Analyzing the effect of gender, geographic and institutional diversity on the radicalness of green patents

49th EBES Conference

October 16-18, 2024
ATHENS, GREECE

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1. Introduction

Motivations

- Rapid environmental degradation and the threat of reaching a tipping point require radical technological solutions (Clark 2001; Raskin et al. 2002;Westley F., et al. 2011)

- The role of radical innovation in the global economy has been widely studied (Tellis G.J. et al., 2009; Colombo et. al, 2017). However, little is known about the specific role of diversity in the production of these inventions.

- Whether there are moderating effects between different types of diversity (Van Knippenberg & Schippers, 2007) and if they promote the development of radical innovation is also of interest.

Objective

The main objective of this paper is to provide evidence on whether institutional, geographic and gender diversity facilitates radical innovation performance of green patents.

Our contribution

- To shed light on which types of diversity can influence radical patent generation.
- To investigate the moderating effects between different types of diversity and how they affect the development of radical innovation.
- To identify what other factors may influence the radicality of green patents.
- To draw on an original and updated sample of over 184k green patents in the period 1979-2022.

2. Literature review and hypotheses

2.1. Gender diversity and innovation.

- Few studies have focused on the analysis of gender diversity on the radical character of inventions.

- Gender diversity in R&D teams enhances innovation (Østergaard et al., 2011; Díaz-García et al., 2013).

- Gender diversity contributes to absorb and combine different types of knowledge to generate technological knowledge (Díaz-García et al., 2013; Ritter-Hayashi et al., 2019; Ruiz-Jiménez et al., 2016).

- The development of a radical invention is positively influenced by gender diversity in the inventor team (Díaz-García et al., 2013; García-Martínez et al., 2016).

Hypothesis 1: Patent radicality index of green patents is significantly affected by gender diversity in inventor teams

2.2. Geographic diversity and radical patents.

- Geographical diversity reflects the different locations of inventors, which is not directly related to the team's tasks (Tang et al., 2015).

- Having collaborative arrangements in different countries allows firms to be exposed to different national knowledge bases, which increases the likelihood of discovering valuable knowledge recombinations (Zahra et al., 2000).

- Several authors found a positive relationship between geographical diversity and patent radicality. (see, por example Kang, B., & Nabeshima, K., 2021; Seo et al., 2020; Zhang, E., et al., 2022)

Hypothesis 2:Geographical diversity of inventor teams has a significant impact on the radicality index of green patents.

2.3. Collaboration (institutional diversity) and radical patents.

- The radicalness of innovations and the time to generate them are influenced by different organisational forms (Wuben, 2015).

