Gender and eco-innovation

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Introduction – green innovation

- **Green Innovation** is part of the solution to:
  - decrease emissions of greenhouse gases (**mitigation**)
  - deal with temperature increases (**adaptation**)
  - accommodate social changes triggered
- **Green technologies** are more complex, original and have more impact than non-green technologies (Barbieri et al, 2020)
- From a policy perspective:
  - the green economy is often recognized as holding the potential for new growth and job creation.
  - Green transition is expected to be inclusive and offer opportunities to underrepresented categories.

Introduction – green technologies

- **Green technologies are not homogenous**, different stages of the technology life-cycle which require different kind of skills (Abernathy & Utterback, 1978; Vona & Consoli, 2014)
- Objectives of the EU commission and members: “sustainable, competitive and **fair** society”

→Green technologies are a key pilar to achieve the transition

→Women must be involved in their development

Introduction – gender diversity in innovation

- Empirical evidence suggests the existence of a positive correlation between **gender diversity in R&D teams** and **innovation**, especially in the face of high market uncertainty and task complexity (see i.e., Østergaard et al, 2011; Díaz-García et al, 2013; Xie et al, 2020)
- **Large share of highly qualified women** and a **gender diverse board** composition are positively correlated to **eco-innovation** activities (Horbach and Jacob 2018)
- **Women** hold a comparative advantage in **non routine cognitive tasks** (Black & Spitz-Oener, 2010)

Research Questions

- Does gender diversity matter for the development of technologies ?
- Are they differences between ‘green’ and ‘non-green’ technologies ? Between green technologies ?
- Do the territories where inventions take place matter?

Data & Methodology

- Greentech DB (www.greentechdatabase.com)
  - Based on PATSTAT 2020a
  - Identification of “green technologies” using CPC code Y02 – “Technologies or applications for mitigation or adaptation against climate change”
- PATSTAT 2020a for non-green technologies
- Detection of gender
  1. Detection of inventors’ firstname
  2. Assignation of a gender using World Gender Name Database (probability of being woman or man by country and language)

Data & Methodology (2)

3. Creation of a unique identifier for inventors across patent family

- to not underestimate women participation
- to improve gender detection rate

Example:

			Without unique ID
Pat family A	Appln 1	John R. Doe Jane V. Smith Robert M. Kay	6 men, 1 woman → share = 1/7
	Appln 2	Doe, Jon Kay, Bob	
	Appln 3	Doe, John R. Kay, Robert M.	

Data & Methodology (2)

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Example:

			Without unique ID	With unique ID
Pat family A	Appln 1	John R. Doe ← Jane V. Smith ← Robert M. Kay ←	6 men, 1 woman → share = 1/7	2 men(●●), 1 woman (●) → share = 1/3
	Appln 2	Doe, Jon ← Kay, Bob ←		
	Appln 3	Doe, John R. ← Kay, Robert M. ←		

Data & Methodology (3)

- Patent quality indicators
  - Complexity
    - Scope: Number of distinct IPC codes (Lerner, 1994)
    - Originality*: Herfindahl-Hirschman (HH) index of IPC codes (Trajtenberg et al., 1997)
  - Novelty
    - Novelty in recombination: number of new pairs of IPC codes (Verhoeven et al., 2016)
    - Radicalness*: radicalness indicator developed by Shane (2001)
  - Impact
    - Forward citations*: number of forward citations at 5 and 7 years
    - Generality*: variety of technology fields to which the citing patents belong (Hall and Trajtenberg, 2004)

