SUSTAINABLE ENERGY TRANSITION AND POLICY MIX DESIGN IN THE EUROPEAN UNION

A TRADE-BASED SUPPLY VALUE CHAIN APPROACH

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OUTLINE

- Sustainable energy transition
- Policy mix
- Beyond national boundaries
- Focus: Energy efficiency in residential sector
- Empirical analysis

SUSTAINABLE ENERGY TRANSITION

- "Structural change in how energy services are created, delivered and used" (Rosenow et al., 2017).
- Complex and uncertain process that involves a radical modification in production, consumption and innovation systems as well as in the regulatory and institutional dynamics, economic structure and industrial dynamics (Foxon, 2011).
- Need to address market and system failures, multiple barriers, lock-in, path dependencies and resistance to change, which require strategic policy efforts and adequate policy mix to drive technological regime shifts, encompassing progress in technology, changes in consumer behaviour and institutional framework (Rogge et al., 2017).

POLICY MIX AND INNOVATION

- *PORTER HYPOTHESIS*: environmental regulation may enhance environmental sustainability and economic competitiveness because of the induced effects on innovation (Porter and van der Linde, 1995).
- *ENERGY TECHNOLOGICAL INNOVATION SYSTEM*: include all aspects of energy system and all stages technology development & innovation process, knowledge creation, entrepreneurial activities, research, market formation & feedbacks, actors, networks (Hekkert et al., 2007; Grubler et al., 1998).
- *POLICY MIX*: the ability of stringent environmental policies of leading to a more sustainable economic system and acquiring structural competitive advantage is subject to the existence of a supporting and coevolving policy framework (EEA, 2013).

BEYOND NATIONAL BOUNDARIES

- Policy induced eco-innovation can generate positive effects on environmental and economic performances of both national and foreign system (Ambec and Lanoie,2008; Costantini and Crespi, 2013; Costantini and Mazzanti, 2012; Markard and Wirth, 2008).
- Decisions and policy strategies adopted by other countries are likely to influence domestic performances through international knowledge and policy spillovers (Dechezleprêtre and Glachant, 2014; Costantini et al., 2017; Marin and Zanfei, 2019).

  → *potential market for eco-innovation & knowledge spillovers for domestic technological capabilities (Peters et al. 2012); knowledge cooperation and proximity and technological developments (Franco et al., 2014; Quatraro and Usai, 2017)*

- International trade: further channel for technological knowledge transfer and diffusion of innovation (learning by exporting, market integration and sustainable supply chains)

  → *exporters might be induced to innovate because they are active in export markets → learning effect and foreign demand effect (Andersson and Loof, 2009; Fassio, 2018)*

AIM OF THE PAPER

To understand if and to what extent a policy mix designed to foster a sustainable energy transition jointly ensures benefits on international competitiveness accounting for policy strategies adopted by other countries.

- Focus on EE technologies for the residential sector
- EE performances depend on the structural characteristics of countries and are linked to innovation in energy-efficient technologies and policy measures for generation, adoption and diffusion.

  - large # implemented policies
  - EE gains are strictly connected to diffusion and adoption of technologically advanced devices by private consumers
  - high EU market integration → international spillovers

EMPIRICAL STARTEGY

GRAVITY MODEL

to analyse the role of policy mix and innovation with respect to trade competitiveness jointly considering the domestic and foreign influence.

- potential bias induced by the existence of many zeros in trade flows (not randomly distributed since they depend on structural factors) → Heckman's two-stage procedure to account for selection and heterogeneity biases, in terms of inverse Mills ratio and firms' heterogeneity (Helpman et al., 2008).
- persistency over time of trade data (sunk costs associated with entry and exit of the export markets and potential endogeneity of covariates) → Arellano–Bover/Blundell–Bond linear dynamic panel-data estimation (Blundell and Bond,1998).

