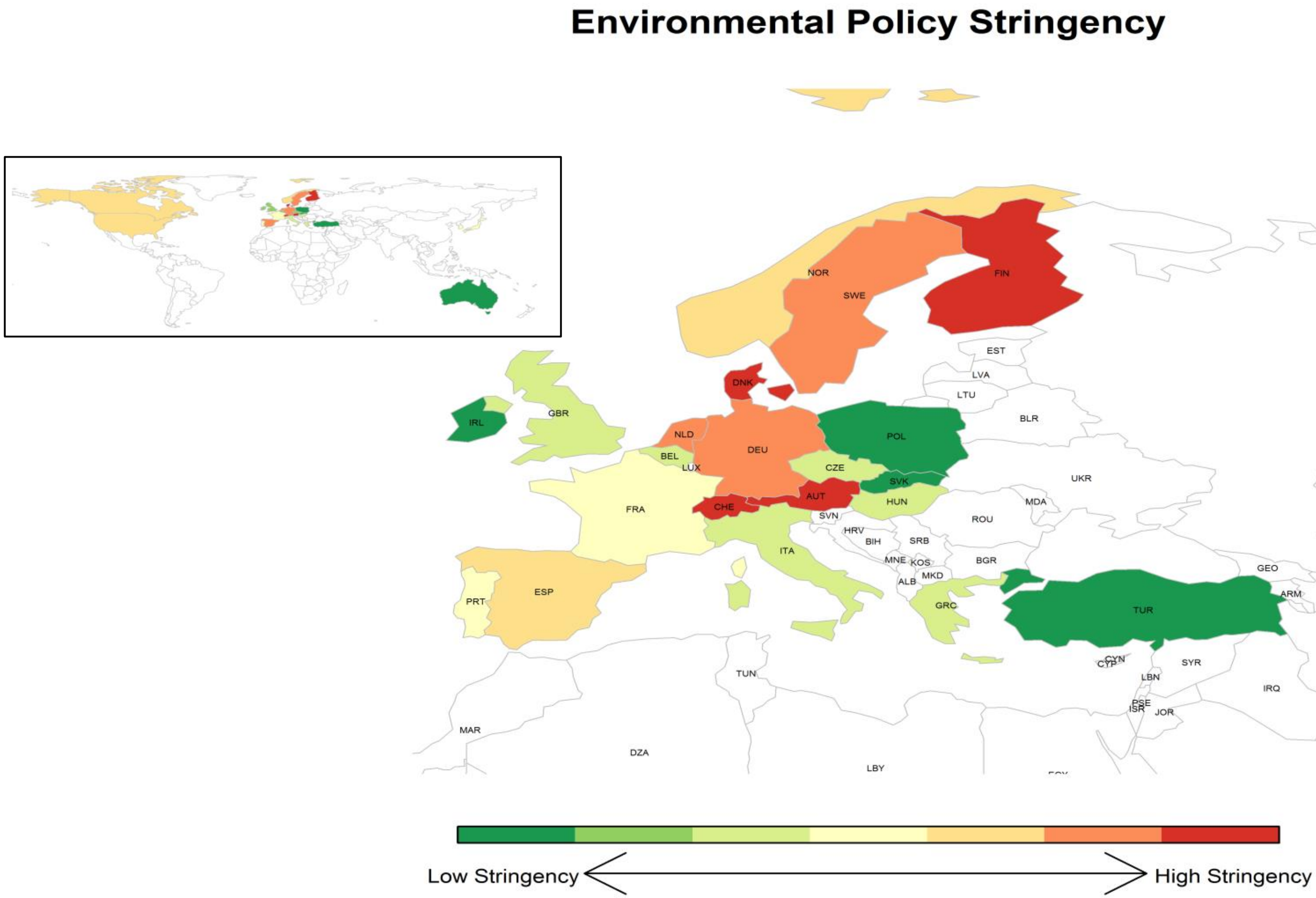
6. Environmental Policy Stringency

- Both market and non-market based environmental policies



- On a scale from 0 to 6, depending on the policy stringency
- Scores are then weighted and aggregated for EPS-Total
- Source: OECD (Botta and Koźluk 2014)