⇨ *Aggregation at docdb patent family level, using the maximum value*

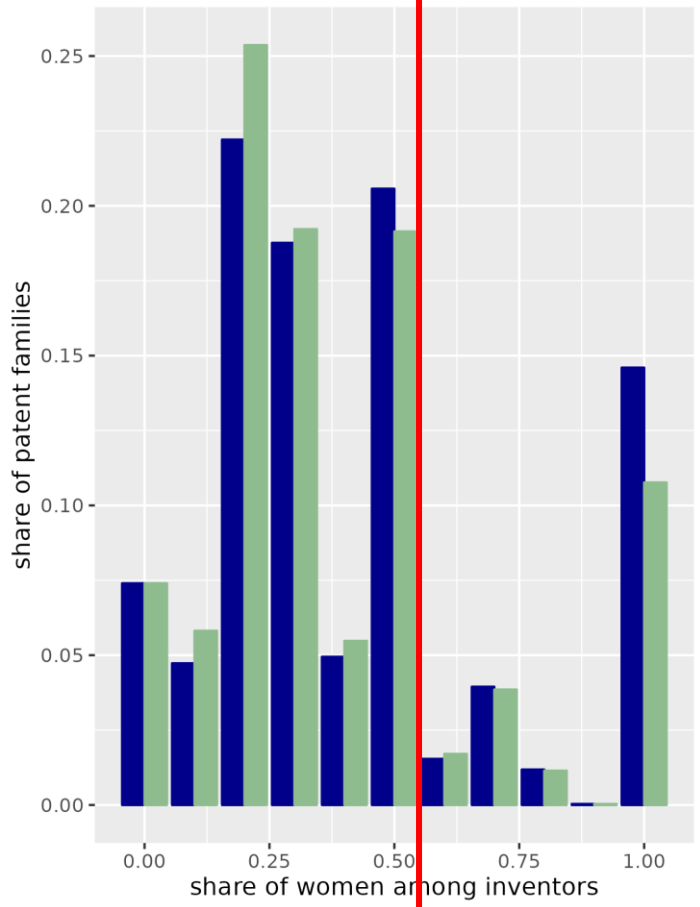
* OECD Patent Quality Indicator Database v.202107, EPO and USPTO filled patent applications

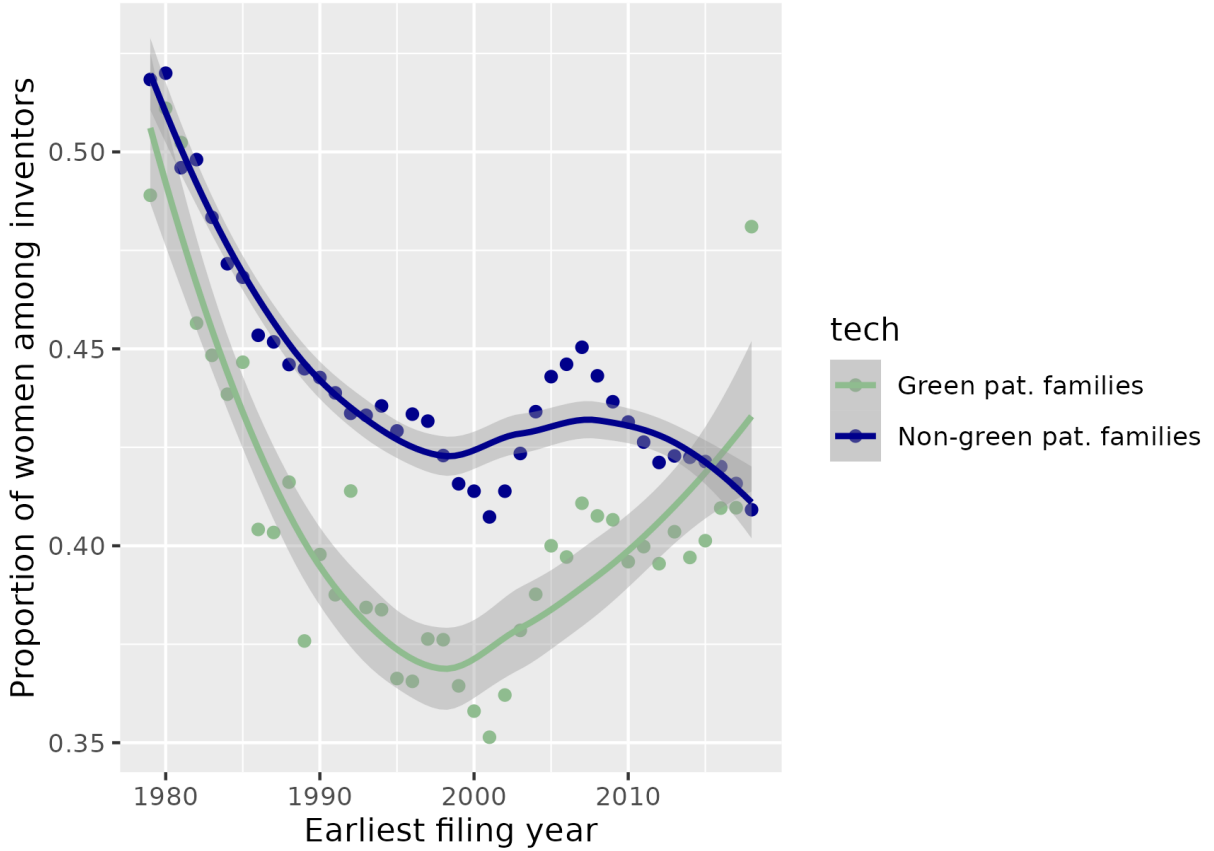
Data & Methodology (4)

