SUSTAINABLE ENERGY TRANSITION AND POLICY MIX DESIGN IN THE EUROPEAN UNION

A TRADE-BASED SUPPLY VALUE CHAIN APPROACH

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- Energy transition and co-evolutionary approach

- Energy efficiency in residential sectors

- Economic objectives

- International cross-country perspective

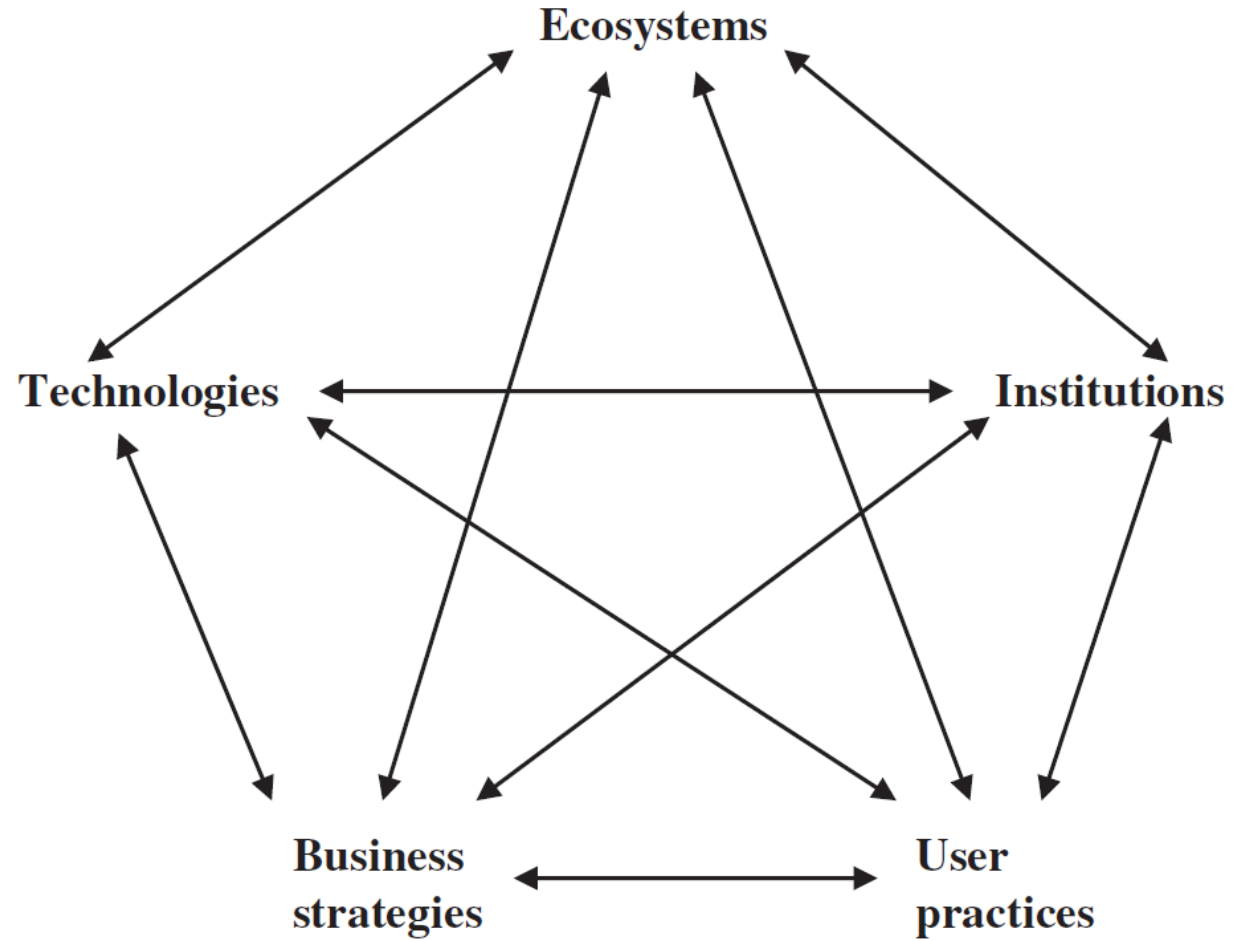- Empirical strategy

ENERGY TRANSITION

- "Structural change in how energy services are created, delivered and used" (Rosenow et al., 2017).

- Face multiple barriers, lock-in, path dependencies and resistance to change & require strategic policy efforts (Rogge et al., 2017).

- Traditional economic approach inappropriate for dynamics of structural and adaptive changes in economic systems (Rammel-van der Bergh 2003).

- Evolutionary economics potential for interpreting the process of sustainable development and environmental policies (Kemp 1997, Nill-Kemp 2009, van der Berg et al. 2000, 2007).

- In the context of energy transition, the aim is to forcing technological regime shifts, change in consumer behaviour and institutional frame (complex adaptive systemic approach).

ENERGY TRANSITION: POLICY AND INNOVATION

- <u>Policy mixes</u> are required to address the various market and system failures associated with sustainability energy transition and drive changes both in terms of production and consumption structures.

- <u>Energy Technological Innovation System</u>: include all aspects of energy system (Demand & Supply) and all stages technology development & innovation process, knowledge creation, entrepreneurial activities, research, market formation & feedbacks, actors, networks, institutions.

Transition policy goes beyond the traditional policy approaches in the fields of environment, energy and technology, encompassing elements of all these policy fields and contributes to changing the structure of the overall socio and techno-economic systems (acknowledging a complex evolutionary process in a system of different agents whose behaviour and interactions are governed both by market forces and non-market institutions).

