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The Political Economy of Energy Innovation

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- 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

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

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
 - Embedded capital R&D to the energy supply sector not included

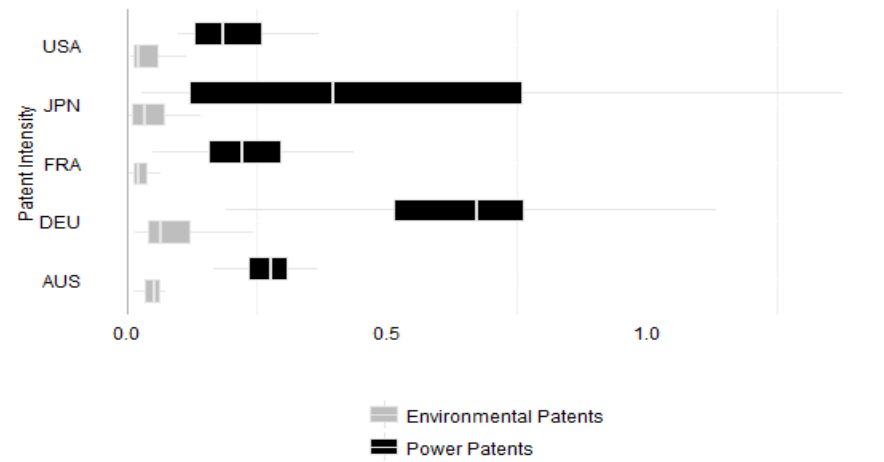
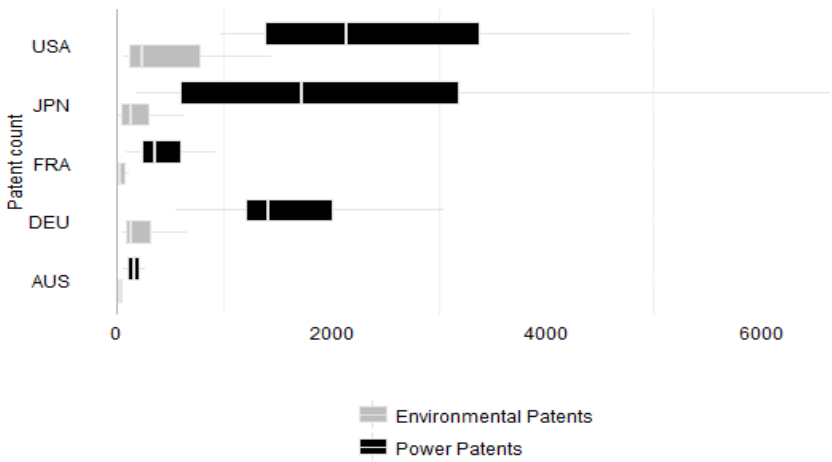
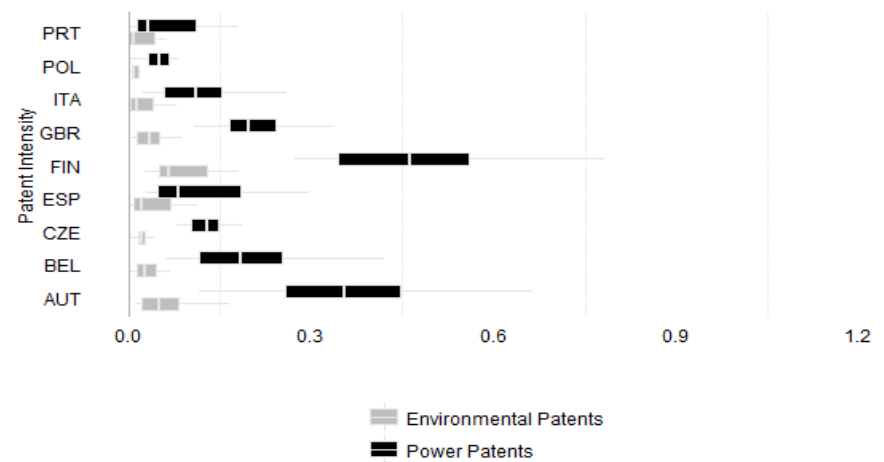
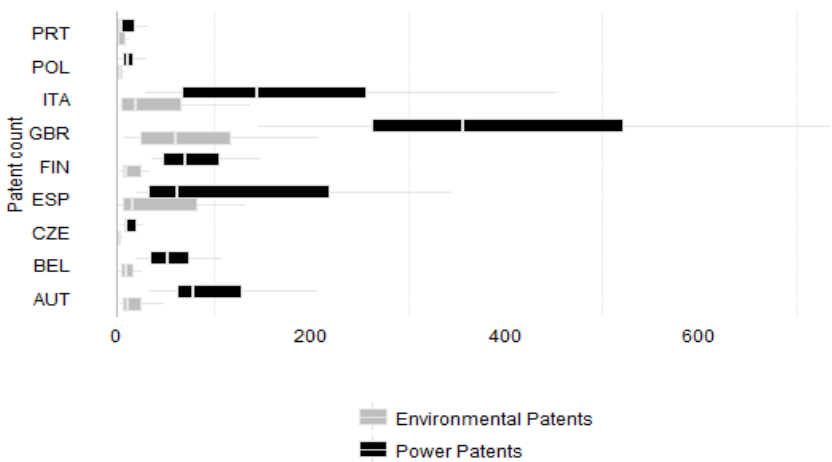
Measuring Energy Innovation: Patents