EMPIRICAL STARTEGY - data

BILATERAL DATASET (19x19 EU COUNTRIES 1990-2015) → EE technologies for residential sector

- *EXPORT (UN Comtrade-WITS SITC Rev.3):*
  household-type laundry equipment, refrigerators & freezers, dishwashing machines, electromechanical and electrothermic appliances, boilers, lighting, shavers.
- *PATENT for EE technologies (PATSTAT):*
  lighting, heating, ventilation or air conditioning, home appliances, ICT and end-user technologies.
- *EE policy stock (IEA), EPS (OECD), RD&D in energy and EE (IEA), Energy Taxes and Prices (EUROSTAT);*
- *ENERGY: Residential energy consumption, production, heating and cooling days (EUROSTAT);*
- *Final consumption expenditure of households (EUROSTAT), GDP (OECD), Population (EUROSTAT);*
- *Common borders and bilateral Distance (CEPII)*

Appendix

EMPIRICAL STARTEGY - policy mix and similarity indicators

- ***Demand-pull***

$$Demand\_pull_{i,t} = HHDL\ consumption_{i,t} / \sum_{1}^{n} \left(HHLD\ Ener\_cons_{i,t}^{n}\right)$$

- ***Technology-push***

$$Technology\_push_{i,t} = KRD\_EE_{i,t} / \sum_{1}^{n} \left(HHLD\ Ener\_cons_{i,t}^{n}\right)$$

- ***Policy mix balance***

$$Pol.Balance_{i,t} = Demand\_pull_{i,t} - Technology\_push_{i,t}$$

- ***Similarity***

$$Similarity\_1_{ijt} = 1 - \left| ln\left(\frac{x_{it}}{x_{it}+x_{jt}}\right) - ln\left(\frac{x_{jt}}{x_{it}+x_{jt}}\right) \right|$$

ECONOMETRIC GRAVITY MODEL: 1ST stage

$$\rho_{ijt} = prob(Trade_{ijt})$$
$$= \beta_1 F_i + \beta_2 F_j + \beta_3 \tau_{ijt} + \beta_4 (1/dist_{ij}) + \beta_5 border_{ij} + \beta_6 eco\_simil_{ijt} + \beta_7 ene\_simil_{ijt}$$
$$+ \beta_8 policy\_simil_{ijt} + \varepsilon_{ijt}$$

- Country-specific time invariant effects (F_i and F_j);
- Country-pair specific time variant effects (τ_{ijt});
- Inverse of geographical distance ($dist_{ij}$);
- Dummy variable for existence of a common border ($border_{ij}$);
- Similarity in terms of residential consumption per capita (eco_simil_{ijt}), residential energy consumption per capita (ene_simil_{ijt}), EE policy stringency ($policy\_sim_{ijt}$);
- Error term (ε_{ijt}).

Extensive and Intensive margins:
fhet & IMR

2nd stage

ECONOMETRIC GRAVITY MODEL: 2ND stage

$$EXP_{ijt} = \tau_{ijt} + \sum_{p=1}^{n} \lambda_p exp_{ij,t-p} + \varphi_1 fhet_{ijt} + \varphi_2 IMR_{ijt} + \beta_4(1/dist_{ij}) + \beta_5 D_t + \beta_6 X_{it} + \beta_7 X_{jt} + \beta_8 simil\_X_{ijt} + \varepsilon_{ijt}$$

- Country-pair specific time variant effects (τ_{ijt});
- Extensive and Intensive margins from Ist stage equation (fhet and IMR);
- Inverse of geographical distance ($dist_{ij}$);
- Time dummy variables, as EU enlargement, crisis (D_t);
- Economic, innovation, policy, and energy variables for exporting country i (X_{it});
- Economic, innovation, policy, and energy variables for destination country j (X_{jt});
- Similarity between country i and j ($simil\_X_{ijt}$);
- Error term (ε_{ijt}).