4

CO-EVOLUTIONARY FRAMEWORK

Ecosystems

Technologies

Institutions

Business strategies

User practices

Source: Foxon, 2011 (after Norgaard, 1994)

FOCUS ON ENERGY EFFICIENCY

EE is one of the preferential and cost-effective means to improve the performance of the national energy system (EC, 2011; IEA, 2010; 2012) and constitutes one of the three pillars of the EU 2030 Climate and Energy Strategy (EC, 2014).

- The overall performance of the energy system depends on the structural characteristics of countries.

- Its evolution is also intimately linked to the rate of generation and adoption of new energy-efficient technologies.

- Increasing efforts to spur EE are pursued through the implementation of national and sector-specific regulation, especially by fostering the generation and diffusion of new technologies (Eco-innovation).

    There is growing interest in understanding the role played by different combinations of the available policy instruments and innovation efforts in stimulating and directing technical change in this specific domain.

TRANSITION TO A SUSTAINABLE ECONOMY

how a transition to a sustainable, low carbon system of production and consumption could occur?

- Focus on co-evolution of policy mixes and innovation system (environmental objectives, generation and diffusion of technologies and innovation), but still limited integration with economic objectives.

- "Technologies evolve within particular social and economic contexts, which are in turn shaped by the technologies that are produced and used" (Foxon, 2011).

- Post-crisis: the induced effect of policy and innovation on both environmental and economic competitiveness performance assumes a crucial role to sustain economic recovery and employment growth.

Co-evolution of residential energy efficiency system, technological capabilities and policy mix

The characteristics and performance of the energy system co-evolve with those of the TIS and of the policy mix, thus shaping processes of *structural change and competitiveness dynamics* in the domain of *residential EE technologies.*

→ reduce environmental impacts

→ changes in the socio-technical system

→ policy and regulatory framework

→ changes in the production structure

→ demand characteristics

Energy efficiency

Eco-innovation

Policy mix

Structural change
(socio-technical-economic)
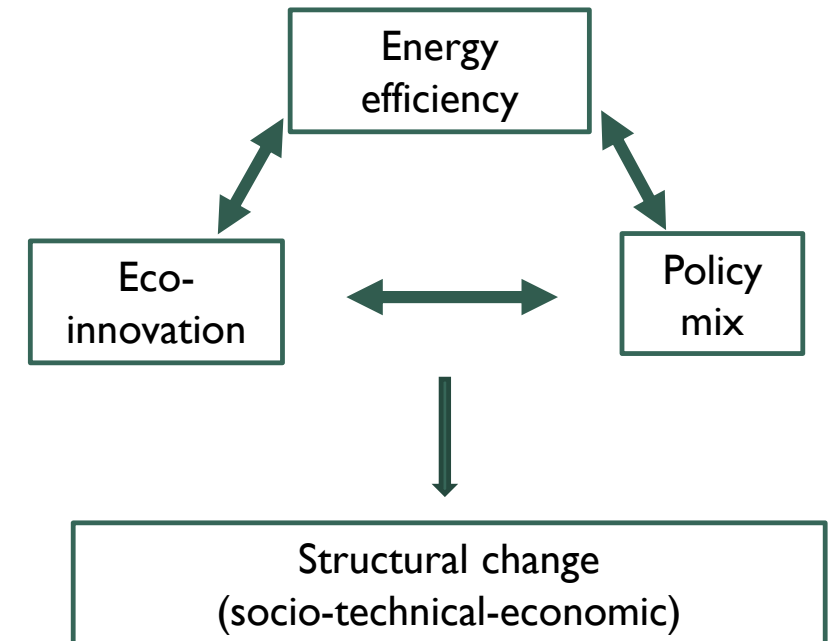
BEYOND DOMESTIC BOUNDARIES

- Consumption, production and innovation systems are increasingly internationalized (Carlsson, 2006).

- (Policy induced) eco-innovation can generate positive effects in terms of performance of the energy systems (not only national), but also in terms of economic and trade competitiveness (Porter and van der Linde, 1995; 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 spillovers (Dechezleprêtre and Glachant, 2014) or policy spillovers (Costantini et al., 2017).

INTERNATIONAL RELATIONSHIPS: POLICY & INNOVATION

Impact of foreign policies on innovation

- Cross-country policy spillovers implies a stronger overall impact of domestic policies on global innovation (and thus on environmental sustainability and green growth).

- Policies adopted by other countries increase the potential market for eco-innovation (higher demand), providing incentive for domestic actors to invest (Peters et al., 2012).

- Policies adopted by other countries generate knowledge spillovers that can benefit domestic technological capabilities (Dechezleprêtre and Glachant, 2014).

- Environmental policies may fail to give rise to competitive advantage for domestic companies [*wind or solar photovoltaic heavily subsidized through guaranteed feed-in tariffs in many developed countries, while major global suppliers of equipment are located in China or India*].

Need of measuring the impact played by *foreign* technological innovation & policy measures

INTERNATIONAL RELATIONSHIPS: ECONOMIC PERFORMANCES

International relationships and economic competitiveness

- Innovative capabilities are important factors able to explain firms' competitiveness in international markets and export success (Basile, 2001; Cassiman et al., 2010; Dosi et al., 2015);

- International trade is a further channel for technological knowledge transfer and diffusion of innovation.