- 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

- 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



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

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*

Econometric Approach

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

y_{it} : energy innovation intensity of the economy

$\boldsymbol{\pi}_{it}$: 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

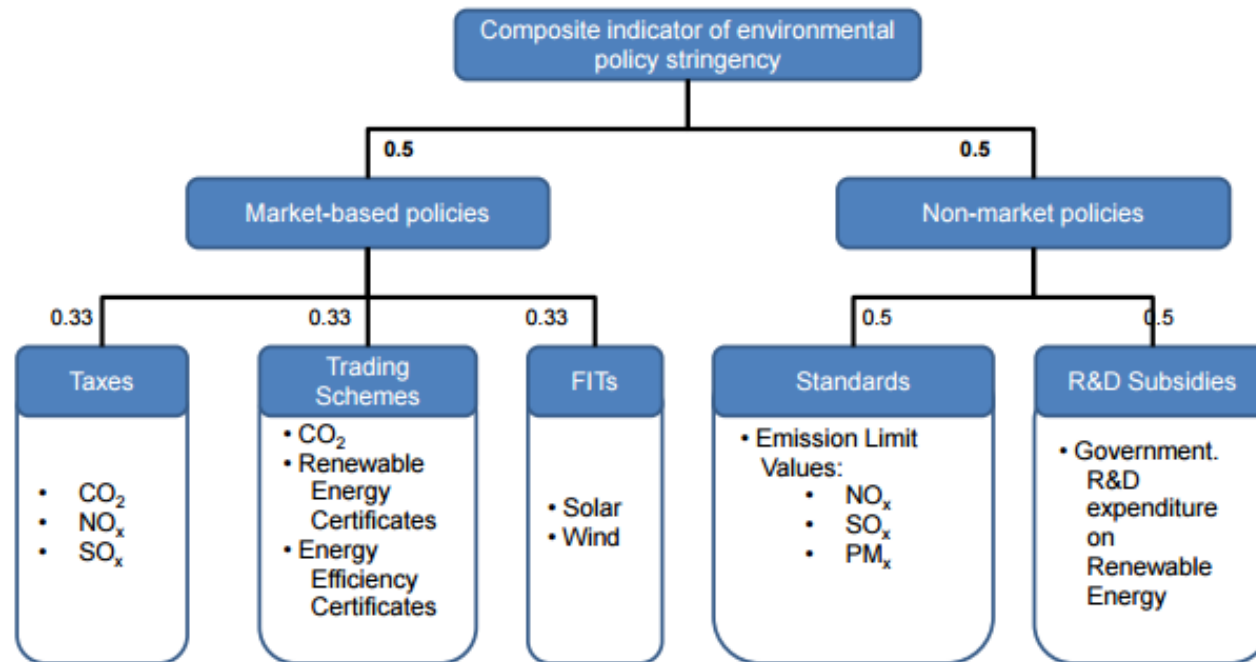
\mathbf{Z}_{it} : vector of other control variables, including industrial energy prices and trade openness

