Diffusion speed of patented eco-technologies. The role of organizational diversification of R&D

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1. Introduction

Motivations

- Accelerating the diffusion processes of eco-innovations is urgent to mitigate the long-term consequences of climate change (Popp, 2005; Li et al., 2023).

- Numerous studies about the diffusion of technologies employing patents (Sharma & Tripathi, 2017; and Jaffe & de Rassenfosse, 2017). Few on the drivers of diffusion speed of eco-technologies (Losacker et al., 2023)

- Eco-technologies rely more on external sources of knowledge (Belin et al., 2011) and R&D collaboration than other innovative technologies (Barbieri et al., 2016; Losacker et al., 2023)

- Little research into the impact of institutional collaboration on the speed of diffusion of ecotechnologies

- Can usefully inform policy makers on the best way to increase technology diffusion

Objective

- To analyze the effects of institutional R&D collaboration and its diversification on the diffusion speed of eco-technologies using patent data

Key contributions

- Quantitative evidence on the effects of organizational collaboration on diffusion speed in the field of eco-technologies

- Duration modelling approach that deals with patent characteristics and other control variables

- We offer evidence on effects by separating eco-technologies and digital eco-technologies

- An original sample of over 144k patents in the eco-technology domain, with 55k in the digital eco-technology field

2. Literature review and hypotheses

2.1. Diffusion speed of patented eco-technologies

- Eco-technologies diffuse far more slowly within and among organizations than traditional technologies, because of their great technological complexity, (Battisti, 2008; Losacker et al., 2023)

- The diffusion process of environmental eco-technologies can be explained by the following groups of factors (Bacchiocch and Montobbio, 2010; Griffith et al., 2011; Kwon et al., 2017; Fichter and Clausen, 2021; Losacker et al., 2023):

- Patent Characteristics (quality)
- Supplier of knowledge (type of institutions and their organization)
- The adopter and motives for adoption
- The regulatory context, e.g. stringent regulations favor early adoption
- Country effects, home bias, patent-office effects, changes over time in the propensity to cite

2.2 The role of institutional collaboration in the diffusion speed of patented eco-technology

- Collaborative efforts can resolve technical barriers that could slow the adoption of eco-patents, which leads to a shorter citing lag (Poncheck, 2016)

    Hypothesis 1: Organizational R&D collaboration has a positive and significant effect on the speed of diffusion of patented eco-technologies

- Empirical eco-innovation literature has shown different type of partners may contribute to explaining differences in the eco-innovation generation/adoption (Ghiseti et al., 2015)

    Hypothesis 2: The higher the organizational diversification of R&D collaboration the higher the speed of diffusion of patented eco-technologies

- Digital eco-technologies have many applications in many other domains (Baccianti et al., 2022), having a generating effect on innovation, as well as room for improvement (Cecere et al., 2014)

    Hypothesis 3: The effect of organizational R&D collaboration and its diversification has a different effect depending whether the eco-technology is digital or non-digital

3. Data

- Patent families with at least one application to the EPO
- Dataset:

  1. To identify patents with environmental applications (OECD, 2022): **144,058** patent families in 20 environmental fields in the period 1991-2017

  2. To distinguish digital/non digital patents from environmental patents (Baruffaldi et al. 2020; Martinelli et al. 2021 y Ardito et Al. 2018, Bianchini, 2023). (**54,951/ 89,107**patent families)

  3. To determine the first citation of the first patent in the family

  4. To obtain the citation-lag. Days between the publication date of the first patent application in the patent family and the date in which such a patent (cited patent) was first cited (citing patent) (self-citations excluded)

  5. To create the collaborative variables and other controls

- **Sources**: EPO Worldwide Patent Statistical Database (PATSTAT, 2023, Spring Edition), OECD.

4. Model and variables

Model

We build on Griffith et al (2011) and Kwon et al. (2017):

- There is a set of inventions i=1,…, I and a set of subsequent inventions j=1,…, J patented by inventors that cited inventions “i”
- The inventors of “j” will learn of invention “i” after a time period T_{ij}
- T_{ij} can be thought of as the diffusion lag between invention i (cited patent) and invention j (citing patent)
- The diffusion lag (speed at which knowledge from invention ”i” is incorporated in invention “j”) is affected by R&D collaboration between organizations (C)
- The diffusion lag is also affected by other variables such as the patent characteristics P, the policy stringency S, and the institutional context L in which inventions ”i” and “j” was produced

- We apply the Cox proportional hazard model (Cox, 1972)

- The hazard function of the diffusion lag is affected by a vector of explanatory variables *X* (that includes C, P, S and L)

$$h(t) = h_0 \exp\left(\beta_1 x_1 + \cdots + \beta_k x_k\right)$$

  - β_k are the regression coefficients to be estimated from the data
  - h_0 is called the baseline hazard and it is left unestimated.