- Exporters might be induced to innovate precisely because they are active in export markets (Liu and Buck, 2007; Andersson and Loof, 2009; Lileeva and Trefler, 2010; Bustos, 2011)

  This positive effect of exporting on innovation varies according to the destinations of exports, and depends on the *learning effect* (level of foreign technological spillovers) and the *foreign demand effect* (Fassio, 2018).

INTERNATIONAL RELATIONSHIPS

- *Learning by exporting effect*

international trade benefits the trading parties through exposing countries to the knowledge stocks of their trading partners (Grossman and Helpman, 1991; Love and Ganotakis, 2013).

- foreign knowledge spillovers by trading with technologically advanced destination markets;

- associated to the increase of demand induced by the access to foreign markets.

Source: Costantini et al. 2018
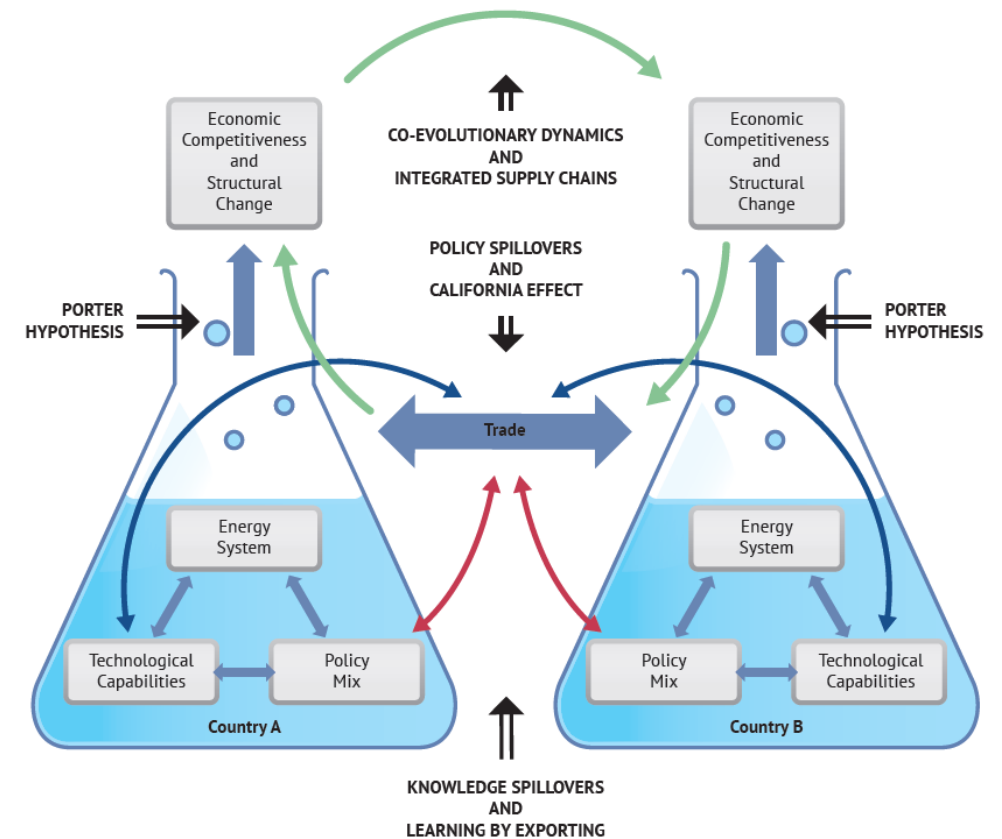
INTERNATIONAL RELATIONSHIPS

▪ *California effect*

tendency of environmental product standards to increase towards levels found in high-regulating countries that are export destination markets.

- *gains from trade* in terms of environmental regulatory standard convergence;

- particularly for product standards, which can constitute non-tariff barriers to trade (rather than process standards).


Source: Costantini et al. 2018
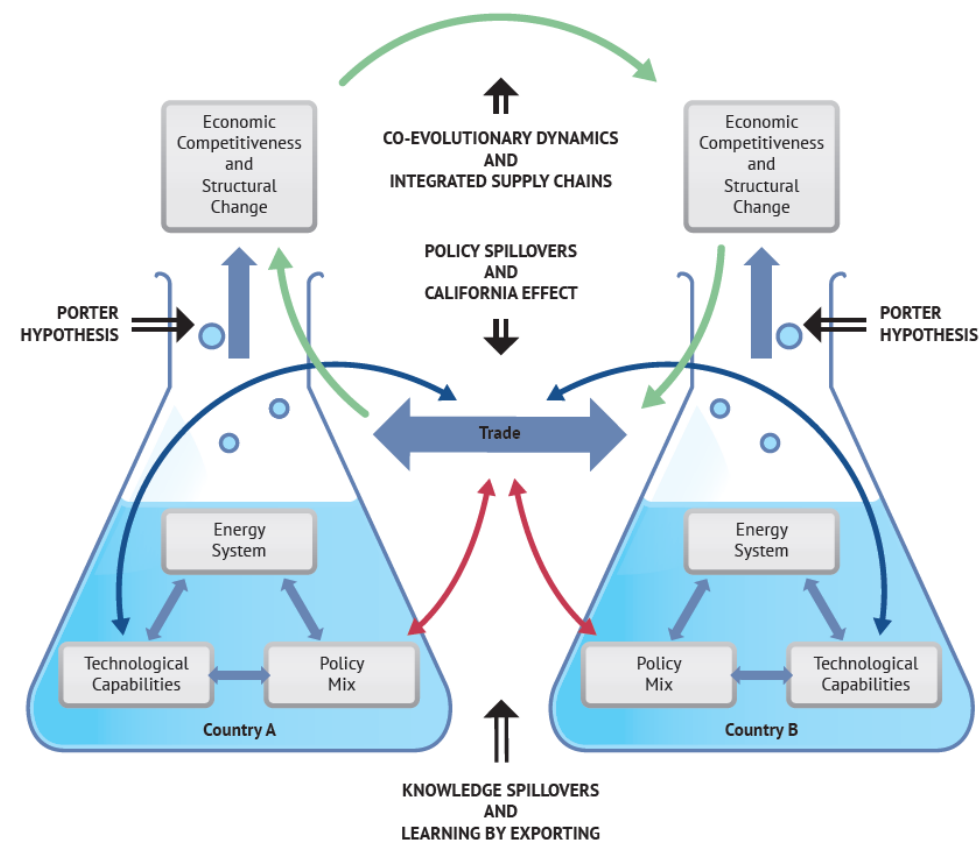
INTERNATIONAL RELATIONSHIPS

