The effect of geographic and gender diversity within inventor teams on the radicality of patented digital eco-technologies

Daniel Coronado Guerrero
Esther Ferrándiz León
Rosario Marín Muñoz
Carmen Puentes Graña
University of Cadiz (Spain)

1. Introduction

Motivations

- There is a growing interest in understanding the relationship between a firm's innovativeness and its various competencies and characteristics (Freel, 2005).

- Some of these characteristics are the composition of innovation teams (Belderbos et al., 2014; Miotti & Sachwald, 2003),in particular the gender diversity of team members (Bilimoria & Wheeler, 2000; Huse & Solberg, 2006) and the geographical location of innovation activities (Ardito et al. 2020-2021; Frost, 2001; Lahiri, 2010; Scalera, Perri, & Hannigan, 2018; Singh, 2008).

- These characteristics are crucial because they promote openness, which will influence the development of radical innovations. Radical innovation is expected to be associated with greater uncertainty and technological complexity (Raz et al., 2002) and less predictable outcomes (Green et al., 1995; Rice et al., 2001).

- In order to address the opportunities and threats associated with ecological and digital transformation, companies and governments have placed the adoption of sustainable technologies among their top priorities.

- This paper focuses on eco-technologies. Many studies have investigated the causes, characteristics and effects of sustainable technologies (Díaz-García et al., 2015; He et al., 2018). However, research on the adoption and diffusion of eco-technologies is still at a very early stage.

Objective

To analyse the influence of the geographical diversity and the gender diversity on the index of radicality of the patented digital eco-technologies.

Why patents?

- We are following the research efforts of a large number of other scholars who have used patents as a measure of technological innovation.
- Patents contain a wealth of information and allow large-scale evaluation.

Our contribution

- We use an original sample of patented digital eco-technologies. We rely on detailed information on more than 193.000 patented digital eco-technologies between the years 1979-2022.
- Our study contributes to the literature by providing evidence on the specific effect of gender and geographic diversity of inventor teams on the rate of patent radicality, as well as on the moderating effects of both variables.
- Regarding the study of gender diversity in an inventor team, the focus is mainly on cognitive differences between women and men (George et al., 1996; Kou et al., 2020; Ruigrok et al., 2014). Cognitive diversity is complemented by geographical diversity, as geographical openness to new ideas ensures flexibility in the application and development of knowledge for innovation (Boschma, 2005).

2. Literature review and hypotheses

2.1. Gender diversity and innovation.

- 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).

- There are very few studies that have focused their research on the analysis of gender diversity on the radicality of the invention.

H1a. Gender diversity in R&D teams boosts the radicality index of digital eco-technology patent applications.

H1b. Gender diversity in R&D teams hampers radicality index of digital eco-technology patents.

2. Literature review and hypotheses

2.2. Geographic diversity and innovation quality.

- Geographical diversity reflects the different locations from which inventor members come, 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. This exposure, helps develop skills and competencies, increases the likelihood of discovering valuable new combinations, and contributes to higher levels of innovation success (Zahra et al., 2000).

H2a. Geographic diversity in R&D teams boosts the radicality index of digital eco-technology patent applications.

H2b. Geographic diversity in R&D teams hampers radicality index of digital eco-technology patents.

- There is empirical evidence to suggest that gender diversity improves the effectiveness of groups up to a certain point, after which increasing diversity leads to sub-optimal outcomes (Richard et al., 2004). There could be a tipping point where increasing the geographic diversity of knowledge inputs leads towards diseconomies of scale (Kim et al., 2020), reducing the value of innovation rather than increasing it (Lahiri, 2010). This suggests that an inverted U-shaped relationship exists.

H3: The relationship of geographical diversity to radicality index has an inverted-U shape.

2. Literature review and hypotheses

- In spite of the existence of opposing theories, there has been a tendency to treat them as complementary to each other because all of them have been empirically supported (Shore et al., 2009). The integration of these theories has addressed two issues. The first is that a curvilinear relationship between gender diversity and innovation should be explored (Haas, 2010), suggesting that the effect of gender diversity may depend on the specific gender composition (Blau, 1977).