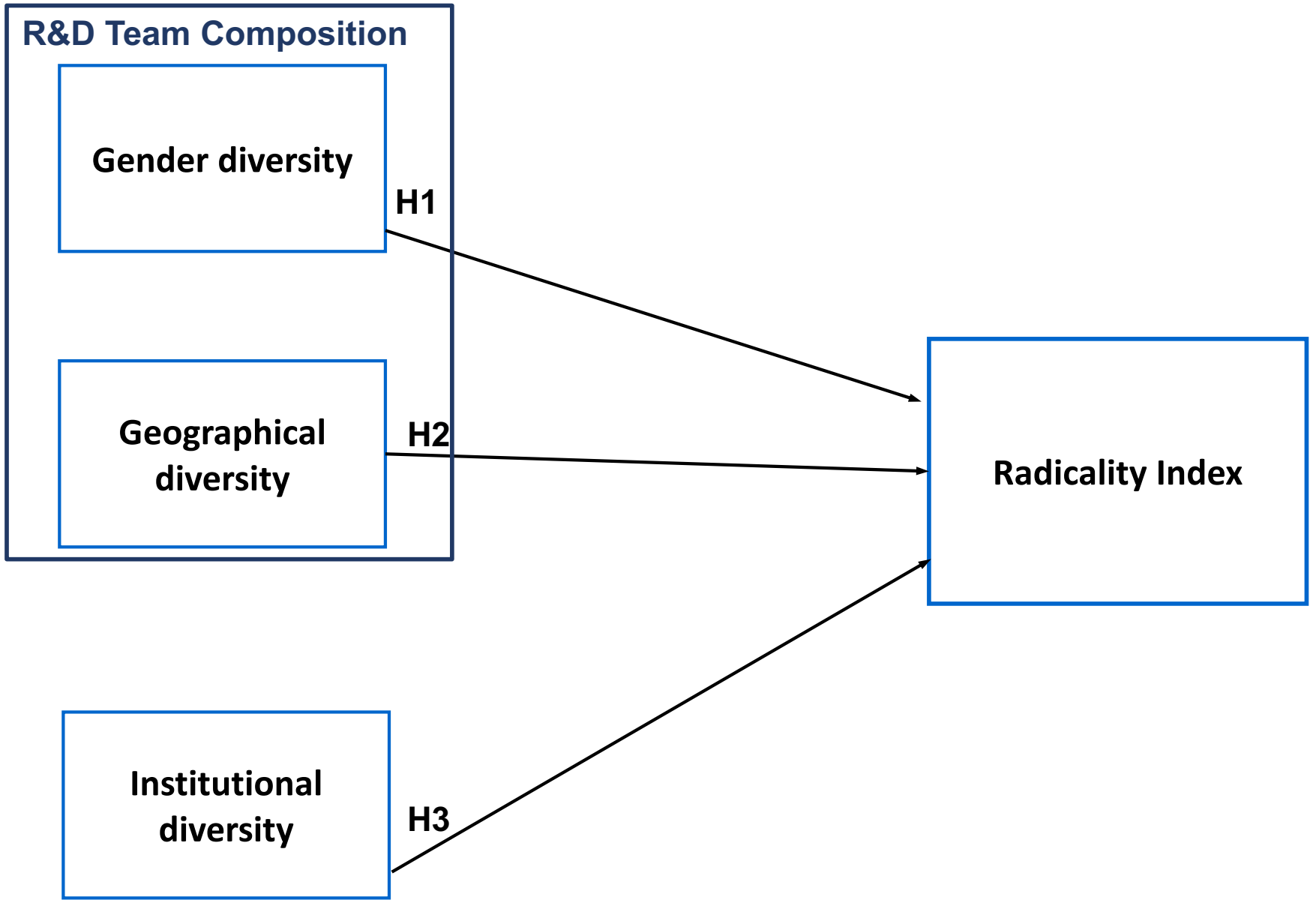
- Different ways to acquire external knowledge give rise to different timeframes and radicalities (Dewar et al., 1986; Kang et al., 2007).

- Inter-firm co-operation could lead to both radical innovation in the long run and incremental innovation in the short run De Man et al. (2005).

- Analysing the effect of collaboration on innovation is complex, as firms may simultaneously engage in different types of collaboration with different firms (Knudsen, 2007; Laursen et al., 2006; Van De Vrande et al., 2006; Faems et al., 2005).

Hypothesis 3:institutional diversity has a positive effect on the radicality index of green patents

Figure 1. Theoretical model on the effect of diversity on radical innovation



3. Data

Dataset:

- Our unit of measurement is the patent family with more than one inventor.
- The final sample contains 184,621 patents between the years 1979-2022.
- We identified the patent families using the International Patent Classification (IPC)

Source:

The patent information was obtained from the EPO Worldwide Patent Statistical Database (PATSTAT).

4. Variables and model

4.1 Variables

- **Dependent variable**

We capture the radicalness of new technologies owned by the firm using the patent radicalness index proposed by Shane (2001)

$$rad_p = \sum_j^{n_p} CT_j/n_p \,; IPC_{pj} \neq IPC_p$$

$$0 \leq rad_p \leq 1$$

- **Main independent variables**

Three variables based on the Blau's index (1977) as a measure of diversity.