- *Market integration and sustainable (global) value chains*

the environmental performance of downstream industries can improve due to the innovation adopted by suppliers.

- from international outsourcing activity to more sophisticated knowledge creation cooperation processes;

- learning and technology acquisition through global value chains and vertical integration strategies.

Source: Costantini et al. 2018
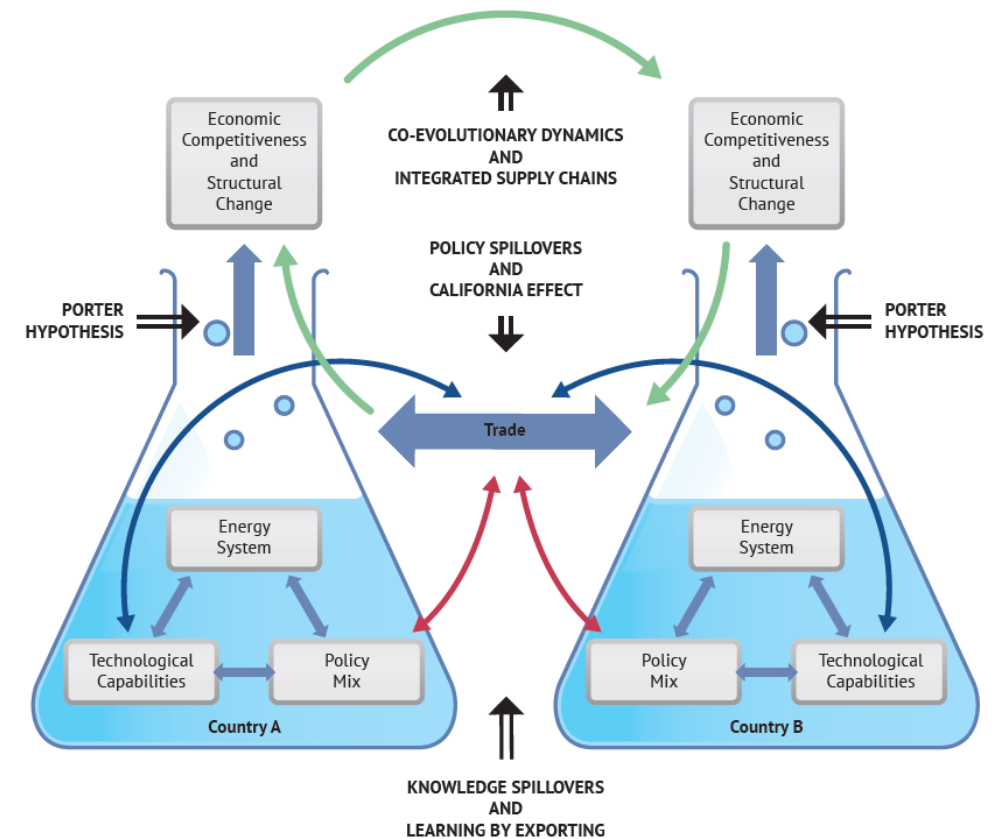
AIM OF THE RESEARCH

Jointly analysing the role of policy mixes and innovation efforts with respect to international economic competitiveness in the energy efficiency technology domain for residential sector, accounting for the domestic and foreign influence.

- Focusing on EE technologies for the residential sector

  Since efficiency gains are strictly connected to diffusion and adoption of technologically advanced devices by private consumers, the systemic approach should cover both the supply and demand side characteristics.

- Bilateral dataset: 19 EU countries (1990-2015)

- Gravity model

16

BILATERAL PANEL DATASET
TRADE, ENERGY SYSTEM, INNOVATION AND POLICY MIX

- *EXPORT for selected EE technologies for residential sector;*

- *PATENT relevant for selected EE technologies for residential sector;*

- *POLICY MIX: Environmental Policy Stringency, EE policy stock (and measures by type: Economic instruments, Information and education instruments, Policy support instruments, Regulatory instruments, RDD instruments, Voluntary approach instruments), RD&D public budget in energy and EE for the building sector;*

- *ENERGY: Taxes, prices and residential Natural Gas and Electricity consumption, Energy Tax revenue;*

- *Gross Domestic Product, Population, Common borders, Distances.*

EXPORT

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

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

Code	Description
Environmental Policy Stringency	
EPS	Environmental Policy Stringency index
EPS_MKT	EPS Market (Taxes, Trading Schemes, Feed-in Tariffs) index
EPS_STD	EPS Standards 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

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

POLICY MIX

Policy mix indicators:

