Modeling Energy Regimes:

A Quantitative and Qualitative Study of Energy Choice Across Countries

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Energy Production and Usage

- What determines how countries use and produce energy?
- Germany has one of the highest levels of solar energy use, but the levels of sunshine are moderate. Why?
- Work experience in Chile and Bangladesh
- Previously existing work focuses on a micro-picture:
  - Industry specific studies
  - Technology specific work
  - Case studies
  - Local market forecasts
  - Effects of specific regulatory actions

Energy Production and Usage

- We lack a meta-theory and empirical evidence regarding the determinants of energy production and usage
- How to think systematically about questions of energy production and usage?
- Energy Regimes: " I define an energy regime as a set of conditions, which describe the interaction of energy supply and demand in given country at a given time"

Energy Production and Usage

- How to measure energy regimes?
  - Clean Energy
  - Fossil Fuels
  - Energy Efficiency
  - Carbon Intensity

- Describing economic and environmental characteristics of an energy regime in developing and developed countries

- Research Question:

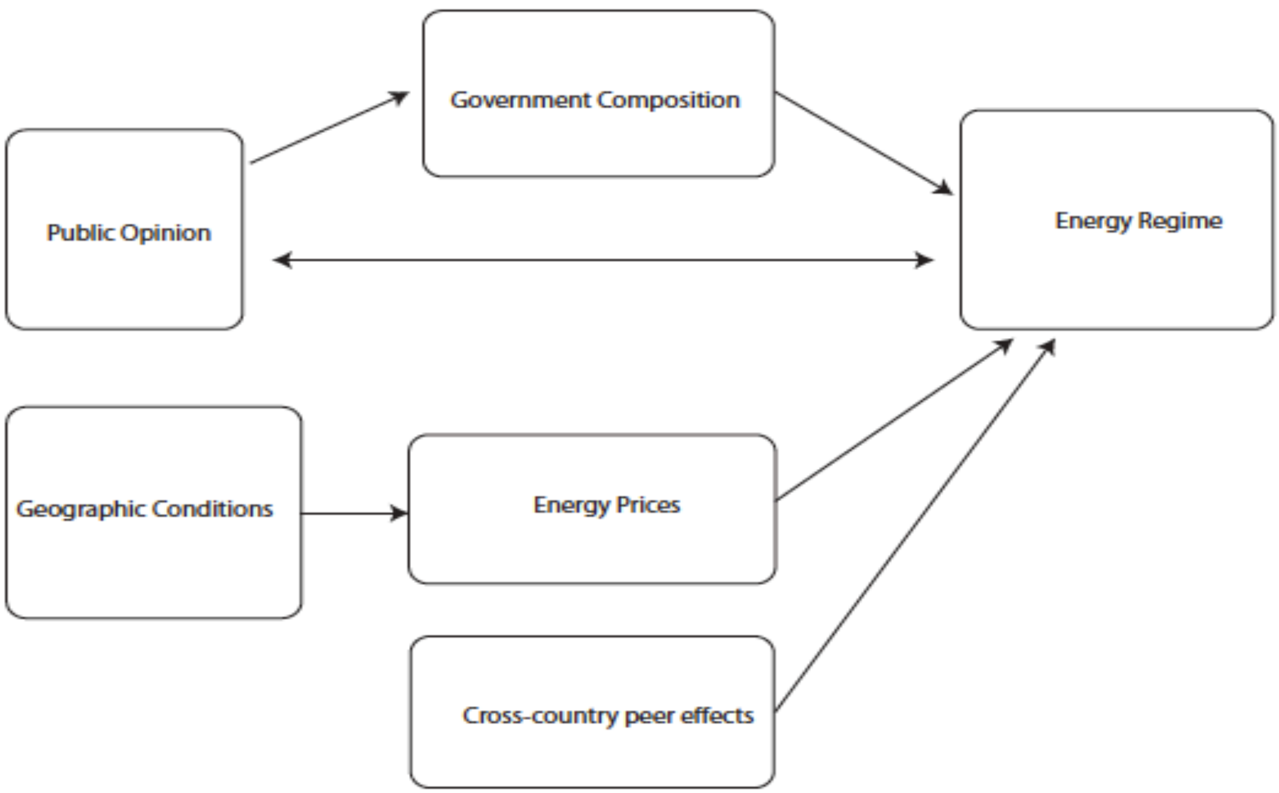
  "I ask what variables determine how an energy regime, as measured by these four dependent variables, develops in a given country?"

