Renewable vs. Efficient Fossil Investments: are they complements or substitutes?

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Motivation and Background

- To lower CO2 emissions and help in creating employment, policies in support of Renewable Energy (RE) should spur investments in these technologies.
- However, recent research has mainly focused on determinants of RE innovations rather than investments.

Motivation and Background (2)

- Incentives to invest in RE technology cannot be seen in isolation.

- Besides on policies, the success of RE investments will depend on their compatibility with regulatory framework and existing technologies.

Motivation and Background (3)

- RE and efficient fossil (EF) can be seen as alternative option to reduce GHGs in the electricity sector.

- RE techs are certainly substitutes to coventional fossil fuel techs: small scale vs. large scale, different competences and know-how.

- REs are intermittent and need backup capacity that can be more easily provided by smaller and quick-to-start EF technologies.

  - ➢ Therefore, while we expect to observe substitutability btw old fossil and RE, we cannot say the same for EF.
  - ➢ The relation of complementarity or subsitutability btw RE and EF remains an empirical one.

Aims

- We investigate the determinants of investments in RE and EF capacity expressed as share of total capacity.

- In doing so, we expand upon previous research by allowing for cross-technology complementarity and adding regulatory proxies and richer set of policies for both RE and EF.

Main Drivers and Method

- Besides cross-technology complementarity, other variables matter:

  Policies

  - feedin tariffs (only for renewables);
  - a index for the other policies in support of EF and RE;
  - three indexes of market liberalization: PMR entry, PMR privat, PMR unbundling; <> changed regulatory framework.

  Features of Electricity Sector

  - a index of energy dependency and share of nuclear production;
  - change in electricity consumption;
  - age of capital and proxies for technological progress in RE and EF.

- The coefficients are estimated using fixed effect regressions, to depurate from unobservable country characteritics.
- The explanatory variables are lagged one year.

Data sources

Long-run correlations

	Δ (Capacity RE)	Δ(Capacity EF)
Δ (Capacity RE)	1	
Δ(Capacity EF)	**0.9051**	1
Δ (Capacity Old Foss.)	**-0.1951**	**-0.3695**
Δ(Nuclear)	**-0.3724**	-0.0175
Δ(Energy Dependence)	**0.1323**	**0.1309**
Δ(Average Age)	0.0205	0.1372
Δ(RE Policy Index)	0.0107	-0.0581
Δ(EF Policy Index)	-0.2183	-0.3123
Δ(Feedin Solar&Wind)	**0.2512**	-0.185
Δ(Feedin Biomass)	-0.0138	-0.1892
Δ(PMR - entry)	-0.0506	0.0494
Δ(PMR - public)	**-0.2813**	0.0413
Δ(PMR - vertical integration)	**0.1979**	**0.2815**

Baseline Results

	(1)	(2)
Dependent variable	Δ in Capacity (percent)	Δ in Capacity (percent)
Technology	Fossil Efficient	Renewable
Log(GDP per capita) (i, t-1)		
Δ Energy Consumption (i, t-1)	- -	
Nuclear Capacity (i, t-1)	+	
Energy Dependence (i, t-1)		++
Log(Average age of capital) (i, t-1)	-	+++
Policy Index (i, k, t-1)		+
Feed-in Solar (i, t-1)		+++
PMR - entry (i, t-1)		-
PMR -public (i, t-1)	-	
PMR - vertical integration (i, t-1)		
PMR - gas (i, t-1)		
Percent capacity in j≠k (i, j, t-1)		+
Log(Own Knowledge Stock) (i, k, t-1)		
Log(Global Knowledge Stock) (k, t-1)	+	
N	426	431
R-squared	0.0643	0.3096

Counterfactuals

	(1)	(2)	(3)	(4)
Dependent variable	Δ in Capacity (percent)	Δ in Capacity (percent)	Δ in Capacity (per capita)	Δ in Capacity (per capita)
Technology	Fossil Efficient	Renewable	Biomass	Wind
Log(GDP per capita) (i, t-1)				
Δ Energy Consumption (i, t-1)				
Nuclear Capacity (i, t-1)	+ +			
Energy Dependence (i, t-1)		+		+ +
Log(Average age of capital) (i, t-1)	-	+ +		+ + +
Policy Index (i, k, t-1)		+		
Feed-in Solar (i, t-1)		+ +	+ +	+ +
PMR - entry (i, t-1)		-		
PMR -public (i, t-1)		+		
PMR - vertical integration (i, t-1)		+		+
PMR - gas (i, t-1)				
Percent capacity in old fossil (i, j, t-1)	+ +	- -		
Percent capacity in j≠k (i, j, t-1)				+
N	426	431	431	431
R-squared	0.117	0.328	0.0674	0.3072