- Gender diversity $(blaugender)$
- Geographic diversity *(blaugeo)*
- Institutional diversity (*blau_inst)*

$$\text{Blau index} = 1 - \sum_{i=1}^{2}.P_i^2$$

- **Control variables:** Citations to non-patent literature (*npl);* Number of claims (*mclaim);* Backward patent citations *(bs);* Family size *(fsize);* Scope of the patent *(scope);* Year and sector dummies

4.2 Model

- Main model→Fractional Model (Papke & Wooldridge, 1996):

$$rad_i = G\Big(\beta_0 + \beta_1 \text{blaugender}_i + \beta_2 \text{blaugeo}_i + \beta_3 \text{blau\_inst}_i + \beta_4 \text{mclaim}_i + \beta_5 \text{npl}_i + \beta_6 \text{bs}_i + \beta_7 \text{fsize}_i + \beta_8 \text{scope}_i + \sum_{f=1}^{F} \mu_j \, \text{firm}_f + \sum_{k=1}^{K} \lambda_j \, \text{sector}_k + \sum_{t=1}^{T} \varphi_j \, \text{year}_t + \varepsilon\Big)$$

- Robustness analysis:

  - Ordinary Least Squares (OLS),
  - Censured Tobit Model

5. Results

Main models (Fractional logit and probit)

	FRACREG LOGIT					FRACREG PROBIT				
	1	2	3	4	5	6	7	8	9	10
	Coef./Std. err.	Coef./Std. err.	Coef./Std. err.	Coef./Std. err.	Coef./Std. err.	Coef./Std. err.	Coef./Std. err.	Coef./Std. err.	Coef./Std. err.	Coef./Std. err.
blaugender	-0.1562***	-0.1302***	-0.1298***	-0.1305***	-0.1310***	-0.0941***	-0.0795***	-0.0792***	-0.0796***	-0.0799***
	(0.0124)	(0.0124)	(0.0124)	(0.0124)	(0.0124)	(0.0074)	(0.0074)	(0.0074)	(0.0074)	(0.0074)
blaugeo	0.0639***	0.0960***	0.1008***	0.0921***	0.0965***	0.0388***	0.0578***	0.0607***	0.0555***	0.0582***
	(0.0182)	(0.0181)	(0.0182)	(0.0186)	(0.0187)	(0.0110)	(0.0109)	(0.0110)	(0.0112)	(0.0113)
blau_inst	0.0690*	0.0675*	0.1045***	0.0831**	0.0891**	0.0424**	0.0391	0.0619***	0.0488**	0.0525**
	(0.0352)	(0.0406)	(0.0371)	(0.0352)	(0.0421)	(0.0212)	(0.0243)	(0.0222)	(0.0211)	(0.0253)
blaugender#blau_inst		0.1340			0.1298		0.0824			0.0791
		(0.1640)			(0.1642)		(0.0987)			(0.0988)
blaugeo#blau_inst			-0.3598*		-0.3790**			-0.2210**		-0.2311**
			(0.1851)		(0.1864)			(0.1104)		(0.1111)
blaugender#blaugeo				0.0863	0.0987				0.0484	0.0557
				(0.0871)	(0.0876)				(0.0525)	(0.0528)
npl		0.0011***	0.0011***	0.0011***	0.0011***		0.0008***	0.0008***	0.0008***	0.0008***
		(0.0003)	(0.0003)	(0.0003)	(0.0003)		(0.0001)	(0.0001)	(0.0001)	(0.0001)
mclaim		0.0046***	0.0045***	0.0046***	0.0045***		0.0028***	0.0028***	0.0028***	0.0028***
		(0.0002)	(0.0002)	(0.0002)	(0.0002)		(0.0001)	(0.0001)	(0.0001)	(0.0001)
bs		0.0008***	0.0008***	0.0008***	0.0008***		0.0004***	0.0004***	0.0004***	0.0004***
		(0.0002)	(0.0002)	(0.0002)	(0.0002)		(0.0001)	(0.0001)	(0.0001)	(0.0001)
fsize		-0.0231***	-0.0231***	-0.0231***	-0.0231***		-0.0138***	-0.0138***	-0.0138***	-0.0138***
		(0.0008)	(0.0008)	(0.0008)	(0.0008)		(0.0005)	(0.0005)	(0.0005)	(0.0005)
scope		-0.0118***	-0.0118***	-0.0118***	-0.0118***		-0.0068***	-0.0068***	-0.0068***	-0.0068***
		(0.0004)	(0.0004)	(0.0004)	(0.0004)		(0.0002)	(0.0002)	(0.0002)	(0.0002)
sector dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
year dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
_cons	-1.1865***	-1.0231***	-1.0227***	-1.0226***	-1.0224***	-0.6265***	-0.6266***	-0.6263***	-0.6263***	-0.6262***
	(0.2916)	(0.2885)	(0.2885)	(0.2884)	(0.2884)	(0.1687)	(0.1687)	(0.1687)	(0.1687)	(0.1687)
Observations	184621	184621	184621	184621	184621	184621	184621	184621	184621	184621
R_A	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Log likelihood	-110631.81	-110269.05	-110268.65	-110269.01	-110268.41	-110273.31	-110273.22	-110272.80	-110273.21	-110272.58
Wald chi2(7)	5591.32***	7992.87***	7996.88***	7990.82***	7999.54***	8052.70***	8054.93***	8059.04***	8052.75***	8061.56***