- 1.523.827 DOCDB patent families
  - 1979-2018
  - At least 1 patent application in USPTO or EPO

Data & Methodology (4)

78 % non-green patent
82 % of green patent
with share women ≤ 0.5





Empirical models

- We assess the relationship between the presence of women in the team and 7 indicators, proxies for **Complexity**, **Novelty** and **Impact**, at the patent family level.

$$\text{Pat. } indic_i^A = \alpha\ Green\_patent_i^{0,1} + \beta\ Women\_share_i^A + \gamma\ Green\_patent_i^{0,1} \text{ x } Women\_share_i^A + \delta\ Controls_i^A + IPC.3dig_i^{0,1} + geo_i^{0,1} + time_i^{0,1} + \varepsilon_i$$

- Controls
  - For all the models: N. citing, N. inventors, N. applicants
  - For generality: N. cited
  - For radicalness, scope and novelty: scope with full digits IPC codes

Barbieri, N., Marzucchi, A., & Rizzo, U. (2020). Knowledge sources and impacts on subsequent inventions: Do green technologies differ from non-green ones? In Research Policy (49) 2, p. 103901

Preliminary results

	Originality		Novelty		Impact		
VARIABLES	Scope	Originality	NR4	Radicalness	Generality	Fwd_cits (5yrs)	Fwd_cits (7yrs)
Green patent	0.047***	0.016***	0.650***	0.041***	0.045***	0.248***	0.225***
	(0.007)	(0.001)	(0.145)	(0.002)	(0.002)	(0.030)	(0.027)
Women share	-0.045***	-0.021***	-0.433***	-0.010***	-0.042***	-1.316***	-1.278***
	(0.002)	(0.001)	(0.128)	(0.001)	(0.001)	(0.019)	(0.018)
Green patent x women share	0.026***	0.009***	-0.242	-0.015***	0.011***	-0.081	-0.042
	(0.010)	(0.002)	(0.336)	(0.004)	(0.004)	(0.067)	(0.062)
scope_IPCfull	0.026***		0.078***	-0.011***			
	(0.002)		(0.004)	(0.000)			
n_inv	0.001***	0.002***	-0.005	0.001***	0.003***	0.029***	0.026***
	(0.000)	(0.000)	(0.011)	(0.000)	(0.000)	(0.002)	(0.002)
bwd_cits	0.000***	0.000***	0.000***	0.000***	0.000***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1,010,996	1,010,996	1,009,788	1,010,996	1,010,996	1,010,996	1,010,996
Regional Dummies	YES	YES	YES	YES	YES	YES	YES
Year Dummies	YES	YES	YES	YES	YES	YES	YES
IPC.3dig	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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n_inv	0.001***	0.002***	-0.005	0.001***	0.003***	0.029***	0.026***
	(0.000)	(0.000)	(0.011)	(0.000)	(0.000)	(0.002)	(0.002)
bwd_cits	0.000***	0.000***	0.000***	0.000***	0.000***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
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Regional Dummies	YES	YES	YES	YES	YES	YES	YES
Year Dummies	YES	YES	YES	YES	YES	YES	YES
IPC.3dig	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Coherent with existing literature: green inventions are more original, novel and impactful