	M1	M2	M3	M4	M5	M6
Exp(t-1)	0.755***	0.822***	0.762***	0.809***	0.799***	0.791***
	(0.027)	(0.034)	(0.026)	(0.020)	(0.020)	(0.021)
Extensive margin	0.000	0.053	0.024	0.227***	0.237***	0.137***
	(0.069)	(0.069)	(0.071)	(0.046)	(0.051)	(0.053)
Intensive margin	-0.002***	-0.003***	-0.002**	-0.002*	-0.002**	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Crisis	-0.078***	-0.069**	-0.085***	-0.063***	-0.061***	-0.064***
	(0.023)	(0.029)	(0.032)	(0.017)	(0.014)	(0.021)
1/distance	1.179***	1.254***	1.016***	0.691***	0.472***	0.619***
	(0.175)	(0.246)	(0.158)	(0.082)	(0.077)	(0.076)
Patent stock i	0.097***		0.098***	0.034*	0.035*	0.068***
	(0.025)		(0.025)	(0.020)	(0.018)	(0.015)
Patent stock j	-0.043*		-0.033*	-0.000	0.002	0.001
	(0.022)		(0.020)	(0.014)	(0.015)	(0.014)
Patent similarity		0.916***	0.559*	0.268	0.312*	0.555***
		(0.194)	(0.296)	(0.209)	(0.177)	(0.165)
Demand pull i				0.682***	0.689***	
				(0.108)	(0.120)	
Demand pull j				0.446***	0.418***	
				(0.091)	(0.079)	
Tech. push i				0.336***	0.499***	
				(0.117)	(0.120)	
Tech. push j				0.251***	0.436***	
				(0.097)	(0.110)	
Domestic balance similarity					1.439***	0.727**
					(0.313)	(0.300)
Domestic balance i						0.135**
						(0.056)
Domestic balance j						0.203***
						(0.061)
Constant	10.316***	10.287***	8.941***	6.163***	3.392***	5.344***
	(1.329)	(1.862)	(1.208)	(0.670)	(0.750)	(0.660)
Country-pair effect	yes	yes	yes	yes	yes	yes
N	8,229	8,229	8,229	8,229	8,229	8,229
Chi-sq	8,358	8,948	12,382	40,191	47,873	41,009
AR(1)	-7.17	-7.09	-7.22	-7.37	-7.35	-7.33
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
AR(2)	2.31	1.81	1.70	2.02	1.81	1.71
	(0.21)	(0.67)	(0.88)	(0.42)	(0.69)	(0.86)
Sargan	341.85	339.80	341.57	341.18	341.25	341.11
	(0.49)	(0.04)	(0.95)	(1.00)	(1.00)	(1.00)

Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

RESULTS (1)

