THE EFFECTS OF RDI REGULATION ON ENERGY SECTOR

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INTRODUCTION

- After the deregulation and privatization movement in **'80-90's** the literature shows a **declining tendency of RDI outcomes in the electricity sector** (Jamasb & Pollitt, 2011; Marino et al., 2019);
- Studies focus on the impacts of the price regulation – **cost-based, incentive-based, and hybrid regulations** – on the RDI outcomes, and highlight the **inadequacies of this regulatory model to promote the expected level of innovation in the sector** (Jamasb & Pollitt, 2008; Marino et al., 2019; Poudineh & Jamasb, 2015);

- **During the first decade of the 2000's**: a new type of regulation emerges in the electricity sector → the **RDI regulations**, designed to give incentives for firms to invest in **research, development, and innovation** initiatives;
- Despite the efforts in **mapping the RDI regulations** (Haffner et al., 2019; Cambini et al., 2020; Jamasb et al., 2021), there still a lack of evidence on the effects of the RDI regulations;

RDI REGULATION

- **Hypothesis:** the introduction of sector-specific RDI regulation has a positive effect on innovation in the electricity sector.
- Our definition and classification of **RDI regulation** is based on the following works: Haffner et al. (2019); Eurelectric (2016); Cambini, Congiu, and Soroush (2020); and (Cambini, Meletiou, et al., 2016).

Definition/Classification of RDI Regulation used in this paper

- **Specific innovation-stimulus mechanisms** in the segments of **generation, transmission, and distribution in the electricity sector provided** by the Regulation – legislation level or Regulatory Authority → **ex: (i)** revenue allowances; **(ii)** subsidies to finance innovative projects; **(iii)** grants; **(iv)** innovation roll-out mechanism; **(v)** and competitions;
- Only countries with an **explicit** RDI regulation in the electricity sector were considered for the treatment group;

** Other regulatory frameworks such as sustainability, or efficiency related were not included in our analysis.

DIFFERENCE-IN-DIFFERENCE (DID)

- **Sample:** 26 European Countries
- **Period:** 1991-2018
- Unbalanced Panel Data
- **Treatment Group:** Belgium (2014), Denmark (2012), Finland (2013), France (2014), Germany (2007), Hungary (2007), Ireland (2016), Italy (2010), Luxembourg (2016), and the United Kingdom (2005).
- **Control Group:** Austria, Bulgaria, Croatia, Czech Republic, Estonia, Greece, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, and Sweden.

Dependent Variable

- Patents on Climate Change Mitigation Technologies Related to Energy Generation, Transmission or Distribution (Y02E) (OECD)

Control Variables

- Market regulation in the electricity sector: Market Regulation in Electricity (OECD)
- R&D expenditure: Business enterprise R&D expenditure by industry (OECD; EUROSTATA)
- R&D personnel: Business enterprise R-D personnel by industry (OECD; EUROSTATA)
- Gross Domestic Product – GDP (World Bank)

EMPIRICAL MODEL

$$Y_{it} = \alpha + \beta\, T_i + \gamma\, Post_{it} + \delta\, (T_{it} * Post_{it}) + \vartheta_i + X1'_{it} + X2'_{it} + X3'_{it} + \varepsilon_{it}$$

- Y_{it} = patent count for country i in year t
- T_i = Dummy variable indicating whether country i belongs to treatment group or not
- $Post_{it}$ = Dummy variable indicating treatment period
- DID coefficient δ
- ϑ_i = variable control for country fixed effects
- $X1'_{it}, X2'_{it}, X3'_{it}$ are R&D expenditure (ValueInvest), R&D personnel (PersonRD) and market regulation in the electricity sector (ValueReg), respectively. Additionally, we included GDP as a control variable
- ε_{it} = the idiosyncratic error term

RESULTS (1)

- Positive impact of RDI regulations on patents;
- Treatment effect decline with the introduction of control variables, but still positive;
- Stricter "market regulation" is negatively associated with patents (higher levels of "ValueReg") and R&D expenditure, have a positive effect on patents (Cambini, et al., 2016; Marino et al., 2019).