Preliminary results

VARIABLES	Originality: Scope	Originality: Originality	Novelty: NR4	Novelty: Radicalness	Impact: Generality	Impact: Fwd_cits (5yrs)	Impact: Fwd_cits (7yrs)
Green patent	0.047***	0.016***	0.650***	0.041***	0.045***	0.248***	0.225***
	(0.007)	(0.001)	(0.145)	(0.002)	(0.002)	(0.030)	(0.027)
Women share	-0.045***	-0.021***	-0.433***	-0.010***	-0.042***	-1.316***	-1.278***
	(0.002)	(0.001)	(0.128)	(0.001)	(0.001)	(0.019)	(0.018)
Green patent x women share	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	(0.002)	(0.336)	(0.004)	(0.004)	(0.067)	(0.062)
scope_IPCfull	0.026***		0.078***	-0.011***			
	(0.002)		(0.004)	(0.000)			
n_inv	0.001***	0.002***	-0.005	0.001***	0.003***	0.029***	0.026***
	(0.000)	(0.000)	(0.011)	(0.000)	(0.000)	(0.002)	(0.002)
bwd_cits	0.000***	0.000***	0.000***	0.000***	0.000***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1,010,996	1,010,996	1,009,788	1,010,996	1,010,996	1,010,996	1,010,996
Regional Dummies	YES	YES	YES	YES	YES	YES	YES
Year Dummies	YES	YES	YES	YES	YES	YES	YES
IPC.3dig	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A higher presence of women among inventors is associated with less originality, novelty and impact in **NON-GREEN** patents

Preliminary results

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Green patent	0.047***	0.016***	0.650***	0.041***	0.045***	0.248***	0.225***
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Women share	-0.045***	-0.021***	-0.433***	-0.010***	-0.042***	-1.316***	-1.278***
	(0.002)	(0.001)	(0.128)	(0.001)	(0.001)	(0.019)	(0.018)
Green patent x women share	0.026***	0.009***	-0.242	-0.015***	0.011***	-0.081	-0.042
	(0.010)	(0.002)	(0.336)	(0.004)	(0.004)	(0.067)	(0.062)
scope_IPCfull	0.026***		0.078***	-0.011***			
	(0.002)		(0.004)	(0.000)			
n_inv	0.001***	0.002***	-0.005	0.001***	0.003***	0.029***	0.026***
	(0.000)	(0.000)	(0.011)	(0.000)	(0.000)	(0.002)	(0.002)
bwd_cits	0.000***	0.000***	0.000***	0.000***	0.000***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1,010,996	1,010,996	1,009,788	1,010,996	1,010,996	1,010,996	1,010,996
Regional Dummies	YES	YES	YES	YES	YES	YES	YES
Year Dummies	YES	YES	YES	YES	YES	YES	YES
IPC.3dig	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A higher presence of women among inventors is associated with more originality (2/2), less novelty (1/2) and more impact (1/3) in **GREEN** patents

Differences by green technologies

8 groups of green technologies:

- Y02A technologies for adaptation to climate change
- Y02B CCMT related to buildings
- Y02C capture, storage, sequestration or disposal of greenhouse gases
- Y02D CCMT in ICT
- Y02E CCMT related to energy generation, transmission or distribution
- Y02P CCMT in the production or processing of goods
- Y02T CCMT related to transportation
- Y02W CCMT related to wastewater treatment or waste management

Differences by green technologies

	Originality		Novelty			Impact	
VARIABLES	Scope	Originality	NR4	Radicalness	Generality	Fwd_cits (5yrs)	Fwd_cits (7yrs)
Women share	**-0.031*** **	**-0.020*** **	**-1.621** **	**-0.014***	**-0.025*** **	**-1.089*** **	**-1.096*** **
	(0.012)	(0.004)	(0.755)	(0.008)	(0.007)	(0.114)	(0.105)
Adaptation x w.sh	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CCMT.buildings x w.sh	-0.021	0.006	1.287	0.013	**0.021***	-0.105	-0.073
	(0.017)	(0.006)	(0.966)	(0.011)	(0.011)	(0.147)	(0.143)
CCMT.Waste x w.sh	-0.019	**0.014** **	**1.921** **	0.008	-0.009	**-0.300** **	-0.173
	(0.021)	(0.007)	(0.928)	(0.015)	(0.014)	(0.144)	(0.135)
CCMT.Goods x w.sh	0.001	**0.010** **	1.061	**0.024** **	**-0.028*** **	**-0.387*** **	**-0.333*** **
	(0.013)	(0.005)	(0.797)	(0.009)	(0.009)	(0.115)	(0.108)
CCMT.ICT x w.sh	**-0.170*** **	**-0.024*** **	-3.989	**-0.119*** **	**-0.116*** **	**-0.407** **	**-0.337** **
	(0.017)	(0.005)	(2.962)	(0.012)	(0.011)	(0.166)	(0.152)
CCMT.Energy x w.sh	**0.023***	**0.020*** **	**2.007*** **	**0.051*** **	0.011	-0.134	-0.040
	(0.013)	(0.004)	(0.776)	(0.009)	(0.008)	(0.118)	(0.112)
CCMT.Transport x w.sh	0.022	**0.016*** **	0.983	-0.002	**0.023*** **	**0.464*** **	**0.587*** **
	(0.014)	(0.004)	(0.946)	(0.009)	(0.009)	(0.132)	(0.129)
CCS.GHG x w.sh	-0.012	**-0.026** **	1.714	0.011	-0.003	0.236	**0.292** **
	(0.027)	(0.011)	(1.241)	(0.019)	(0.019)	(0.151)	(0.142)