	(1) M1	(2) M2	(3) M3	(4) M4	(5) M5	(6) M6
Exp(t-1)	0.790***	0.767***	0.760***	0.799***	0.778***	0.783***
	(0.021)	(0.021)	(0.023)	(0.023)	(0.021)	(0.023)
Extensive margin	0.207***	0.192***	0.118**	0.176***	0.177***	0.074
	(0.043)	(0.049)	(0.055)	(0.050)	(0.046)	(0.051)
Intensive margin	-0.001*	-0.002*	-0.002**	-0.002*	-0.002**	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Crisis	-0.051**	-0.051**	-0.043*	-0.071***	-0.068***	-0.069***
	(0.020)	(0.021)	(0.025)	(0.021)	(0.024)	(0.027)
1/distance	0.734***	0.536***	0.653***	0.740***	0.545***	0.655***
	(0.087)	(0.093)	(0.104)	(0.083)	(0.079)	(0.103)
Patent stock - bilateral	0.093***	0.080***	0.138***			
	(0.020)	(0.027)	(0.022)			
Patent stock CC mitigation - bilateral				0.088**	0.063	0.117***
				(0.037)	(0.043)	(0.033)
Demand pull i	0.643***	0.724***		0.715***	0.795***	
	(0.102)	(0.118)		(0.125)	(0.123)	
Demand pull j	0.244**	0.283**		0.372***	0.406***	
	(0.099)	(0.117)		(0.092)	(0.115)	
Tech. push i	0.211**	0.445***		0.285***	0.522***	
	(0.100)	(0.134)		(0.109)	(0.134)	
Tech. push j	0.023	0.289**		0.090	0.358***	
	(0.087)	(0.120)		(0.092)	(0.113)	
Domestic balance similarity		1.354***	1.076***		1.455***	1.029***
		(0.309)	(0.325)		(0.264)	(0.311)
Domestic balance i			0.078			0.079
			(0.080)			(0.082)
Domestic balance j			0.115			0.233**
			(0.099)			(0.093)
Constant	6.728***	4.233***	5.616***	6.715***	4.147***	5.655***
	(0.677)	(0.805)	(0.925)	(0.660)	(0.658)	(0.887)
Country-pair effect	yes	yes	yes	yes	yes	yes
N	8,229	8,229	8,229	8,229	8,229	8,229
Chi-sq	31,990	26,280	18,055	34,009	32,221	16,569
AR(1)	-7.31	-7.29	-7.21	-7.27	-7.30	-7.24
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
AR(2)	1.40	0.89	0.84	1.37	1.14	1.51
	(0.16)	(0.37)	(0.41)	(0.17)	(0.25)	(0.13)
Sargan	341.47	341.59	341.55	341.33	341.71	341.62
	(1.00)	(1.00)	(0.99)	(1.00)	(1.00)	(0.99)

Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

RESULTS (2)

RESULTS

- Domestic EE Patent stock (+)
- EE Patent stock similarity (+)
- Technological cooperation - bilateral patent (+)
- Domestic Demand pull (+) and Technology push (+)
- Foreign Demand pull (+) and Policy mix balance (+)
- Policy mix balance similarity (+)

EU enlargement (+); total patent stock; without distance; origin and destination country effects; policy indicators not normalized; gas and electricity residential energy consumption; feed-in-tariff origin and destination (-) country.

CONCLUSION

- Role of technology and policy mix
- Technological proximity and knowledge cooperation
- Policy mix and policy similarity

Next steps

- Heterogeneity by Household-type EE equipment
- Heterogeneity by technology
- Energy policy mix

Thank you for your attention!

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Code	Description
775.1 - Laundry	Household-type laundry equipment, n.e.s., whether or not electrical
775.2 – Refrigerators & Freezers	Household-type refrigerators and food freezers (electrical and other)
775.3 - Dishwashing	Dishwashing machines of the household type
775.4 - Shavers	Shavers and hair clippers, with self-contained electric motor, and parts thereof
775.7 – Electromechanical appliances	Electromechanical domestic appliances with self-contained electric motor; parts thereof (e.g., Vacuum cleaners, food grinders and mixers)
775.8 – Electrothermic appliances	Electrothermic appliances, n.e.s. (e.g., irons, electric ovens, electric space heating, electric water heaters)
812.1 – Boilers	Boilers etc non-electric
813.1 - Lighting	Lamps and lighting fittings (including searchlights and spotlights), n.e.s.

Source: WITS database; SITC Rev3 digit 775

EXPORT

data

Code	Description
PATENT	
PAT_LIGHT	Energy Efficiency lighting
PAT_HEAT	Energy Efficiency heating, ventilation or air conditioning
PAT_APPL	Energy Efficiency Home appliances
PAT_ICT	Energy Efficiency ICT
PAT_END_USE	Energy Efficiency end-user side
RDD	*Research, Development and Demonstration budget*
RDD_ENE	Total RD&D public budget in ENERGY
RDD_EFF_BUI	Total RD&D public budget in EE FOR THE BUILDING SECTOR

Sources: PATSTAT; IEA R&D Energy statistics.