- *Demand pull*

- *Technology push*

- *Policy balance*

- *Comprehensiveness*

- *Soft and systemic*

- *Cross-country similarity*

POLICY MIX INDICATORS

- The **Demand-pull** policy indicator is a price-based instrument that represents the impact of energy taxation on the market price for energy demand in the residential sector (weighting tax rates by energy consumption):

$$Demand\_pull_{i,t} = Energy\ tax_{i,t} = \sum_{1}^{n}\left(Energy\ tax_{i,t}^{n} \cdot Ener\_cons_{i,t}^{n}\right)\Big/\sum_{1}^{n}\left(Ener\_cons_{i,t}^{n}\right)$$

- The **Technology-push** policy indicator is quantified by taking the stock of public R&D in EE by the total residential energy consumption:

$$Technology\_push_{i,t} = KRD\_EE_{i,t}\Big/\sum_{1}^{n}\left(Ener\_cons_{i,t}^{n}\right)$$
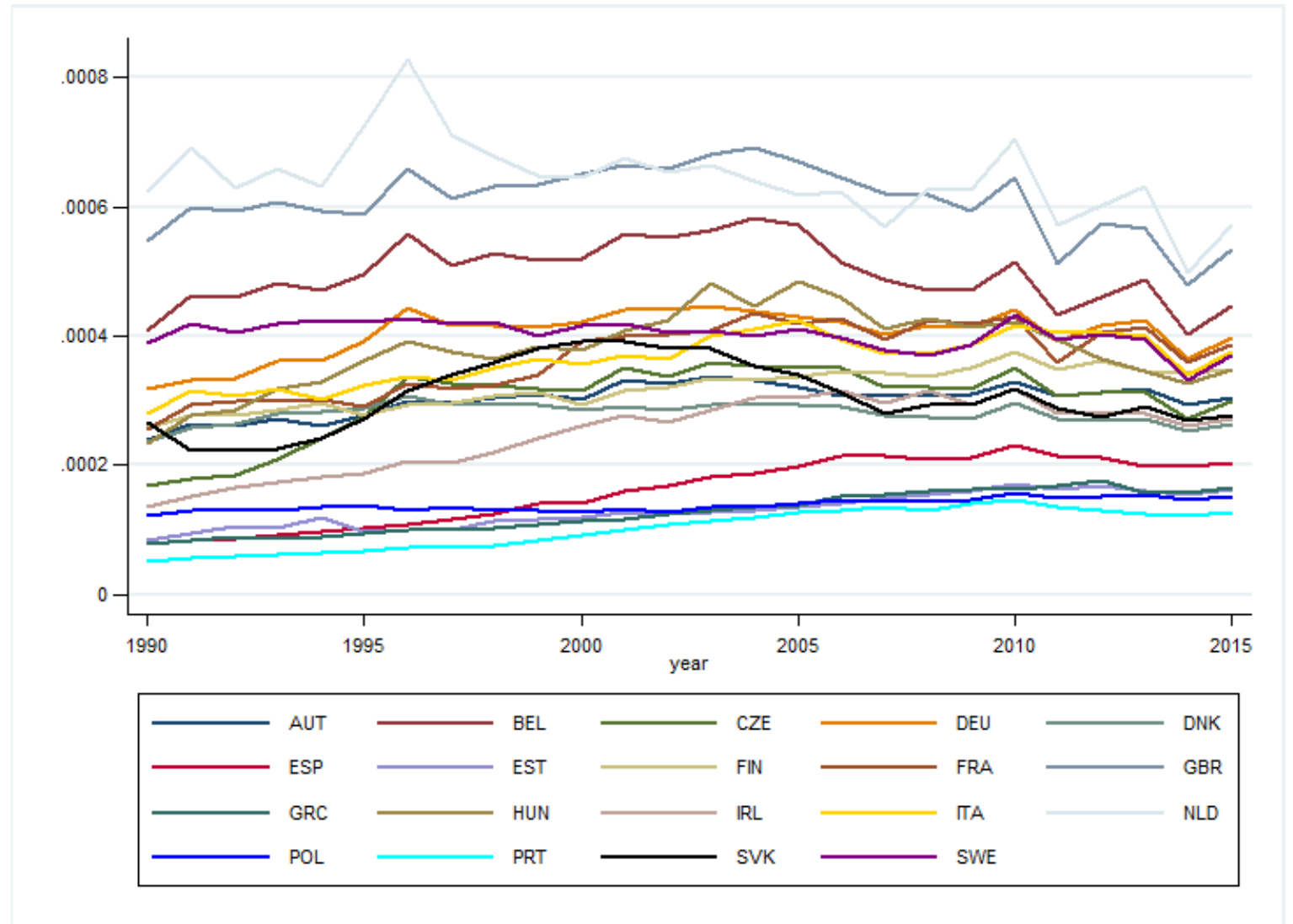
- The **Policy mix balance** is the difference between these two policy domains (both expressed in USD per toe):