Less mature

Are they differences along the life cycle of green technologies?

TLC stages identified with 2 dimensions

- **Ubiquity of GT**: Country specialisation / Technology diffusion

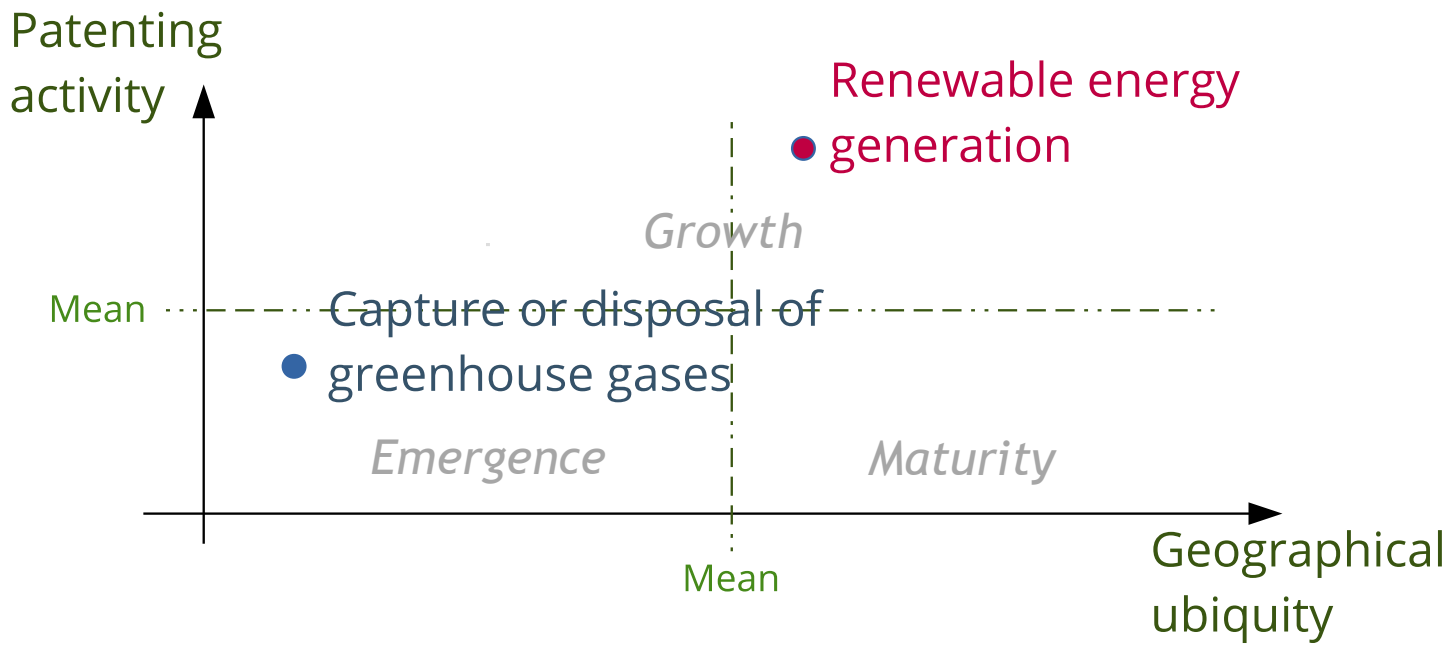
⇨ Reveal Technological Advantage (RTA) for each GT / country worldwide

$$UBIQUITY_{j,t} = \sum_{c} M_{c,j} \quad \text{with } M_{c,j} = 1 \text{ if } RTA > 1$$