Table 1. Difference-in-difference analysis with fixed effect. Dependent variable: Climate Change Mitigation Technologies Related to Energy Generation, Transmission or Distribution (Y02E) patents.

	(1) Reg DiD	(2) With X1, X2, and X3	(3) With X1, X2, X3, and GDP	(4) Fixed Effects
intercept	34.92	287.43***	-52.23	
	(0.131)	(0.000)	(0.251)	
T	194.19***	100.79**	-40.34	
	(0.000)	(0.007)	(0.190)	
Post	44.36	-82.49	16.41	
	(0.298)	(0.219)	(0.75)	
Post*T	272.92***	210.34*	173.6*	218.05***
	(0.000)	(0.030)	(0.023)	(0.000)
ValueReg		-67.35***	-2.72	-42.82***
		(0.000)	(0.773)	(0.000)
ValueInvest		2.27***	0.816***	1.636***
		(0.000)	(0.000)	(0.000)
PersonRD		0.011	-0.147***	0.0626
		(0.733)	(0.000)	(0.183)
GDP			4.09e-10	
			(0.000)	
R-squared	0.1376	0.3455	0.5976	0.3373
Adj. R-squared	0.1339	0.3371	0.5916	0.294

Figure 1. Control group with a linear trendline.

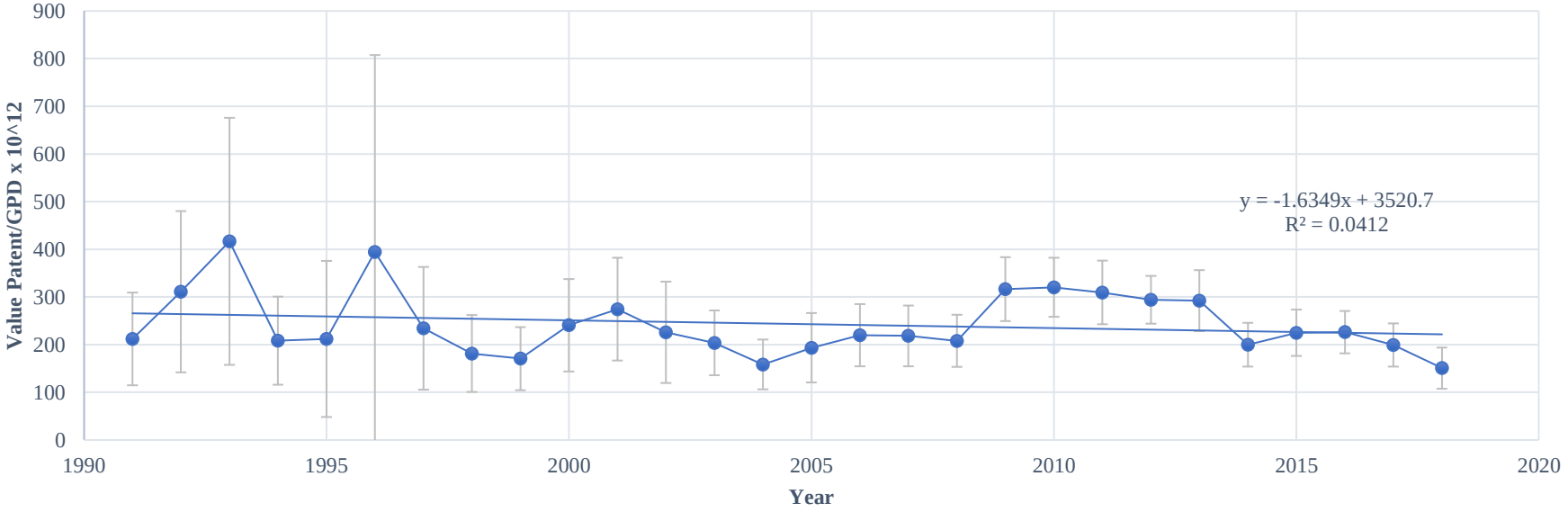
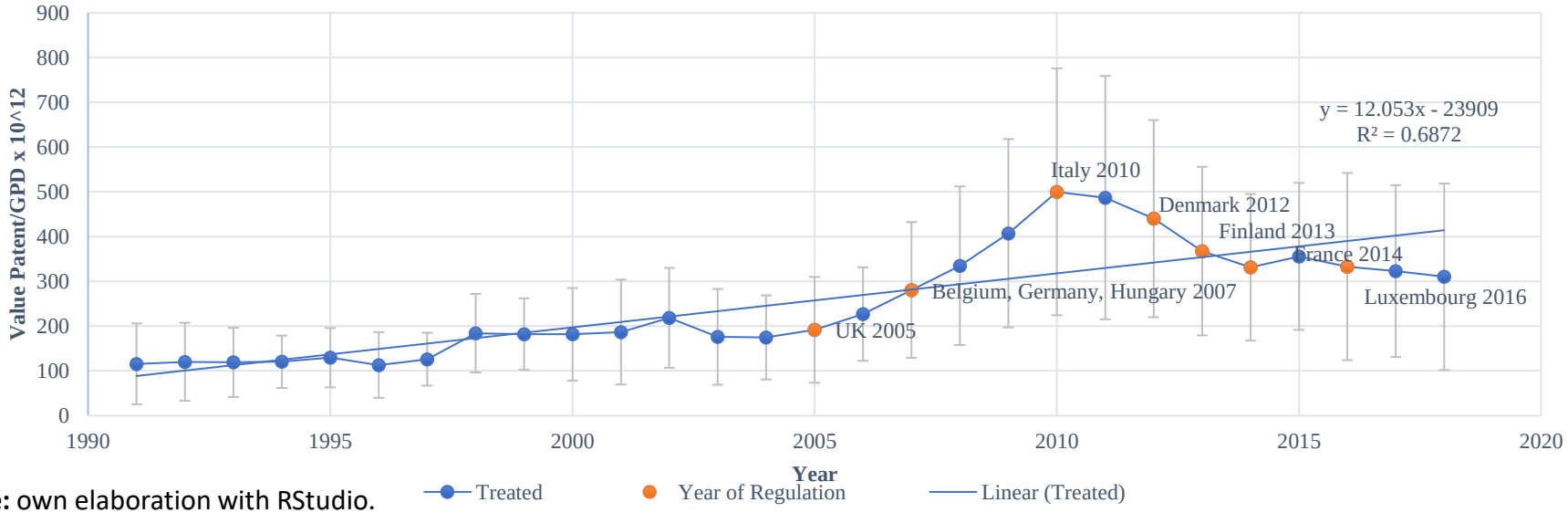


Figure 2. Treatment group with a linear trendline.



Source: own elaboration with RStudio.

CONCLUSIONS

- The results show a **positive relationship** between the introduction of **RDI policies** and **patenting** activity in the electricity sector;

- The results also demonstrate a **negative correlation** between **patents and a stricter product market regulation** in the electricity sector, as well as a **positive relationship** between **R&D investments** and **patents**, thereby confirming previous research (Cambini, et al., 2016; Marino et al., 2019);

- The **limitations** in the present research are related to the (a) **limited number of countries** in the sample and; (b) **difficulty in distinguishing the impact of different RDI regulations** – revenue allowances, subsidies to finance these projects, grants, innovation roll-out mechanism, and competitions;

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Table 1. Sample composition.