Policy Interactions

Dependent variable	Δ in Capacity (percent)	Δ in Capacity (percent)	Δ in Capacity (percent)
Technology	Renewable	Renewable	Renewable
Log(GDP per capita) (i, t-1)			
Δ Energy Consumption (i, t-1)			
Nuclear Capacity (i, t-1)			
Energy Dependence (i, t-1)	+ + +	+ +	+ +
Log(Average age of capital) (i, t-1)	+	+ + +	+ +
Policy Index (i, k, t-1)	+ +	+ +	+
Feed-in Solar/Wind (i, t-1)	+ + +	+ + +	
PMR - entry (i, t-1)			-
PMR -public (i, t-1)			
PMR - vertical integration (i, t-1)	+	+	+
Percent capacity in j≠k (i, j, t-1)	+	+	0.0096 [0.010]
PMR - entry * Feed-in (i, t-1)	- - -		
PMR - public * Feed-in (i, t-1)		- -	
EF capacity * Feed-in (i, j, t-1)			+
N	431	431	431
R-squared	0.365	0.3393	0.3486

Quantification on RE investments

	% Total Capacity	% Renewable Capacity
Capacity in EF, increase of one std dev. (10% of tot.)	0.2%	6.1%
Feedin solar-wind, increase of one std dev. (7% of price)	0.3%	10.9%
RE policy, inter-quartile change	0.3%	10.0%
PMR entry, inter-quartile change	0.5%	15.0%
PMR pub, inter-quartile change	0.3%	10.0%
Feedin and PMR entry, both change	1.2%	39.9%
Feedin and Capacity, both change	0.4%	13.3%

Summary of findings

- RE and EF investments are complements, while RE and old fossil ones are substitutes.

- Quantitatively, the main driver of RE investments is the combination of feedin tariffs and entry barrier reductions.

- Policy in support of EF seems not very effective and the predictive power of our empirical model is poor for EF.

Baseline Results

	(1)	(2)
Dependent variable	Δ in Capacity (percent)	Δ in Capacity (percent)
Technology	Fossil Efficient	Renewable
Log(GDP per capita) (i, t-1)	0.017	0.006
	[0.030]	[0.012]
Δ Energy Consumption (i, t-1)	-0.0011**	0.0002
	[0.000]	[0.000]
Nuclear Capacity (i, t-1)	0.1017*	-0.0164
	[0.058]	[0.020]
Energy Dependence (i, t-1)	-0.0018	0.0015**
	[0.004]	[0.001]
Log(Average age of capital) (i, t-1)	-0.0390*	0.0071***
	[0.021]	[0.003]
Policy Index (i, k, t-1)	0.0031	0.0009*
	[0.002]	[0.000]
Feed-in Solar (i, t-1)		0.0466***
		[0.013]
PMR - entry (i, t-1)	0.000	-0.0007+
	[0.001]	[0.000]
PMR -public (i, t-1)	-0.0059+	-0.0012
	[0.003]	[0.001]
PMR - vertical integration (i, t-1)	0.000	0.0009
	[0.002]	[0.001]
PMR - gas (i, t-1)	0.0053	
	[0.004]	
Percent capacity in j≠k (i, j, t-1)	0.0133	0.0179*
	[0.058]	[0.010]
Log(Own Knowledge Stock) (i, k, t-1)	0.0023	0.0012
	[0.007]	[0.001]
Log(Global Knowledge Stock) (k, t-1)	0.0703*	0.0021
	[0.041]	[0.014]
N	426	431
R-squared	0.0643	0.3096