- **Patenting intensity**: efforts in developing GT

Barbieri, N., et al (2020). Specialization, diversification, and environmental technology life cycle. Economic Geography, 96(2), 161-186

Identification of Technology Life-Cycle stages



- TLC stages computed every year for all green technologies worldwide
  - Using inventors' addresses
  - 4 year moving average

- If a patent family belongs to more than one GT in distinct TLC stages, we keep the earliest
- Following Barbieri et al (2023), we limit the TLC to 3 stages

Preliminary results - TLC

VARIABLES	Originality		Novelty		Impact		
	Scope	Originality	NR4	Radicalness	Generality	Fwd_cits (5yrs)	Fwd_cits (7yrs)
Women share	-0.019	**-0.032*** **	-0.905	**-0.055*** **	**-0.063*** **	**-0.612*** **	**-0.591*** **
	(0.026)	(0.011)	(1.128)	(0.020)	(0.021)	(0.160)	(0.152)
Women share x emergence	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Women share x growth	0.018	**0.021***	1.206	**0.074*** **	**0.069*** **	-0.043	0.061
	(0.026)	(0.011)	(1.165)	(0.020)	(0.021)	(0.167)	(0.161)
Women share x maturity	-0.023	**0.021***	-0.093	**0.041** **	0.024	**-0.791*** **	**-0.774*** **
	(0.026)	(0.011)	(1.155)	(0.020)	(0.021)	(0.159)	(0.151)
scope_IPCfull	0.020***		0.073***	-0.009***			
	(0.002)		(0.011)	(0.000)			
n_inv	0.002***	0.001***	0.015	0.002***	0.001***	0.034***	0.032***
	(0.001)	(0.000)	(0.016)	(0.000)	(0.000)	(0.004)	(0.004)
bwd_cits	0.000***	0.000***	0.001***	0.000***	0.000***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	68,649	68,649	64,501	68,649	68,649	68,649	68,649
Regional Dummies	YES	YES	YES	YES	YES	YES	YES
Year Dummies	YES	YES	YES	YES	YES	YES	YES
IPC.3dig	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Preliminary results - TLC

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	Scope	Originality	NR4	Radicalness	Generality	Fwd_cits (5yrs)	Fwd_cits (7yrs)
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Women share x emergence	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Women share x growth	0.018	**0.021***	1.206	**0.074*** **	**0.069*** **	-0.043	0.061
	(0.026)	(0.011)	(1.165)	(0.020)	(0.021)	(0.167)	(0.161)
Women share x maturity	-0.023	**0.021***	-0.093	**0.041** **	0.024	**-0.791*** **	**-0.774*** **
	(0.026)	(0.011)	(1.155)	(0.020)	(0.021)	(0.159)	(0.151)

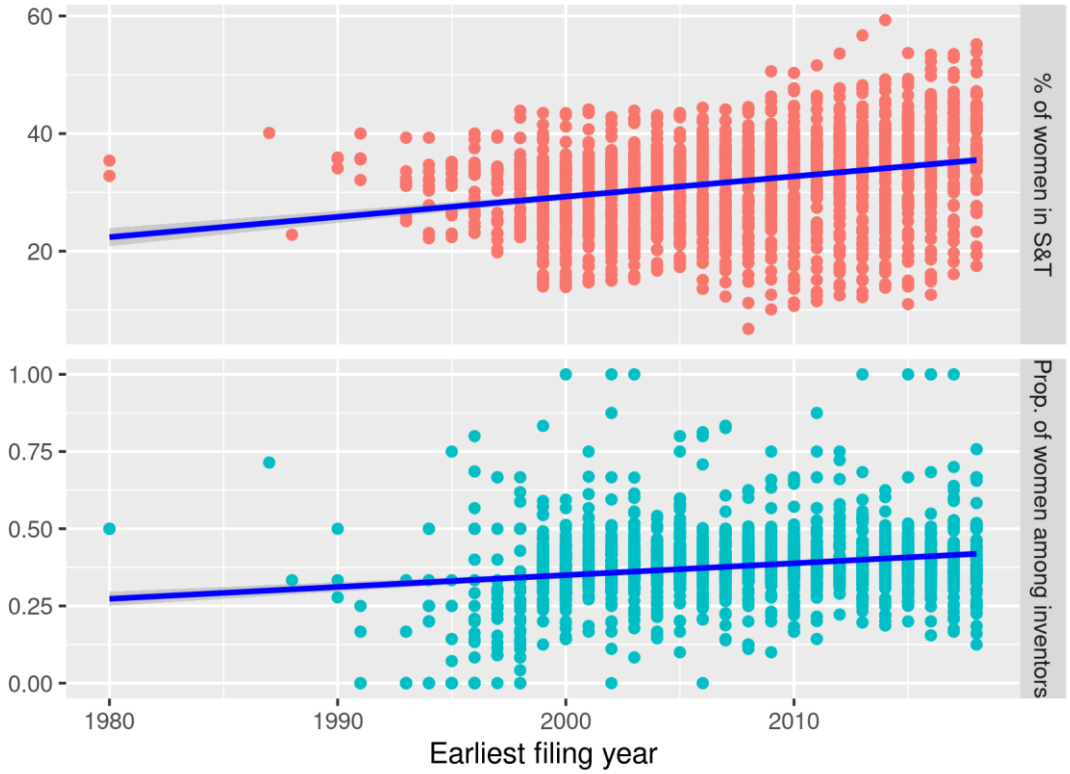
Positive association in growth and maturity stages vs emergence