$$Pol.\,Balance_{i,t} = Energy\ tax_{i,t} - Technology\_push_{i,t}$$

21

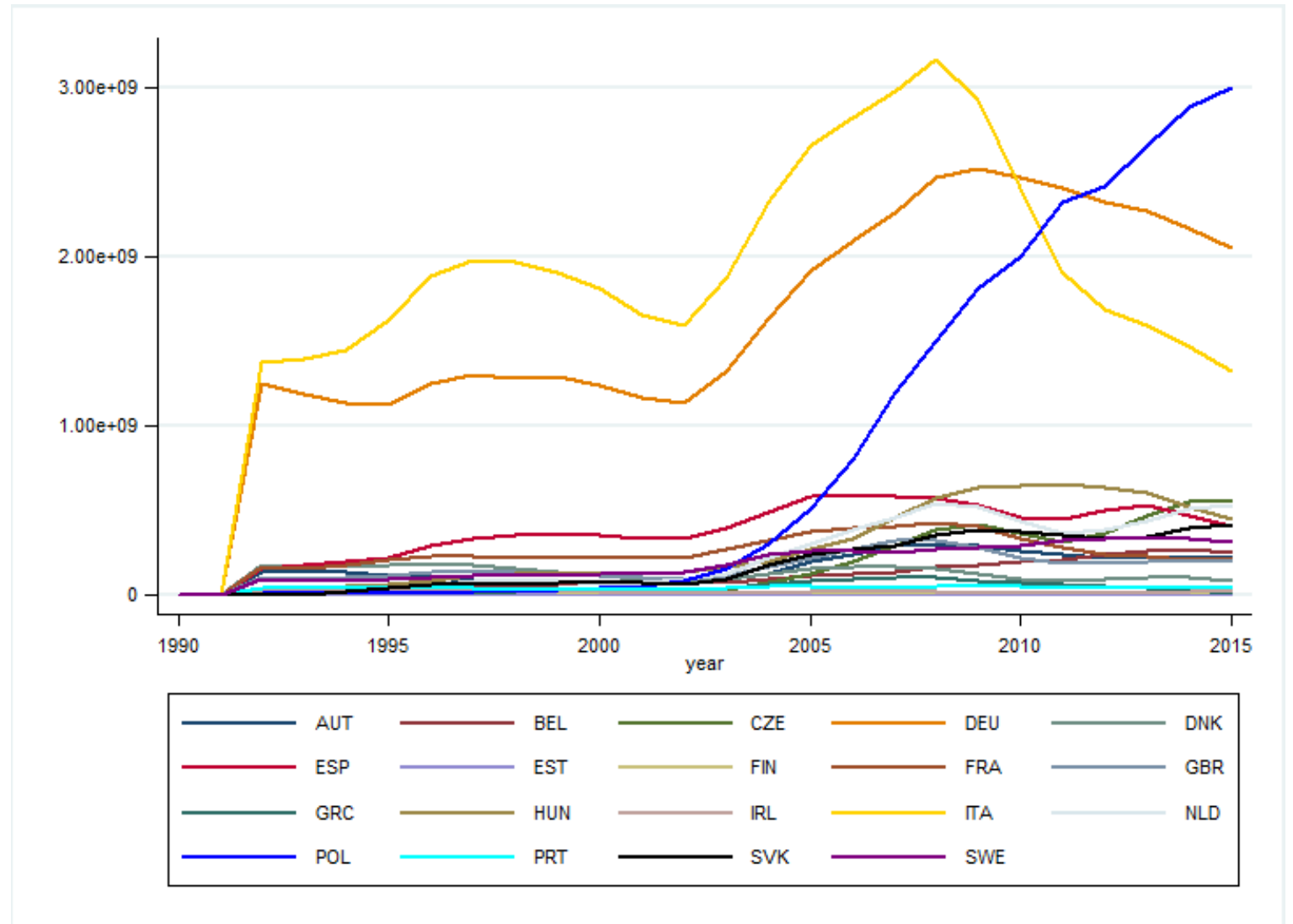# Residential energy consumption per capita

Source: Eurostat

Electricity and Natural gas (toe per capita)
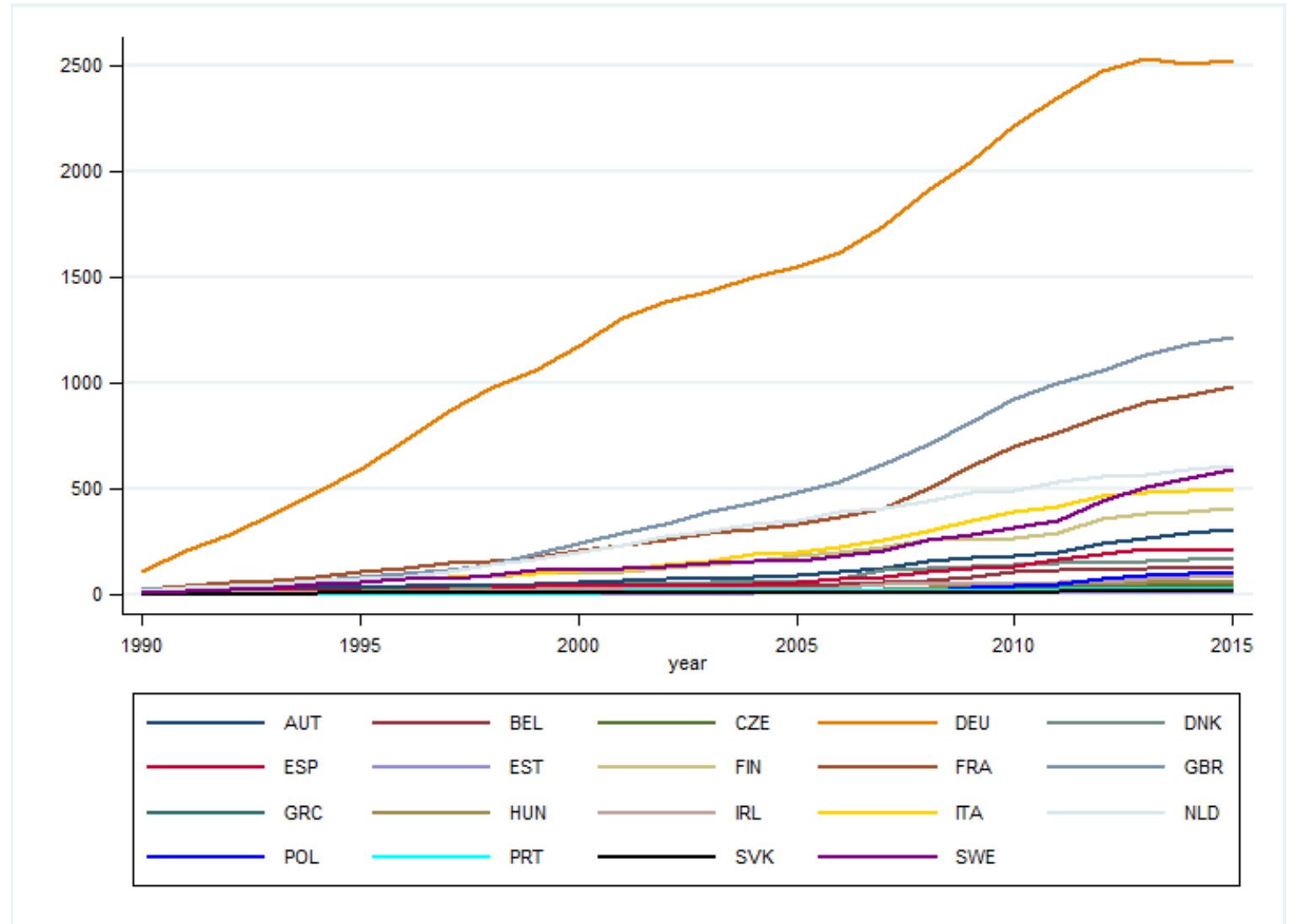
Export in EE residential technologies