Theory

Three Clusters of Theory:

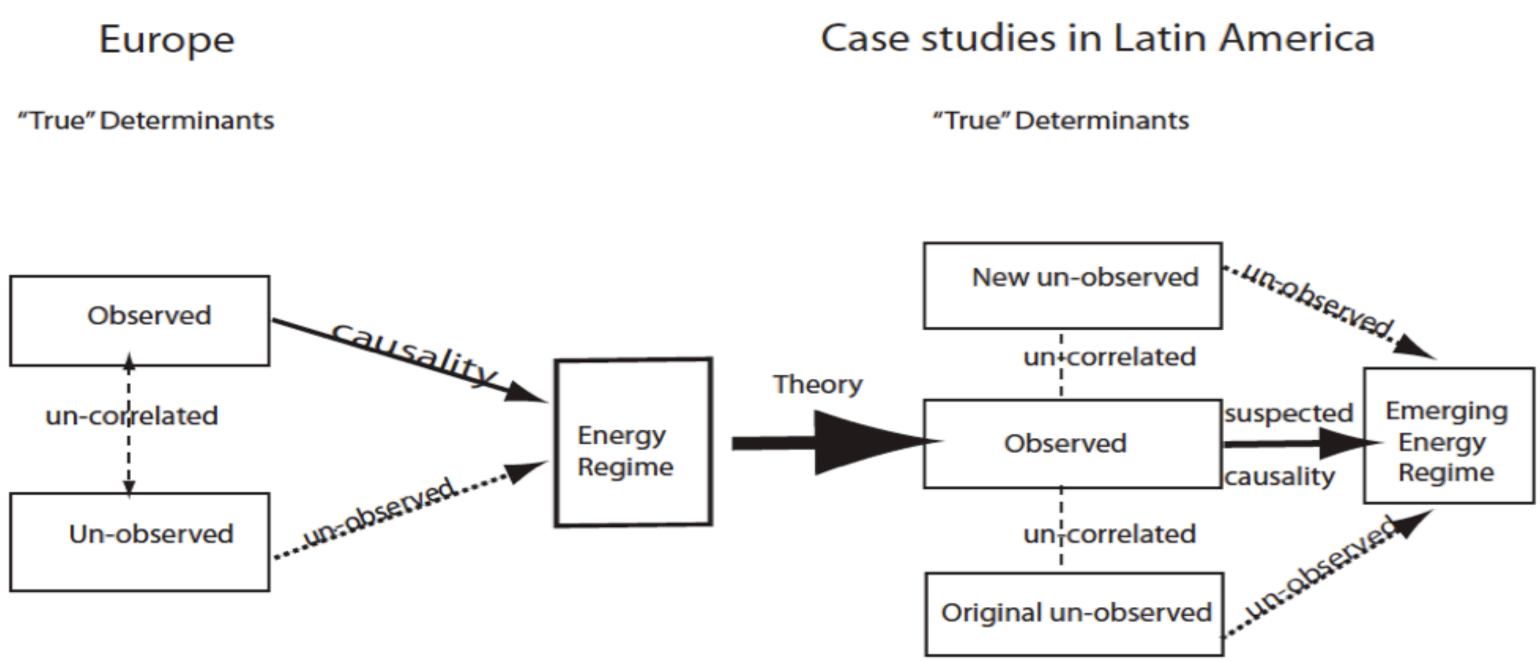
- Theories of Rational Decision-Making (standard economic theory and realist IR theory)
- Theories of Mutual Actor Interdependence (Krasnerian regime theory, economic theories of conformism, herding and cooperation)
- Theories of Ideation and Popular Opinion (Constructivism and theories of democratic decision-making)

Hypotheses


Government Composition
Public Opinion
Energy Regime
Geographic Conditions
Energy Prices
Cross-country peer effects

Research Design

Figure1.3 –Research Design



Quantitative Approach

- The Dataset:
  - Dependent Variables — Energy Efficiency, Share of Clean Energy, Share of Fossil Fuels and CO2 Intensity (World Development Indicators)
  - Independent Variables:
  - Schmidt-Index (Schmidt et al.)
  - Energy Price Data (IEA)
  - Opinion Data (WVS/EVS)
  - Geography / Suitability to development of renewable energy (IEA and EEA)
  - Peer-Effects / Krasnerian Variable

