Diffusion speed of eco-technologies. Does institutional collaboration matter?

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1. Introduction

Motivations

- To accelerate 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 (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)

- Despite the importance of R&D collaboration in the development of eco-technologies, there has been little research into its impact on the speed of diffusion

Objective

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

Our contribution

- We provide quantitative evidence on the effects of organizational collaboration on diffusion speed in the field of eco-technologies

- We investigate the speed with which a patent is cited, presenting a duration modelling approach that deals with patent characteristics and other control variables

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

- An original sample of over 200k patents in the eco-technology domain, with 73k 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 (Griffith et al., 2011; Kwon et al., 2017; Fichter and Clausen, 2021; Losacker et al., 2023):

- The characteristics of the invention (e.g. its quality). Inventions with broad applications will also spread faster (Lee et al., 2003)
- The supplier, which means that the diffusion speed will depend on their characteristics (e.g. firms are more efficient than universities)
- The adopter and motives for adoption (home bias) (Griffith et al., 2011)
- The regulatory context. e.g. stringent regulations favor early adoption (Popp 2010)

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 affect positively and significantly the speed of diffusion of patented eco-technologies

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

Hypothesis 2: The higher 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): **208,774** 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). (**73,378/ 135,396** patent families)

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

  4. To obtain the citation-lag. Number of 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 by a subsequent patent (citing patent)

  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 (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 invention "i" was developed

- To identify the effect of institutional collaboration and institutional diversification on the citation lag (diffusion speed) of eco-technologies, 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 incorporate 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

  - Many patents in the sample were never cited. To handle data censoring in the Cox model we use the Breslow method, consisting of using the largest citation lag for each failure event

- **Collaboration**:

  - Dummy variables capturing different forms of collaboration between institutions: firm-firm, firm-uni, firm-gov, uni-uni,…, firm-uni-gov (reference category: patents owned by a single organization)

  - Institutional diversification variable. Blau index= $1 - \Sigma \mathrm{Pi}^2$

- **Control variables**: patent characteristics (n. inventors, back cit., fsize, scope, us, jp, originality); policy stringency; country, sector and time dummies

5. Results

	All (with controls)		Deco=1		Deco=0	
	(3)	(4)	(5)	(6)	(7)	(8)
blau	-0.1709***		-0.0331		-0.1739***	
	(0.0441)		(0.0806)		(0.0529)	
comp_comp		0.1754***		0.2222***		0.1161***
		(0.0109)		(0.0163)		(0.0149)
uni_uni		0.1290***		0.1906***		0.0856
		(0.0460)		(0.0723)		(0.0598)
gov_gov		0.0394		0.2093**		-0.0216
		(0.0614)		(0.1026)		(0.0766)
comp_uni		-0.0522*		0.0401		-0.0793**
		(0.0317)		(0.0543)		(0.0391)
comp_gov		-0.0268		0.0789		-0.0527
		(0.0388)		(0.0719)		(0.0463)
uni_gov		-0.1108**		-0.0825		-0.0882
		(0.0516)		(0.1050)		(0.0593)
comp_uni_gov		-0.0340		0.1433		-0.0425
		(0.0943)		(0.2015)		(0.1068)
Patent ch.-Str	Yes	Yes	Yes	Yes	Yes	Yes
Sect. dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Ctr. dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	208,774	208,774	73,378	73,378	135,396	135,396
Log likelihood	-1649696.1	-1649569.1	-570098.7	-570005.8	-983257.9	-983226.7
Wald chi2	25326.70***	25580.58***	9033.60***	9219.42***	14381.10***	14443.52***

Control for patent characteristics: n inventors, backward citations, family size, n of claims, priority us-jp, scope, originality. Institutional environment: Stringency index, country dummies.
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

Effect of institutional diversification on diffusion speed

- Institutional diversification has a detrimental effect on diffusion speed

What type of collaboration accelerate diffusion speed?

- Cooperating between firms or between universities accelerate the diffusion speed by 15% (compared to patents with no-collaboration)
- Other types of mixed collaborations have no effect or even negative effect.

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

- The negative effect of diversification affects only to non-digital eco-technologies Deco=0
- For Deco=1 collaboration between the same type of institution has a positive and significant effect. For Deco=0 only the collaboration between firms has a positive and significant effect on diffusion speed

Policy implication. 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. country of the citing institution, technological distance)

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

Future research:

- To focus on the role of stringency policy on the diffusion speed

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