α_i and γ_t : country and year fixed effects

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

Environmental Policy Stringency

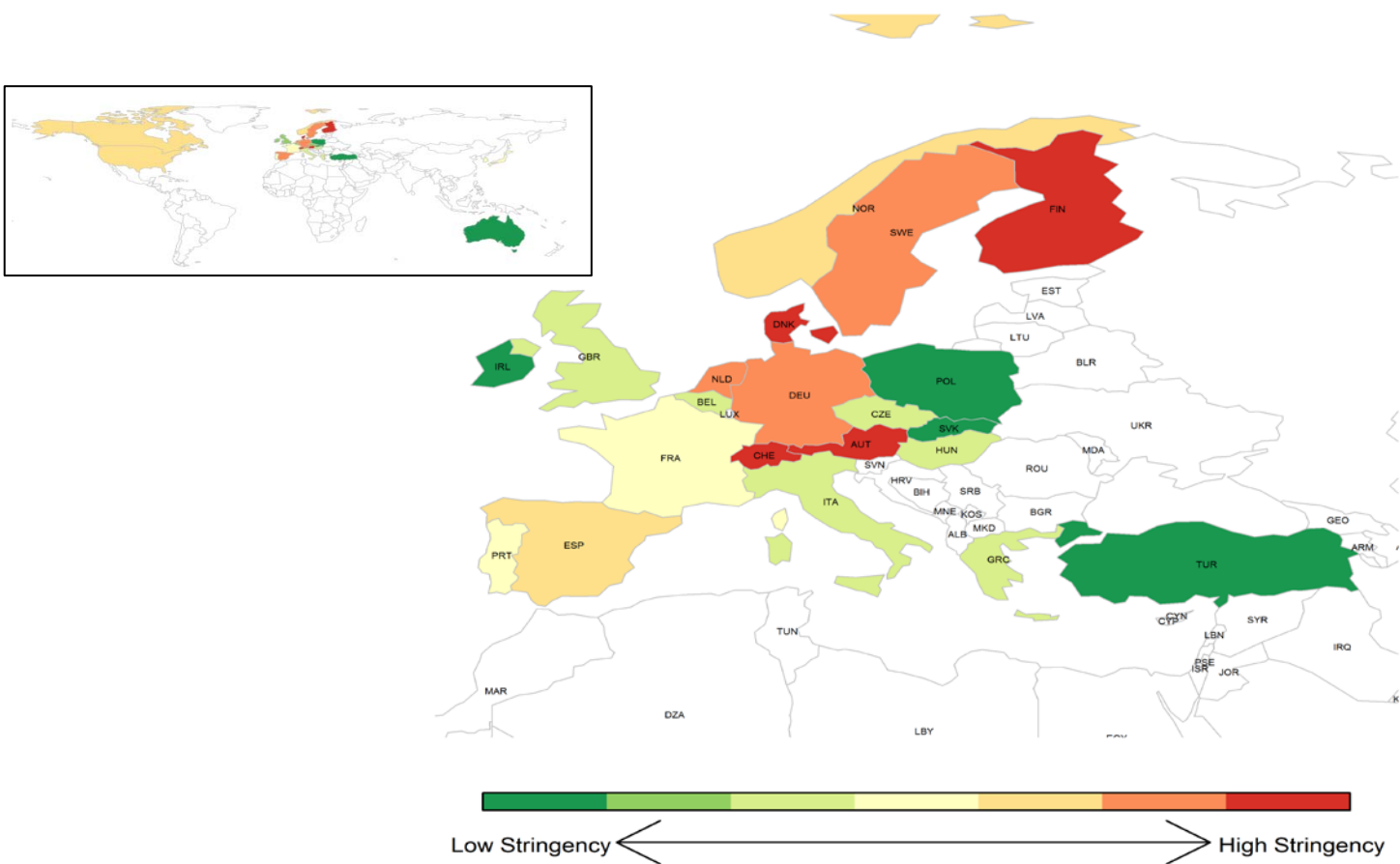
- Both market and non-market based environmental policies



- 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

Environmental Policy Stringency



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

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

Descriptive Statistics

Variable	Mean	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 Koźluk (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

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

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

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			
<i>H1</i> EPS Market Score	0.198+	0.189+	0.165			-0.006	-0.018		
	(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)
<i>H2</i> Govt. Effectiveness	0.964***	0.769**		0.619**	0.666*	0.399		0.409	0.549+
	(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)
<i>H3</i> 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)
<i>H4</i> VA Share Energy-intensive industries	0.710**	0.827**	0.814**	0.815**	0.822**	0.537+	0.525+	0.542+	0.553+
	(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				
<i>H1</i> EPS Market Score	0.013*** (0.005)	0.014*** (0.003)	0.013*** (0.007)			0.031*** (0.012)	0.032*** (0.007)	0.029** (0.016)		
EPS Non-market Score	0.012*** (0.004)	0.013*** (0.005)	0.015*** (0.001)			0.018+ (0.011)	0.018+ (0.110)	0.023** (0.046)		
EPS Total Score				0.017*** (0.000)	0.004 (0.587)			-0.007	0.030** (0.011)	0.020 (0.277)
<i>H2</i> Govt. Effectiveness	0.069*** (0.013)	0.070*** (0.000)		0.065*** (0.000)	0.045*** (0.003)	0.211*** (0.033)	0.212*** (0.000)		0.199*** (0.000)	0.183*** (0.000)
WGI			0.095*** (0.000)					0.313*** (0.000)		
Govt. Effectiveness*EPS Interaction					0.015** (0.010)					0.012 (0.416)
<i>H3</i> Political Orientation	-0.002 (0.003)	-0.002 (0.395)	-0.002 (0.379)	-0.002 (0.330)	-0.002 (0.514)	-0.006 (0.006)	-0.007 (0.286)	-0.007 (0.314)	-0.008 (0.212)	-0.007 (0.256)
<i>H4</i> VA Share Energy-intensive industries	-0.003 (0.014)	-0.009 (0.546)	-0.009 (0.557)	-0.012 (0.419)	-0.012 (0.380)	-0.048 (0.035)	-0.061* (0.089)	-0.058+ (0.114)	-0.068* (0.061)	-0.069* (0.059)
Energy price index		0.025 (0.338)	0.016 (0.544)	0.024 (0.367)	0.027 (0.309)		0.058 (0.390)	0.032 (0.640)	0.053 (0.431)	0.056 (0.413)
Trade Openness		-0.000 (0.170)	-0.000+ (0.130)	-0.000 (0.175)	-0.000 (0.277)		-0.001 (0.180)	-0.001+ (0.127)	-0.001 (0.189)	-0.001 (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

- 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

- 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

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

- 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