ID	Country	RDI Regulation	Year of Policy Change	Regulatory Authority	Policy
1	Austria	No Evidence	-	E-Control	-
2	Belgium	Explicit	2014	Commission for Electricity and Gas Regulation (CREG)	Electricity Law 2014
3	Denmark	Explicit	2012	Danish Utility Regulator (DUR) and Danish Energy Agency (DEA)	Electricity Supply Act 2012
4	Finland	Explicit	2013	Energy Authority (EA)	Electricity Market Act 588/2013
5	France	Explicit	2014	Commission de Régulation de l'Énergie (CRE)	Tarif d'utilisation du réseau public d'électricité (TURPE) 4
6	Germany	Explicit	2007	Federal Network Agency (Bundesnetzagentur – BnetzA)	The incentive regulation 2007 (ARegV)
7	Greece	No Evidence	-	Regulatory Authority for Energy (RAE)	
8	Hungary	Explicit	2007	Hungarian Energy and Public Utility Regulatory Authority (HEA)	The "Electricity Act"Act LXXXVI of 2007
9	Ireland	Explicit	2016	Commission for Regulation of Utilities (CRU)	CER/15/295 and CER/16248
10	Italy	Explicit	2010	Autorità di Regolazione per Energia Reti e Ambiente (ARERA)	Deliberazione ARG/elt 39/10
11	Luxembourg	Explicit	2016	Institut Luxembourgeois de Regulation (ILR)	Regulation E16/12/ILR, 2016
12	Netherlands	No Evidence	-	Authority for Consumers and Markets (ACM)	Electricity Act 1998
13	Poland	No Evidence	-	President of the Energy Regulatory Office (herein referred to as the "President of ERO")	-
14	Portugal	No Evidence	-	Entidade Reguladora dos Serviços Energéticos (ERSE)	-
15	Spain	No Evidence	-	National Commission for Markets and Competition (CNMC)	-
16	Sweden	No Evidence	-	Swedish Energy Markets Inspectorate (the Inspectorate)	-
17	United Kingdom	Explicit	2005	The Office of Gas and Electricity Markets (Ofgem)	Innovation Funding Incentive (IFI) 2005
18	Lithuania	No Evidence	-	National Energy Regulatory Council (NERC)	-
19	Latvia	No Evidence	-	Centralized public services regulatory institution (herein referred to the "Regulator")	-
20	Romania	No Evidence	-	Romanian Energy Regulatory Authority (ANRE)	-
21	Slovak Republic	No Evidence	-	Regulatory Office for Network Industries (RONI)	-
22	Slovenia	No Evidence	-	Energy Agency	-
23	Bulgaria	No Evidence	-	State Energy and Water Regulatory Commission - EWRC	-
24	Croatia	No Evidence	-	Croatian Energy Regulatory Agency (CERA)	-
25	Czech Republic	No Evidence	-	Energy Regulatory Office (ERO)	-
26	Estonia	No Evidence	-	Estonian Competition Authority (ECA)	-

Appendix A. Patents Classification: Climate Change Mitigation Technologies Related to Energy Generation, Transmission or Distribution (Y02E).

Climate Change Mitigation Technologies Related to Energy Generation, Transmission or Distribution (Y02E)	CODE	DESCRIPTION
2.1. Renewable Energy Generation	Y02E10	Wind energy; Solar thermal energy; Solar photovoltaic (PV) energy; Solar thermal-PV hybrids; Geothermal energy; Marine energy; and Hydro energy.
2.2. Energy Generation from Fuels of Non-Fossil Origin	Y02E50	Biofuels; and Fuel from waste
2.3. Combustion Technologies with Mitigation Potential (E.G. Using Fossil Fuels, Biomass, Waste, Etc.)	Y02E20	Technologies for improved output efficiency (combined heat and power, combined cycles, etc.); and Technologies for improved input efficiency (efficient combustion or heat usage).
2.4. Nuclear Energy	Y02E30	Nuclear fusion reactors; and Nuclear fission reactors.
2.5. Technologies for an Efficient Electrical Power Generation, Transmission or Distribution	Y02E40	Superconducting electric elements or equipment; Smart grids as climate change mitigation technology in the energy generation sector; and Not elsewhere classified
2.6. Enabling Technologies (Technologies with Potential or Indirect Contribution to GHG Emission Mitigation)	Y02E60	Energy storage; Hydrogen technology; Fuel cells; and High-voltage direct current transmission
2.7. Other Energy Conversion or Management Systems Reducing GHG Emissions	Y02E70	Synergies among renewable energies, fuel cells and energy storage