Hypotheses

H1:Patent radicality index of green patents is significantly affected by gender diversity in inventor teams	*Gender diversity in R&D teams hampers radicality index of green technology patents applications.*	✓
H2:Geographical diversity of inventor teams has a significant impact on the radicality index of green patents.	*Geographical diversity in R&D teams boosts the radicality index of green technology patent applications.*	✓
H3:Institutional diversity has a positive effect on the radicality index of green patents	*The institutional diversity boosts the radicality index of green techonology patents.*	✓

5. Conclusions

Main findings

- Gender diversity has a negative effect on patent radicality. Our results differ from Díaz-García, et al., (2013), who found a positive relationship between gender diversity in R&D teams and patent radicality. López Cabrales et. al., (2008) show that a highly diverse team seems to favour incremental rather than radical innovation.

- Geographic diversity affects positively the radicality index. Team diversity improves performance due to the unique combination of knowledge and novel resources that geographic diversity provides to a firm's innovation system as pointed out, for example, by Phene et al., (2006) and Gulati (1999).

- The relationship between the institutional diversity and the radicality of the patent is positive. Our results are consistent with Bouncken et al. (2018); Ritala et al., (2018); Haus-Reve et al. (2019), who find that institutional cooperation drives radical innovation.

- The moderating effect of combining two types of diversity is negative, so managing different types of diversity can be difficult and complicated.

Policy implications

- Encourage collaboration between inventors from different countries and collaboration between different types of institutions, such as companies, universities and public administrations, for the development of radical green patents.
- Regarding the gender composition of the team of inventors, if the aim is to improve the radicality of green patents, the more homogeneous the gender, the better.

Limitations and extensions

- The main limitation is the lack of knowledge about the background of the inventors and the nature of the collaboration between different institutions leading to the development of the patent.
- An extension of this work would be to determine the impact of diversity in R&D teams on other indicators of innovation performance, such as the originality and generality of green patents.
- Future studies could rely on survey data to include more diversity dimensions and examine how they interact in practice.

Many thanks

Funding: This research is part of the R&D project TED2021-131181B-I00 funded by MCIN/ AEI/10.13039/501100011033/ and by the “Unión Europea NextGenerationEU/PRTR”.