PATENT

RD&D

data

Code	Description
Environmental Policy Stringency	
EPS	Environmental Policy Stringency index
Energy Efficiency policy measures	
ECO	Economic instruments
INFO	Information and education instruments
SUPP	Policy support instruments
REG	Regulatory instruments
RDD	Research, Development and Deployment instruments
VOL	Voluntary approach instruments
KPOL	Policy stock
Energy price and consumption	
PRICE	Prices for Household natural gas and electricity consumption
TAX	Taxes for Household natural gas and electricity consumption
ENE_CONS	Household energy consumption

Sources: OECD; IEA Energy Efficiency Policy and Measure database; EUROSTAT.

data

POLICY MIX

Code	Description
Hhld_cons	Final consumption expenditure of households
GDP	Gross Domestic product
POP	Population
BORDER	Common borders
DIST	Bilateral Distance (Weighted distances) calculate distance between two countries based on bilateral distances between the biggest cities of those two countries, those inter-city distances being weighted by the share of the city in the overall country's population

Sources: EUROSTAT; OECD; CEPII.

data

In order to account for self-selection of firms in export markets, and their impact on trade volumes where the decision to export is not independent of the volume of exports, the impact of trade frictions can be decomposed in:

- *INTENSIVE MARGIN (IMR) - trade volume per exporter (selection bias):* calculated in terms of inverse Mills ratio as the ratio between the probability density function of predicted values from probit estimation and the cumulative distribution function of predicted values.

- *EXTENSIVE MARGIN (fhet) - number of exporters (firms' heterogeneity)*: the characteristics of the marginal exporters towards different destinations can be identified from the variation in features of the destination countries and of observable bilateral trade costs. Calculated as $\hat{g}^{*}_{ijt} = \varphi^{-1}(\hat{\rho}_{ijt})$, where $\hat{\rho}_{ijt}$ is the predicted probability of export from *i* to *j and* φ cumulative distribution function of the unit-normal distribution.

	All EE Domestic equipment	Laundry equipment	Refrigerators & freezers	Dishwashing machines	Shavers	Electromech. appliances	Electrotherm. appliances	Electric lamps	Boilers	Lamps & lighting fittings
Similarity Residential Consumption per capita	2.205***	1.079***	0.880***	1.074***	1.445***	1.313***	1.724***	1.475***	1.363***	2.140***
	(0.213)	(0.093)	(0.092)	(0.096)	(0.103)	(0.107)	(0.141)	(0.118)	(0.103)	(0.180)
Similarity EE policy stringency	-0.092	-1.230***	-1.667***	-0.874***	-0.528***	-1.678***	-1.621***	-1.304***	-1.058***	-1.769***
	(0.299)	(0.112)	(0.122)	(0.104)	(0.108)	(0.140)	(0.196)	(0.170)	(0.129)	(0.257)
Similarity Residential Energy Consumption per capita	0.773*	-0.086	0.770***	-0.113	0.721***	-0.322	0.944***	0.452	0.686***	-0.164
	(0.412)	(0.236)	(0.250)	(0.244)	(0.250)	(0.265)	(0.354)	(0.302)	(0.251)	(0.409)
1/distance	0.373*	1.167***	0.890***	1.592***	1.573***	0.789***	0.508**	0.570***	0.846***	0.413*
	(0.200)	(0.156)	(0.151)	(0.168)	(0.168)	(0.166)	(0.199)	(0.171)	(0.151)	(0.214)
Contiguity	-0.140	-0.057	0.019	0.299	-0.146	-0.262	-0.313	-0.436	-0.541**	-0.091
	(0.301)	(0.257)	(0.246)	(0.278)	(0.271)	(0.281)	(0.320)	(0.285)	(0.258)	(0.341)
N	8892	8892	8892	8892	8892	8892	8892	8892	8892	8892
aic	1172.321	4912.036	3892.830	5726.214	5092.683	3333.640	2056.766	2482.331	3570.968	1521.048
bic	1484.409	5224.124	4204.918	6038.302	5404.771	3645.728	2368.854	2794.419	3883.056	1833.136
FEi FEj ijtrend	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

RESULTS 1ST STAGE

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