6.1. Environmental Policy Stringency



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7. Political Economy Factors

Four institutional and political economic factors

- Stringency of government support to energy innovation
  - EPS indicators
- Quality of governance (WGI)
  - Government effectiveness, rule of law, and control of corruption
  - Standardized score (-2.5 to 2.5)
- Political orientation of the government (DPI)
  - Left-leaning vs. right-leaning
- Distribution of resources across interest groups
  - Market-size effect and the power of the energy lobby
  - Value added share of energy intensive industries

8. Variables and Hypotheses

Hypothesis	Proxy Variables
Environmental policy	EPS-Market, EPS-Non market, EPS-Total
Governance	Governance effectiveness, Governance Average WGI indicator, Governance x EPS-Total
Political orientation	Left-leaning vs. right-leaning
Lobbying	Value added share of energy-intensive industries Value added share of carbon-intensive industries Value added share of electricity

9. Descriptive Statistics

Variable	Me an	Std. Dev.	Min	Max	Source
Log of Patent Intensity—Power	0.05	0.05	0.00	0.38	OECD, 2015
Log of Patent Intensity—Environment	0.23	0.17	0.00	0.97	OECD, 2015
Log of R&D Intensity—Power	-5.09	1.25	-9.38	-2.55	OECD, 2016
Patent Intensity—Power	0.05	0.06	0.00	0.46	OECD, 2015
Patent Intensity—Environment	0.28	0.26	0.00	1.65	OECD, 2015
R&D Intensity—Power	0.01	0.01	0.00	0.08	OECD, 2016
R&D Intensity—Energy	0.03	0.05	0.00	0.33	OECD, 2016
EPS Score	1.79	1.00	0.00	4.16	Botta and Koźuk (2014)
EPS Market Score	1.79	0.94	0.25	4.00	Botta and Koźluk (2014)
EPS Non-market Score	1.98	1.17	0.00	5.38	Botta and Koźluk (2014)
Government Effectiveness	1.35	0.57	-0.28	2.26	WB WGI (Kaufman et al. 2010)
Corruption Control	1.27	0.74	-0.71	2.59	WB WGI (Kaufman et al. 2010)
Average WGI	1.28	0.53	-0.16	2.14	WB WGI (Kaufman et al. 2010)
Political Orientation	2.06	0.95	1.00	3.00	DPI (Beck et al. 2001)
Energy-Intensive Industries - VA Share	3.80	2.10	1.59	13.81	WIOD (Timmer et al. 2015)
Carbon-Intensive Industries - VA Share	7.21	2.46	4.10	16.36	WIOD (Timmer et al. 2015)
Electricity—VA Share	0.02	0.01	0.01	0.04	WIOD (Timmer et al. 2015)
Energy Price Index	4.51	0.16	4.09	4.87	IEA, 2016
Trade Openness (% of GDP)	70.08	33.08	18.76	159.89	WDI, 2016

10. Results

Role of Environmental Policy Stringency

- Effect is weaker for energy-related R&D compared to patents
  - EPS has a positive and significant effect only on electricity R&D
- Inducement effect of market-based instruments is larger for environmental patents (broader definition)
- One unit increase in EPS (one IQR change)
  - Market based: increases power patents intensity by between 1.3% - 1.4%; and environmental patent intensity by between 3% - 3.2%
  - Non-market based: increases power patents intensity by between 1.2% - 1.5%; and environmental patents intensity by 2.3%
- Stringent policies do result in efficiency gains.

