RESEARCH AND DEVELOPMENT REGULATIONS TO STIMULATE INNOVATION IN THE ELECTRICITY SECTOR: A QUANTITATIVE STUDY ON EUROPEAN COUNTRIES

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Overview

Energy transition demand drives substantial technology improvements from the power sector to ensure green and reliable electricity for a continuously growing world economy. Studies also highlight the limitation of market forces to provide the necessary incentives for investment in the development and diffusion of sustainable technologies (Popp, 2019).

The literature reveals the necessity of specific regulations to foster innovation (Cambini et al., 2016b; Cambini et al., 2020). This is consistent with the regulated nature of the electricity sector. To fulfill this gap, a new form of regulation emerged in the electricity sector in the recent period, especially in Europe(Cambini et al., 2016a; Cambini et al., 2020; EURELECTRIC, 2016; Haffner et al., 2019). These regulations focus on providing research, development, and innovation (RDI) regulation stimulus and mitigate the financial, technical, and regulatory risks associated with this type of investment.

So far, few studies have focused on analyzing the so-called "innovation-stimuli regulation" (Cambini et al., 2016b; Cambini et al., 2020; Marques et al., 2014), and most of the literature addressing this regulation has a descriptive nature (EURELECTRIC, 2016; Haffner et al., 2019). To the best of our knowledge, only Cambini et al. (2016b) demonstrated the positive effect of the research, development, and innovation (RDI) regulations on investments allocation however it does not explore its impact on innovation outcomes. To address this gap, we investigate the effects of RDI regulation on patenting activity in the European electricity sector.

Methods

The empirical analysis comprises 21 European countries during the period of 1991-2016. The countries selected for this study were firstly classified into two groups based on the innovation-stimulus initiatives in the European electricity sector identified by the existing literature on innovation-stimuli regulation, as well as websites, reports, norms, and laws available at the government and regulatory authorities.

Countries that meet this requirement are the following: Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Norway, Portugal, Sweden, United Kingdom. To the best of our knowledge, the other following countries: Austria, Estonia, Greece, Netherlands, Poland, Portugal, Slovak Republic, Spain, Turkey, and Switzerland lacked explicit RDI regulations and were thereafter allocated to the control group.

Therefore, we performed a difference-in-difference analysis, comparing these two groups using patents as our dependent variable to measure innovation efforts. More specifically, we use patents classified in section Y02E40 from the International Patent Classification (IPC), which refers to "Technologies for an Efficient Electrical Power Generation, Transmission or Distribution". Our model also controlled for other measures that may have an impact on innovation in the electricity sector; we include time- and country-fixed effects as well as the following control variables: Energy Technologies Research, Development, and Demonstration (RD&D) Budget, R&D Personnel, Market Regulation in Electricity Sector, and Electricity Consumption. These measures were retrieved from the IEA, OECD, and EUROSTAT databases.

As a result, our difference-in-difference analysis, which is measured by a two-way fixed effects model, takes the following form:

$$Y_{it} = \beta * RDI_{it} + \gamma * Budget_{it} + \omega * Personell_{it} + \partial * Market\_reg_{it} + \varphi * Elec\_consum_{it} + \vartheta_i + \delta_t + \varepsilon_{it} \qquad (1)$$

Additionally, we measure the treatment effect across parts of the treatment group by the group-specific treatment effect estimation by Callaway & Sant'anna (2020). This allowed verifying different treatment effects depending on the period of adoption - "early adopters" and "later adopters". The resultant group-specific ATT is defined for each group entering treatment at time s ≤ t as is given by the following equation:

$$ATT_t^s = \in [\tau_{it} \mid t_i^* = s] \qquad (2)$$

Results

Model (1) constitutes the OLS regression without fixed effects, Model (2) represents the time-fixed effects, Model (3) includes country fixed effects, and Model (4) is the two-way fixed effects model (Table 1).

Table 1. OLS, Time Fixed-Effects, Country Fixed-Effects, and Two-Way Fixed Effects.

	Dependent Variable: Patents "Technologies for an Efficient Electrical Power Generation, Transmission or Distribution" (Y02E40)			
	Model (1)	**Model (2)**	**Model (3)**	**Model (4)**
Innovation-stimuli regulation	10.161***	9.418***	5.736***	7.537**
	(1.610)	(2.783)	(2.161)	(3.549)
RD&D Budget	0.003	-0.003	0.020***	0.017**
	(0.003)	(0.003)	(0.006)	(0.008)
R&D Personnel	-0.005***	-0.004***	-0.002	-0.002
	(0.001)	(0.001)	(0.003)	(0.003)
Market Regulation	0.097	0.327	-0.005	0.710
	(0.468)	(0.287)	(0.308)	(0.513)
Electricity Consumption	0.001***	0.001***	0.0001	0.0004
	(0.0001)	(0.0001)	(0.0002)	(0.0003)
Constant	-3.282**			
	(1.474)			
Time FE	NO	YES	NO	YES
Country FE	NO	NO	YES	YES
Observations	273	273	273	273
R2	0.468	0.48233	0.24532	0.13885
Adjusted R2	0.459	0.41816	0.17228	-0.050372
F Statistic	47.067*** (df = 5; 267)	45.0957*** (df = 5; 242)	16.123*** (df= 5; 248)	7.19117*** (df = 5; 223)

Notes:
1. *p<0.1; **p<0.05; ***p<0.01
2. Cluster-Robust Standard Errors (White-Arellano) correction for cross-sectional dependence, serial correlation, and heteroskedasticity for models 3, 4, and 5.

All four models indicate a positive and significant effect of the innovation-stimuli regulation on patents. As expected, the point estimates decrease when controlling for time and country-specific effects, but the effect remains significant in all four specifications. We tested for the presence of time and country-fixed effects and found significance for both, which means that our primary specification is Model (4), in which the average treatment on the treated of 7.5 patents. Model (1) – (3) are presented to show the evolution of the estimates through the inclusion of the fixed effects.

The results from the group-time average treatment effect, which weight the average treatment effect for (a) all countries that adopted the innovation-stimuli regulation, (b) the "early adopters", and (c) "late adopters". According to the estimation, the overall average treatment of the treated group is positively significant and estimated as an increment of 5 patents and 11 patents on the "earlier adopters". However, there is no effect on the "later adopters".

Conclusions

We conclude that innovation stimuli regulation has positively impacted patent applicants in the sector of electricity distribution and transmission. The findings complement the evidence of Cambini et al. (2016b) about the positive impact of this regulation on investment. Additionally, when we compare the early and late adopters, the early adopters demonstrated a better performance, which could be related to the characteristics of the innovation-stimuli regulation adopted by the countries during that time. Therefore, the paper does not exhaust the discussion of innovation-stimuli regulation because the distinct regulatory instruments focus on promoting innovation differently in the electricity sector, as described in the study (Schittekatte et al., 2021).

In terms of policy implication, the innovation-stimuli regulation is shown to have a consistent effect in terms of patent increase demonstrated by the DiD, along with the group-specific treatment effects. Therefore, including the innovation-stimuli regulation seems to constitute an important part of the technological advancements in sustainable transition in the following years, especially in European countries which have challenging energy transition goals (Percebois and Pommeret 2021; Bohnsack et al. 2021), even though there are still some lacunas regarding the better innovation-stimuli regulation approach.