Source: UN-WITS

SITC Rev3

Constant 2010 USD

Patent stock in EE residential technologies
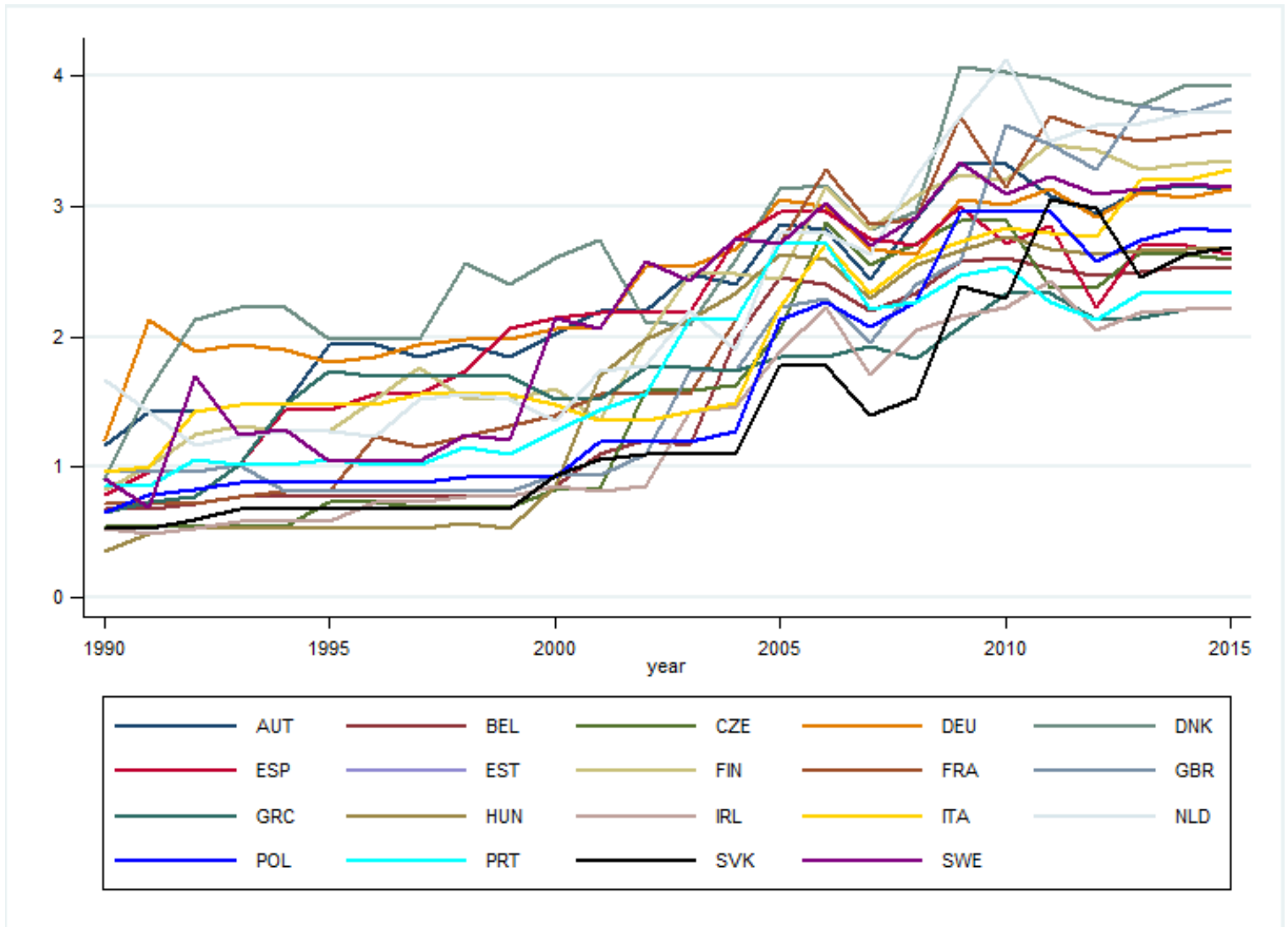
Source: PATSTAT