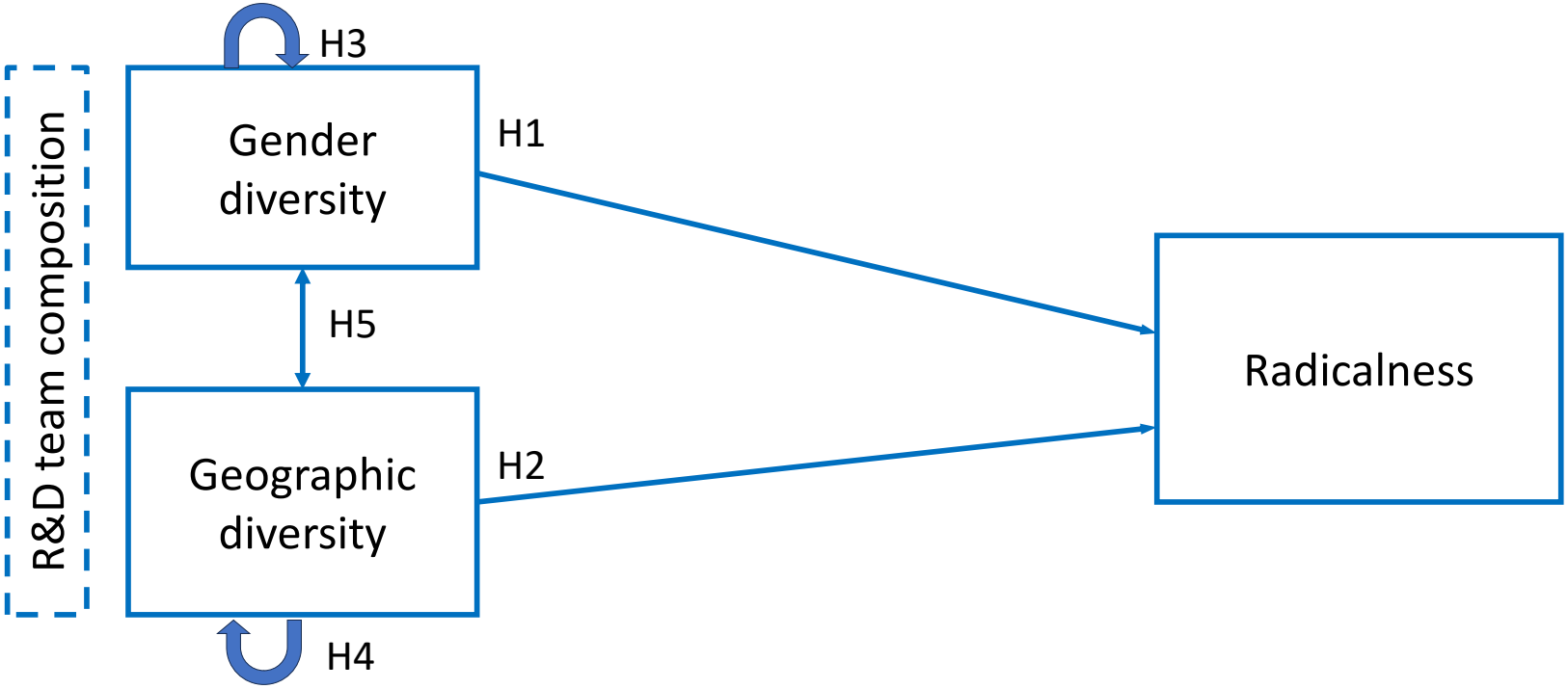
H4: The relationship of gender diversity to radicality index has an inverted-U shape.

- Research on diversity has focused on the effects of different types of diversity in isolation, without considering that the effects of one type of diversity may be related to other aspects. Rather than looking at the additive effects of diversity, it is better to look at their different moderating effects by looking at the interaction of the differing aspects of diversity (Van Knippenberg & Schippers, 2007). This motivates the following hypothesis:

H5. Gender diversity and geographical diversity in R&D teams have a complementary effect on the radical index of the invention.

2. Literature review and hypotheses

Figure 1. Theoretical background and hypothesis



3.-Data

We address our objective using a sample of patented digital eco-technologies. We rely on detailed information on more than 193.000 patented digital eco-technologies between the years 1979-2022.

Our unit of measurement is the patent family. We discarded patents that only listed one inventor (single inventor patents) since we are interested in R&D teams. We identified the patent families using the International Patent Classification (IPC) codes defined by the The patent information was obtained from the EPO Worldwide Patent Statistical Database (PATSTAT).

4.- Variables

- **Dependent variable**

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

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

$$0 \leq rad_p \leq 1$$

4.- Variables

▪ Main independent variables

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

- Gender diversity
- Geographic diversity

▪ Other 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.