- Because many inventions were never cited by subsequent inventions, our data are right censored

Variables

- **Diffusion speed**:
  - We focus on the first citation and indicator of diffusion speed (Griffiths et al.,2011; Poncheck, 2016)
  - Diffusion lag: number of days between the publication date of the first patent in the patent family and the date of the first-citation (Gay et al. 2005; Fisch et al. 2017; Lee and Sohn 2017)
  - Many patents in the sample were never cited. Breslow method to handle data censoring in the Cox model
- **Collaboration**:
  - Dummy variables capturing different forms of collaboration: firm-firm, firm-uni, firm-gov, uni-uni,…, firm-uni-gov
  - Institutional diversification variable. Blau index= $1 - \Sigma Pi^2$
- **Control variables**: patent characteristics (n. inventors, back cit., fsize, scope, originality); policy stringency; country effects, home bias, patent office, sector and time dummies

5. Results

	All (base models)		All (with controls)		Deco=1		Deco=0	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
blau	0.0890**		0.0124		-0.0890		0.0798	
	(0.0442)		(0.0443)		(0.0813)		(0.0532)	
comp_comp		0.1407***		0.1213***		0.1661***		0.0675***
		(0.0108)		(0.0110)		(0.0163)		(0.0148)
uni_uni		0.1863***		0.1569***		0.1944***		0.1235**
		(0.0464)		(0.0465)		(0.0731)		(0.0607)
gov_gov		0.0234		0.0495		0.0585		0.0501
		(0.0614)		(0.0614)		(0.1028)		(0.0767)
comp_uni		0.0752**		0.0466		-0.0345		0.0927**
		(0.0318)		(0.0319)		(0.0547)		(0.0394)
comp_gov		0.1240***		0.0683*		0.0874		0.0652
		(0.0392)		(0.0393)		(0.0738)		(0.0467)
uni_gov		-0.0467		-0.0684		-0.1097		-0.0367
		(0.0518)		(0.0519)		(0.1067)		(0.0597)
comp_uni_gov		0.0881		0.0033		0.2190		-0.0395
		(0.0947)		(0.0948)		(0.2012)		(0.1077)
Control var.	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	144,058	144,058	144,058	144,058	54,951	54,951	89,107	89,107
Log likelihood	-1,553,929	-1,553,951	-1,546,906	-1,546,839	-536,835	-536,782	-914,601	-914,587
Wald chi2	26529.66***	26486.09***	40576.10***	40709.13***	16041.08***	16148.91***	23958.10***	23986.21***

The control variables includes the patent characteristics, the patent offices, the stringency index and the home bias.
The omitted base category of variables capturing collaboration is: patent family with a single applicant (patent without institutional collaboration).
Deco=1: Patents in which a digital patent code is in the list of IPC codes of the patent family (along with the environmental codes).
Deco=0: Only environmental codes in the list of IPC codes of the patent family.
* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

5. Conclusions

What type of collaboration accelerate diffusion speed? H1 ✓

- Cooperating between firms or between universities accelerates the diffusion speed by 12%-16%, respectively (compared to patents with no-collaboration)

- Other types of mixed collaborations have no effect

Does institutional diversification affect diffusion speed? H2 ✘

- Institutional diversification has no effect on diffusion speed

Is there any difference between deco-environmental technologies (Deco=1) and other environmental technologies (Deco=0)? H3 ✓

- Similar results. The impact of collaboration is greater for Deco=1

- For Deco=0 collaboration between the firm and university has a positive significant effect compared to Deco=1

Policy implication for technology diffusion speed. Should R&D collaboration to produce joint-patents between institution be promoted?

- Favouring collaboration between organizations is claimed to have positive impact on technological performance (e.g. in patent quality: Belderbos et al., 2014; Briggs and Wade; in breakthroughs: Singh and Fleming, 2010)

- However, if the objective is achieving technological diffusion, incentives to collaborate should go to entities that share the same objectives, routines and methods of work (e.g. firm-firm; university-university)

Limitations:

- More control variables (e.g., technological distance)

- More robustness with alternative measures of diffusion speed (e.g. using dates of EPO patents and UPSTO patents in the family), and other ways of measuring diffusion speed (average time spans of 1^{st}-5^{th}-7^{th} citations)

Future research:

- To focus on the role of environmental policy regulation (stringency) on diffusion speed

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