Quantitative Approach

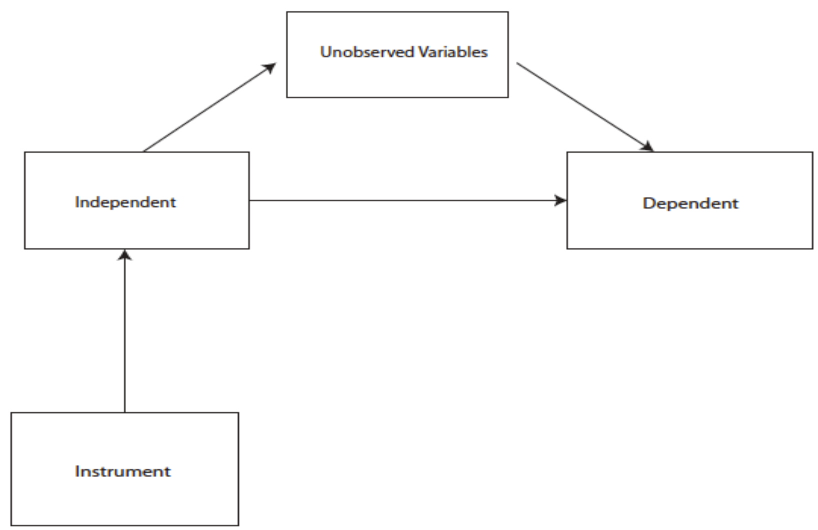
- A linear regression model (OLS) of the determinants of energy regimes:

$$Y = \beta_0 + \beta_1 \ln(GDP)_{c,t} + \beta_2 Schmidt_{c,t}$$
$$+\beta_3 Krasnerian_{c,t} + \beta_4 solar_c + \beta_5 wind_c + price'_{c,t}\gamma + \varepsilon_{c,t}$$

- Three types of specifications
  - Ordinary Least Square — Endogenous predictors
  - Fixed Effects — Statistical Power
  - Instrumental Variables — Instrument Relevance & Exclusion Restriction

Quantitative Approach

- Solving the issue of endogenous predictors:



Instruments:

- R&D Expenditure for Electricity Prices
- Country Size for Gas Prices
- Neighbor’s government for Peer-Effects

OLS & FE Specifications

	OLS	FE	OLS	FE	OLS	FE	OLS	FE	OLS	FE
VARIABLES	Cleanenergy		Fossilfuels		Energyefficiency		CO2intensity		Energy Use	
Household Electricity Prices (cent/kwh)	-2.088***	0.114	1.518***	-0.139	0.156***	0.0407	0.0235*	-0.00642	-75.36***	-11.59
	(0.285)	(0.0971)	(0.294)	(0.122)	(0.0378)	(0.0254)	(0.0128)	(0.00513)	(22.79)	(13.38)
Industry Natural Gas ($ per 10^7kcal)	0.0604**	0.000698	-0.0311	-0.00325	0.000533	0.00169*	0.000409	0.000192	0.919	1.014
	(0.0259)	(0.00242)	(0.0210)	(0.00544)	(0.00244)	(0.000866)	(0.000815)	(0.000201)	(1.462)	(0.693)
Industry Diesel Fuel ($ per litre)	11.95*	-0.643	-5.447	-0.945	-1.748*	-0.229	-0.733***	-0.0605	669.0	-101.4
	(6.639)	(0.991)	(6.443)	(2.303)	(0.910)	(0.751)	(0.263)	(0.105)	(558.3)	(177.8)
Mean Political Opinion	-22.87***		5.226		0.880*		0.486***		-265.9	
	(3.432)		(3.316)		(0.475)		(0.159)		(244.3)	
Mean Environmental Opinion	42.80***		-19.77**		-2.667***		-0.366		-368.1	
	(9.743)		(9.514)		(0.808)		(0.393)		(705.9)	
Maximum Solar Irradiation (kwh/kwp)	-0.00782		-0.0153**		0.00413***		-0.000241		-1.701***	
	(0.00560)		(0.00638)		(0.00101)		(0.000334)		(0.568)	
Wind Energy Cost Index	0.313		-6.124***		0.169		-0.172**		158.1*	
	(1.126)		(1.539)		(0.165)		(0.0771)		(93.96)	
Time trend	-0.779*	-0.0796	0.262	0.0553	-0.0281	0.0259	0.0296*	-0.0150**	-11.57	80.52***
	(0.461)	(0.0910)	(0.448)	(0.129)	(0.0537)	(0.0274)	(0.0175)	(0.00637)	(35.92)	(19.43)
LN GDP (per capita)	3.060	1.027	-1.741	0.418	0.951***	0.405	-0.340***	0.0689	713.5***	101.1
	[illegible]	[illegible]	(2.415)	(2.213)	(0.251)	(0.438)	(0.0919)	(0.106)	(177.7)	(149.6)
Schmidt-Index (5yr lag)	1.362**	0.205	-1.653***	-0.297	-0.0733	-0.0471	-0.0555***	-0.00715	22.44	11.02
	(0.570)	(0.197)	(0.524)	(0.214)	(0.0635)	(0.0467)	(0.0193)	(0.00899)	(34.47)	(19.76)
Neighbor_Cleanenergy	0.357***	0.211							2.390	-57.51**
	(0.0851)	(0.148)							(19.54)	(21.16)
Neighbor_Fossilfuels			0.853***	0.251					-18.13	-23.65
			(0.103)	(0.190)					(16.39)	(25.90)
Neighbor_Energyefficiency					0.662***	0.742***			-110.5*	-182.4***
					(0.113)	(0.202)			(60.32)	(57.33)
Neighbor_CO2intensity							0.774***	0.323*	-756.8	377.0
							(0.122)	(0.179)	(571.3)	(499.9)
Constant	34.72	-0.122	77.60**	60.46***	-10.01**	-2.996	2.406	1.849**	5,516*	3,128
	(24.18)	(16.02)	(32.47)	(17.02)	(3.927)	(4.424)	(1.552)	(0.821)	(3,111)	(2,376)
Observations	134	134	134	134	134	134	134	134	134	134
R-squared	0.542	0.153	0.696	0.229	0.632	0.807	0.659	0.513	0.773	0.655
Number of countries		15		15		15		15		15