10.1. Results

Role of Good Governance

- Critical driver of energy innovation
- One unit increase in governance indicators increases
  - Power R&D intensity by 62% - 96.4%
  - Patent intensity 6.5% - 31.3%
- 1 unit change: Portugal (1.02) to that of Sweden (2.01) in 2010
- Good governance enhances the effect of environmental policies

Role of Political orientation

- Significant impact only on R&D intensity
- Change from *right* to *left* orientation increases industrial R&D
  - 11% (power) and 22% (energy)
- Portugal changed to left-leaning government in 1995, while Canada and Sweden went the opposite direction

10.2. Results

Role of Resource Distribution, Market-size effect, and Lobbying

- Positive impact on R&D intensity
  - A larger energy sector can lobby for larger R&D allocation
- 1% increase in the value added share of energy intensive industries increases power R&D intensity by 0.54% - 0.83%
- Lobbying has greater effect on inward-oriented sectors – power
- Do not result in higher number of cleaner patents

Role of Other Factors

- Energy price has a negative effect on power and energy R&D
- Trade openness reduces incentives for R&D innovation

10.3. Results: R&D Intensity

		1	2	3	4	5	6	7	8	9
	Dependent Variable	Log of R&D Intensity—Power					Log of R&D Intensity—Energy			
	EPS Market Score	0.198+	0.189+	0.165			-0.006	-0.018		
H1		(0.125)	(0.121)	(0.122)			(0.111)	(0.111)		
	EPS Non-market Score	-0.089	-0.014	0.018			-0.058	-0.043		
		(0.108)	(0.107)	(0.108)			(0.098)	(0.098)		
	EPS Total Score				0.135	0.164			-0.079	0.006
					(0.110)	(0.162)			(0.101)	(0.148)
	Govt. Effectiveness	0.964***	0.769**		0.619**	0.666*	0.399		0.409	0.549+
H2		(0.323)	(0.317)		(0.312)	(0.367)	(0.294)		(0.288)	(0.338)
	WGI			0.754				0.418		
				(0.538)				(0.498)		
	Govt. Effectiveness*EPS Interaction					-0.033				-0.098
						(0.135)				(0.123)
H3	Political orientation	0.222***	0.211***	0.202***	0.200***	0.199***	0.112*	0.107*	0.111*	0.106*
		(0.065)	(0.063)	(0.064)	(0.063)	(0.063)	(0.058)	(0.058)	(0.057)	(0.058)
	VA Share Energy-intensive industries	0.710**	0.827**	0.814**	0.815**	0.822**	0.537+	0.525+	0.542+	0.553+
H4		(0.356)	(0.356)	(0.363)	(0.356)	(0.358)	(0.342)	(0.348)	(0.341)	(0.341)
	Energy price index		-3.053***	-3.203***	-3.193***	-3.202***	-8.309***	-8.629***	-8.286***	-8.388***
			(0.756)	(0.760)	(0.753)	(0.756)	(3.034)	(3.029)	(3.012)	(3.017)
	Trade openness		0.005	0.005	0.004	0.004	-0.027***	-0.027***	-0.027***	-0.027***
			(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
	Observations	256	256	256	256	256	256	256	256	256
	R-squared	0.200	0.257	0.244	0.254	0.254	0.235	0.231	0.236	0.239
	Number of countries	20	20	20	20	20	20	20	20	20