Counterfactuals

	(1)	(2)	(3)	(4)
Dependent variable	Δ in Capacity (percent)	Δ in Capacity (percent)	Δ in Capacity (per capita)	Δ in Capacity (per capita)
Technology	Fossil Efficient	Renewable	Biomass	Wind
Log(GDP per capita) (i, t-1)	0.0224	0.0065	0.0004	0.0056
	[0.040]	[0.012]	[0.002]	[0.014]
Δ Energy Consumption (i, t-1)	-0.0006	0.0002	0	0.0002
	[0.001]	[0.000]	[0.000]	[0.000]
Nuclear Capacity (i, t-1)	0.1249**	-0.0228	-0.0085	-0.0094
	[0.054]	[0.024]	[0.012]	[0.021]
Energy Dependence (i, t-1)	-0.0011	0.0015*	0.0001	0.0015**
	[0.003]	[0.001]	[0.000]	[0.001]
Log(Average age of capital) (i, t-1)	-0.0440+	0.0065**	0.0003	0.0080***
	[0.026]	[0.002]	[0.002]	[0.003]
Policy Index (i, k, t-1)	0.0025	0.0010*	0.0002	0.0007
	[0.003]	[0.000]	[0.000]	[0.000]
Feed-in Solar (i, t-1)		0.0469***	0.0221**	0.0328**
		[0.013]	[0.008]	[0.014]
PMR - entry (i, t-1)	0.0002	-0.0008*	0.000	-0.0007
	[0.001]	[0.000]	[0.000]	[0.000]
PMR -public (i, t-1)	-0.0038	-0.0015+	0	-0.001
	[0.003]	[0.001]	[0.000]	[0.001]
PMR - vertical integration (i, t-1)	-0.0007	0.0011*	-0.0001	0.0009+
	[0.002]	[0.001]	[0.000]	[0.001]
PMR - gas (i, t-1)	0.0019			
	[0.004]			
Percent capacity in old fossil (i, j, t-1)	0.0937**	-0.0240**		
	[0.045]	[0.011]		
Percent capacity in j≠k (i, j, t-1)			-0.0017	0.0187*
			[0.003]	[0.010]
N	426	431	431	431
R-squared	0.117	0.328	0.0674	0.3072

Policy Interactions

Dependent variable	Δ in Capacity (percent)	Δ in Capacity (percent)	Δ in Capacity (percent)
Technology	Renewable	Renewable	Renewable
Log(GDP per capita) (i, t-1)	0.0087	0.0077	0.0082
	[0.011]	[0.012]	[0.012]
Δ Energy Consumption (i, t-1)	0.0002	0.0002	0.0002
	[0.000]	[0.000]	[0.000]
Nuclear Capacity (i, t-1)	-0.0227	-0.0009	-0.0068
	[0.021]	[0.019]	[0.017]
Energy Dependence (i, t-1)	0.0015***	0.0015**	0.0016**
	[0.001]	[0.001]	[0.001]
Log(Average age of capital) (i, t-1)	0.0047*	0.0071***	0.0076**
	[0.002]	[0.002]	[0.003]
Policy Index (i, k, t-1)	0.0011**	0.0011**	0.0008*
	[0.001]	[0.000]	[0.000]
Feed-in Solar/Wind (i, t-1)	0.0601***	0.0915***	0.0171
	[0.014]	[0.029]	[0.014]
PMR - entry (i, t-1)	-0.0003	-0.0007	-0.0008+
	[0.000]	[0.001]	[0.000]
PMR -public (i, t-1)	-0.0003	-0.0004	-0.0009
	[0.001]	[0.001]	[0.001]
PMR - vertical integration (i, t-1)	0.0010*	0.0008+	0.0009*
	[0.001]	[0.001]	[0.001]
Percent capacity in j≠k (i, j, t-1)	0.0185*	0.0163+	0.0096
	[0.010]	[0.010]	[0.010]
PMR - entry * Feed-in (i, t-1)	-0.0147***		
	[0.005]		
PMR - public * Feed-in (i, t-1)		-0.0113**	
		[0.005]	
EF capacity * Feed-in (i, j, t-1)			0.2906*
			[0.157]
N	431	431	431
R-squared	0.365	0.3393	0.3486

Data sources of main variables

- Installed Capacity: IEA Electricity Information Database (IEA, 2013a) and the IEA Renewable Energy Sources database (IEA 2013b).
- RE and EF policies- IEA renewable energy dataset.
- PMR- indexes of product market regulation of the OECD.
- Feedin tariffs, see Nicolli and Vona (2012).