Does the share of women in S&T matter ?

- At European level, for each NUTS1
  - Women employed in science and technology, as a percentage of population in the labour force, 1999-2019 (Eurostat)
  - Classification by quintiles per year
    - Q1 = regions with the lowest percentage of women in S&T
    - Q5 = regions with the highest percentage of women in S&T

Does the share of women in S&T matter ?

Green and non-green patents



Preliminary results – European regions

Green and non-green patents

	Originality		Novelty		Impact		
VARIABLES	Scope	Originality	NR4	Radicalness	Generality	Fwd_cits (5yrs)	Fwd_cits (7yrs)
women share	0.026	-0.005	-1.222	-0.033	0.004	**-1.170*** **	**-1.087*** **
	(0.041)	(0.013)	(1.667)	(0.032)	(0.035)	(0.288)	(0.274)
Q1 x women share	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Q2 x women share	-0.008	0.007		**0.071***	-0.044	**0.777** **	**0.730** **
	(0.049)	(0.015)		(0.038)	(0.039)	(0.313)	(0.295)
Q3 x women share	0.006	0.009	2.008	0.039	-0.015	**0.702** **	**0.687** **
	(0.044)	(0.015)	(1.763)	(0.036)	(0.038)	(0.303)	(0.292)
Q4 x women share	-0.032	-0.004	0.400	0.043	-0.026	**0.530***	**0.521** **
	(0.041)	(0.013)	(1.639)	(0.033)	(0.035)	(0.275)	(0.263)
Q5 x women share	-0.007	-0.000	2.038	0.023	-0.030	**0.566** **	**0.538** **
	(0.040)	(0.013)	(1.500)	(0.032)	(0.035)	(0.274)	(0.263)
scope_IPCfull	0.027***		0.059***	-0.009***			
	(0.003)		(0.015)	(0.001)			
n_inv	0.001	0.001***	0.023	0.004***	0.001	0.031***	0.031***
	(0.002)	(0.000)	(0.051)	(0.001)	(0.001)	(0.004)	(0.004)
bwd_cits	0.000	0.000***	0.001	0.001***	0.000***	0.003***	0.003***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)

Closing remarks

- We confirm existing literature about the intrinsic characteristics of green technologies
- Higher proportions of women among inventors are associated negatively with originality, novelty, impact in **non-green inventions**
- **In green inventions**, a higher proportion of women is associated with more originality (2/2), less novelty (1/2) and more impact (1/3)
- By green technologies, important differences between **adaptation** and **mitigation**, but there is not a clear pattern within mitigation technologies, except maybe more impact in emerging tech.
- At regional level in Europe, only impact indicators are associated with the characteristics of the region

Closing remarks

What can explain those preliminary results:

- a difference of skills between women and men?
- discrimination against women in already settled domains, which force them to develop their own path in emerging technologies?
- both?

Future avenues

- Update data with PATSTAT 2024
- Patent data might not report all the contributions ⇨ investigate where and which patent applications, use alternative data on women inventors (firm data, LFS,…)
- Delve into regional specificities, using more targeted indicators
- Delve into technology specificities

Thank you

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