10.4. Results: Patents Intensity

		1	2	3	4	5	6	7	8	9	10
	Dependent Variable	Log of Patent intensity—Power					Log of Patent intensity—Environment				
H1	EPS Market Score	0.013***	0.014***	0.013***			0.031***	0.032***	0.029**		
		(0.005)	(0.003)	(0.007)			(0.012)	(0.007)	(0.016)		
	EPS Non-market Score	0.012***	0.013***	0.015***			0.018+	0.018+	0.023**		
		(0.004)	(0.005)	(0.001)			(0.011)	(0.110)	(0.046)		
	EPS Total Score				0.017***	0.004			-0.007	0.030**	0.020
					(0.000)	(0.587)				(0.011)	(0.277)
H2	Govt. Effectiveness	0.069***	0.070***		0.065***	0.045***	0.211***	0.212***		0.199***	0.183***
		(0.013)	(0.000)		(0.000)	(0.003)	(0.033)	(0.000)		(0.000)	(0.000)
	WGI			0.095***					0.313***		
				(0.000)					(0.000)		
	Govt. Effectiveness*EPS Interaction					0.015**					0.012
						(0.010)					(0.416)
H3	Political Orientation	-0.002	-0.002	-0.002	-0.002	-0.002	-0.006	-0.007	-0.007	-0.008	-0.007
		(0.003)	(0.395)	(0.379)	(0.330)	(0.514)	(0.006)	(0.286)	(0.314)	(0.212)	(0.256)
H4	VA Share Energy-intensive industries	-0.003	-0.009	-0.009	-0.012	-0.012	-0.048	-0.061*	-0.058+	-0.068*	-0.069*
		(0.014)	(0.546)	(0.557)	(0.419)	(0.380)	(0.035)	(0.089)	(0.114)	(0.061)	(0.059)
	Energy price index		0.025	0.016	0.024	0.027		0.058	0.032	0.053	0.056
			(0.338)	(0.544)	(0.367)	(0.309)		(0.390)	(0.640)	(0.431)	(0.413)
	Trade Openness		-0.000	-0.000+	-0.000	-0.000		-0.001	-0.001+	-0.001	-0.001
			(0.170)	(0.130)	(0.175)	(0.277)		(0.180)	(0.127)	(0.189)	(0.224)
	Observations	256	256	256	256	256	256	256	256	256	256
	R-squared	0.662	0.666	0.651	0.657	0.663	0.634	0.638	0.623	0.630	0.630
	Number of countries	20	20	20	20	20	20	20	20	20	20

11. Summary

- Both market and non-market based incentives result in dynamic efficiency gains
- Better governance promotes energy innovation
- Left-wing governments are more likely to devote R&D resources to the energy sector
  - Does not translate into higher power-related patent intensity
- A larger distribution of resources toward energy intensive sectors can induce market-size effects

11.1 Conclusion

- Political economy factors can act as barriers even in the presence of stringent environmental policy
- To move towards a greener economy, countries should combine environmental policy with
  - Improved institutional quality
  - Consider the influence of government's political orientation
  - Size of energy intensive sectors in the economy which affect both the lobbying structure and the demand for energy innovations
- Focus on the determinants of energy innovation and go beyond environmental policy instruments

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Backup Slides

Upper-bound of Energy R&D

- Input–output data from the World Input–Output Database
- Weight representing the average production share
  - By manufacturing sector *m* of country *i* in the energy sector *e* (i.e. electricity and mining) of country *j* (including the case *i*=*j*)

$$S_{m,i,e,j} = \frac{EX_{m,i,e,j}}{\sum_j EX_{m,i,j}}$$

  - $EX_{m,i,e,j}$ is the trade between the manufacturing sector of country *i* (*m*, *i*) to the energy sector in country *j* (*e*, *j*)
  - $\sum_j EX_{m,i,j}$ is the sum of all exports from the manufacturing sector of country *i* to all other sectors (including energy) and countries

Upper-bound of Energy R&D

- Use $S_{m,i,e,j}$ to apply weights to the annual R&D expenditures in the manufacturing sector (*m*) of country i. ($S_{m,i,e,j} * \ R\&D_{m,i,t}$)
  - Represents the share of R&D expenditures in the manufacturing sector (*m, i*) from which sector (*e, j*) benefits through trade of goods and capital
- Sum of direct and embedded R&D expenditures provides an upper-bound estimate of industrial energy-related innovation

$$R\&D\_UP_{e,j,t} = R\&D_{e,j,t} + \sum_{m,i} \left(S_{m,i,e,j} * R\&D_{m,i,t}\right)$$

- Can only be produced for a subset of countries and years
  - Due to data availability

Direct and indirect estimate of energy R&D and of energy R&D intensity