Continuous discount approach (d=15%)

EPS

Environmental Policy Stringency

Source: OECD

"Degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behaviour ranging from 0 (not stringent) to 6 (highest degree of stringency)

ECONOMETRIC STRATEGY

1. *potential bias induced by the existence of many zeros in trade flows*

    zero values in bilateral trade data are not randomly distributed across countries since they depend on structural factors- not due to a sample selection problem but is due to neglecting the impact of firm heterogeneity) → Heckman's two-stage procedure

    intensive margins/selection bias/IMR & extensive margins/firms heterogeneity

2. *existence of persistency over time of trade data*

    given the existence of sunk costs associated with entry and exit of the export markets and potential endogeneity of covariates → dynamic specification (sys-GMM) to account for a persistent dependent variable and to correct for autocorrelation

26

ECONOMETRIC GRAVITY MODEL: general formulation

$$Trade_{ij} = Y_i^{\beta_1} Y_j^{\beta_2} POP_i^{\beta_3} POP_j^{\beta_4} DIST_{ij}^{\beta_5} Z_{ij}^{\beta_6} F_i^{\beta_7} F_j^{\beta_8} exp(\tau_{ij} + \gamma D_{ij})\mu_{ij}$$

- Income and population of both *i* and *j* trading partners;

- Geographical distance ($DIST_{ij}$);

- Other factors aiding/preventing trade between each pair of countries (Z_{ij});

- Specific exporter and partner features (F_i and F_j);

- Specific effect associated with each bilateral trade flow (τ_{ij});

- Dummy variables for common language, common border, past colonial relationships, trading blocs (D_{ij})

- Error term (μ_{ij}).

ECONOMETRIC GRAVITY MODEL: 1ST stage

$$prob\_exp_{ijt} = \rho_{ijt}$$
$$= \alpha_{it} + \delta_{jt} + \tau_{ijt} + \beta_1 dist_{ij} + \beta_2 B_{ij} + \beta_3 T_t + \beta_4 eco\_size_{ijt} + \beta_5 enecons\_sim_{ijt} + \beta_6 policy\_sim_{ijt}$$
$$+ \beta_7 inn\_sim_{ijt} + \varepsilon_{ijt}$$

- Country-specific time variant effects (α_{it} and δ_{jt});

- Country-pair specific time variant effects (τ_{ijt});

- Log of geographical distance ($dist_{ij}$);

- Dummy variable for existence of a common border (B_{ij});

- Dummy variables for structural breaks (euro, EU enlargement, crisis);

- Sum of per-capita GDP (eco_size_{ijt});

- Similarity in terms of energy demand ($enecons\_sim_{ijt}$), EPS ($policy\_sim_{ijt}$), innovation (inn_sim_{ijt});

- Error term (ε_{ij}).

> Extensive and Intensive margins:
> *fhet & IMR*

2nd stage

ECONOMETRIC GRAVITY MODEL: 2ND stage

$$EXP_{ijt} = X_{ijt} = \alpha_{it} + \delta_{jt} + \tau_{ijt} + \sum_{p=1}^{n} \lambda_p x_{ij,t-p} + \beta_1 dist_{ij} + \beta_2 B_{ij} + \beta_3 T_t + \beta_4 fhet_{ijt} + \beta_5 IMR_{ijt} +$$

$$\beta_6 eco_{ijt} + \beta_7 innovation_{ijt} + \beta_8 policy\_mix_{ijt} + \beta_9 energy_{ijt} + \varepsilon_{ijt}$$

- Country-specific and Country-pair specific time variant effects (α_{it} δ_{jt} τ_{ijt});

- Geographical distance ($dist_{ij}$) and common Border (B_{ij});

- Dummy variables for structural breaks (euro, EU enlargement, crisis: T_t);

- Extensive and Intensive margins from 1st stage equation (fhet and IMR);

- *Eco, innovation, policy mix, energy: i, j, mass/similarity;*

- Error term (ε_{ij}).

CONCLUSION / NEXT STEPS

- Aim at analysing the energy transition focusing on energy efficiency technologies for residential sector in a co-evolutionary framework accounting for: Regulatory framework & innovation system; Supply and demand characteristics; Impact in terms of economic performances; International perspective (interaction among countries).

➢ Domestic indicators (economic performance, trade specialization)

➢ Cross-country indicators (policy mix)

➢ Econometric model

Thank you for your attention!

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- According to Egger (2000):

$$similarity_{ijt} = ln\left[1 - \left|\left(\frac{x_{it}}{x_{it}+x_{jt}}\right)^2 - \left(\frac{x_{jt}}{x_{it}+x_{jt}}\right)^2\right|\right]$$

- Country-pair size: $mass_{ijt} = ln(GDP_{it} + GDP_{jt})$ or $mass_{ijt} = ln(GDP\_pc_{it} + GDP\_pc_{jt})$

- *EXTENSIVE MARGIN (fhet)*: explained by firms' heterogeneity 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.

- *INTENSIVE MARGIN (IMR)*: (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.

Ist 2nd