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

IV Specifications

VARIABLES	IV Cleanenergy	IV Fossilfuels	IV Energyefficiency	IV CO2intensity
Industry Natural Gas ($ per 10^7kcal)	0.157***	0.106	-0.0383***	0.00119
	(0.0467)	(0.109)	[illegible]	(0.00249)
Household Electricity Prices (cent/kwh)	-3.081***	-1.022	0.580***	-0.00153
	(0.701)	(1.521)	(0.174)	(0.0267)
Industry Diesel Fuel ($ per litre)	1.299	-31.03	[illegible]**	-0.922
	(13.53)	(22.94)	(3.802)	(0.666)
Mean Political Opinion	-33.54***	1.800	0.902	0.439*
	(4.866)	(8.161)	(0.795)	(0.231)
Mean Environmental Opinion	70.10***	9.705	-3.832	-0.719
	(15.28)	(36.87)	(2.937)	(1.357)
Maximum Solar Irradiation (kwh/kwp)	-0.0177	-0.0654*	0.00830***	-0.000550
	(0.0153)	(0.0378)	(0.00305)	(0.00119)
Wind Energy Cost Index	2.951	-18.35***	1.340***	-0.331*
	(2.369)	(6.934)	(0.458)	(0.197)
Time trend	-1.962**	-0.301	0.465***	0.0236
	(0.869)	(1.190)	(0.172)	(0.0358)
LN GDP (per capita)	0.674	4.006	1.809**	-0.0401
	(8.552)	(10.65)	(0.822)	(0.410)
Schmidt-Index (5yr lag)	2.009***	-2.385***	0.0281	-0.0772***
	(0.505)	(0.747)	(0.139)	(0.0169)
Electric power transmission and distribution losses (% of output)	1.882*	-0.00858	0.558	-0.00441
	(0.994)	(1.479)	(0.369)	(0.0382)
Neighbor_Cleanenergy	0.743***			
	(0.227)			
Neighbor_Fossilfuels		1.708***		
		(0.374)		
Neighbor_Energyefficiency			-1.513***	
			(0.586)	
Neighbor_CO2intensity				1.050***
				(0.384)
Constant	81.70	55.62	-39.54***	1.410
	(65.58)	(102.1)	(14.11)	(2.520)
Observations	97	97	97	97
R-squared	0.617	0.427	-0.133	0.619

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Chile

- Interviews with President Lagos and César Morales
- Largely confirms findings from quantitative analysis
  - Argentine Gas Crisis
  - Perception of mining industry as environmentally sustainable
  - Membership in associations such as OECD

Brazil

- Case study based on primary and secondary sources
- Concoction of factors leads to regime change towards bioethanol in the 1970s:
  - Oil crises of the 1970s (very strong price signal)
  - Poor economic conditions
  - Geo-economic suitability (large sugarcane industry)
  - *Programa Nacional do Álcool (1974)*
  - Industry cooperation: Fiat 147

Conclusion & Implications

- Practical Implications:
  - Historical Anchoring of Energy Trajectories
  - The Effect of Government Composition on Energy Trajectories
  - The Effect of Energy Prices on Energy Trajectories
  - The Significance of Peer Effects in Shaping Energy Trajectories

  Implications for forecasting, international understanding and potential for efficiency gains through cooperation

Conclusion & Implications

- Theoretical and Methodological Implications:
  - The Concept of Energy Regimes and the Meta-Model of Energy Trajectories
  - Explanatory value of Krasnerian regime theory
  - Use of instrumental variables in cross-country studies; in particular to test the relevance of regimes
- Future research on the role of opinions and geography, drivers of Krasnerian regimes and non-linear models of energy choice