5.- Models and results

▪ Models

- Main model→Fractional Model

$$rad_i = G\left(\beta_0+\beta_1 blaugender_i+\beta_2 blaugeo_i+\beta_3 blaugender_i{}^2+\beta_4 blaugeo_i{}^2+\beta_5 blaugender_i.blaugeo_i+\beta_6 mclaim_i+\beta_7 npl_i+\beta_8 bs_i+\beta_9 fsize_i+\beta_{10} scope_i + \sum_{f=1}^{F}\mu_j firm_f + \sum_{k=1}^{K}\lambda_j sector_k + \sum_{t=1}^{T}\phi_j year_t+\varepsilon\right)$$

- Robustness analysis

  Ordinary Least Squares (OLS),

5.- Models and results

- **Results**

Table 1. Definitions of variables and descriptive statistics

Variable	Description	Mean	Std. dev.	Min	Max
rad	Radicality index	0.29274	0.23333	0	1
blaugender	Blau index for gender diversity	0.16079	0.21114	0	0.5
blaugeo	Blau index for geographical diversity	0.04551	0.14118	0	1
npl	No. of non patent literature	4.01704	14.48467	0	1087
mclaim	No. of claims	13.85275	10.77343	0	358
bs	No. of backwards patent citations	15.55673	72.99716	0	5787
fsize	No. of jurisdictions in which patets seeks protection	6.05474	3.59156	1	51
scope	No. of ipc4 digits	11.81142	8.63235	0	314
Nº obs. (patent families): 193,594					

The radicality index ranges between 0 and 1, with a mean of 0.2927349 per patent. The number of patents for which there is some level of geographic diversity is 19,785 (10.22%) and those where is some level of gender diversity is 73,507 (37.97%).

5.- Models and results

Table 2. Effect of diversity on patent radicality

	MAIN MODELS		ROBUSTNESS
	FRL	FRP	OLS
C_blaugender	-0.0345	-0.0224	-0.0073
	(0.0731)	(0.0438)	(0.0148)
C_blaugeo	0.1902***	0.1148***	0.0400***
	(0.0575)	(0.0347)	(0.0120)
C_sqblaugender	-0.2223	-0.1326	-0.0453
	(0.1588)	(0.0949)	(0.0320)
C_sqblaugeo	-0.2027*	-0.1223*	-0.0426*
	(0.1045)	(0.0631)	(0.0218)
c.C_blaugender#c.C_blaugeo	0.0393	0.0204	0.0068
	(0.0852)	(0.0513)	(0.0176)
npl	0.0010***	0.0007***	0.0002***
	(0.0003)	(0.0001)	(0.0000)
mclaim	0.0045***	0.0027***	0.0009***
	(0.0002)	(0.0001)	(0.0000)
bs	0.0009***	0.0004***	0.0002***
	(0.0002)	(0.0001)	(0.0000)
fsize	-0.0230***	-0.0138***	-0.0046***
	(0.0008)	(0.0005)	(0.0001)
scope	-0.0119***	-0.0069***	-0.0022***
	(0.0004)	(0.0002)	(0.0001)
	0.1506***	0.0916***	0.0315***
_cons	-0.6558**	-0.4095**	0.3386***
	(0.2799)	(0.1687)	(0.0591)
Sector dummies	YES	YES	YES
Year dummies	YES	YES	YES
Observations	193594	193594	193594

Dependent variable: Radicality Index (rad)
(Standard errors in parentheses)
* p < 0.10; ** p < 0.05; *** p < 0.01.

5.- Models and results

Table 3. Results

HYPOTHESES		CONCLUSION
H1	Gender diversity in R&D teams boosts the radicality index of digital eco-technology patent applications.	**NO EVIDENCE**
H2	Geographic diversity in R&D teams boosts the radicality index of digital eco-technology patent applications.	**TRUE**
H3	The relationship of geographical diversity to radicality index has an inverted-U shape	**TRUE**
H4	The relationship of gender diversity to radicality index has an inverted-U shape	**NO EVIDENCE**
H5	Gender diversity and geographical diversity in R&D teams have a complementary effect on the radical index of the invention.	**NO EVIDENCE**

6. Conclusions

- Gender diversity has not effects on patent radicality. Our results are not in accordance with the analysis of Díaz-García, et al., (2013), who found a positive relationship between gender diversity in R&D teams and patent radicality. The results obtained by López Cabrales et. al., 2008, show that a highly diverse team seems to favour incremental rather than radical innovation. In the latter, where team members have to deal with high levels of uncertainty, team collaboration is critical and diversity conflict can become a real and important issue (López Cabrales et. al., 2008).

- Geographic diversity affects positively on 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). A diversity of national origins broadens the scope of the knowledge base that is accessible and provides access to network resources that can stimulate innovation (Gulati, 1999).

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”.