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Green FDI and Green Knowledge Transfer

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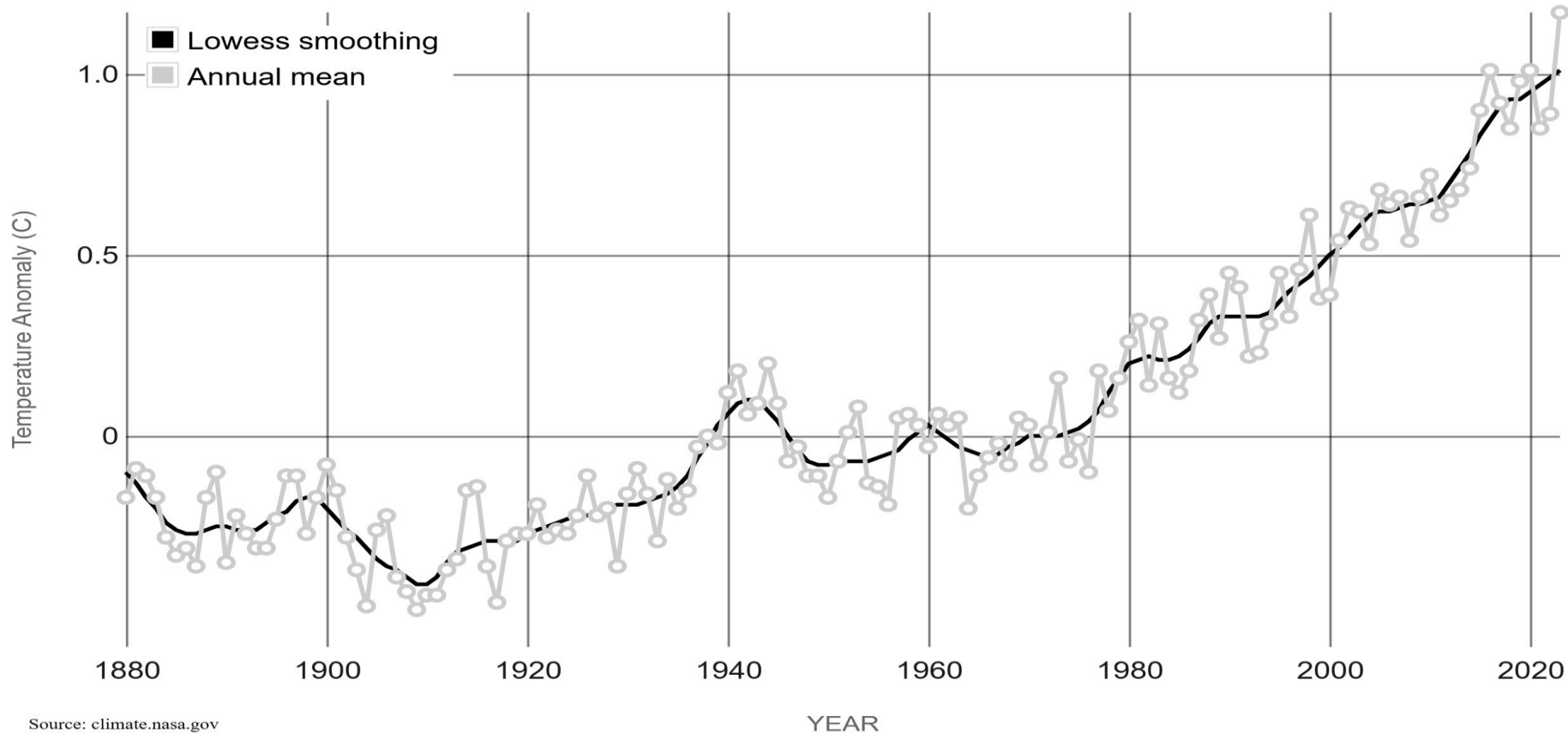
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Internazionalization and Green Innovation

- **Green innovation** is fundamental for the ecological transition (Barbieri et al., 2023; Corrocher et al., 2024; Dechezleprêtre et al., 2015; IRENA, 2020).
 - Urgent need to address increasingly evident climate change
 - Need for greater efficiency and lower environmental impact of green technologies
- **Participation in global value chains** can support the development and diffusion of knowledge required for green innovation (Ambos et al., 2021; Lema et al., 2019)
 - “**Green**” foreign direct investment (FDI) by multinationals can play a specific role in the ecological transition (Amendolagine et al., 2021; De Marchi et al., 2022; Amendolagine et al., 2023)

Evidence of the increase in global temperature



- The graph shows the annual change in the Earth's surface with respect to the 1951-1980 average.
- **In 2023 the temperature was the highest since the first record (1880).**
- Data source:
Climate.nasa.gov

Multinationals and green technology

Applicants of green patents (# and %) (1970–2018).

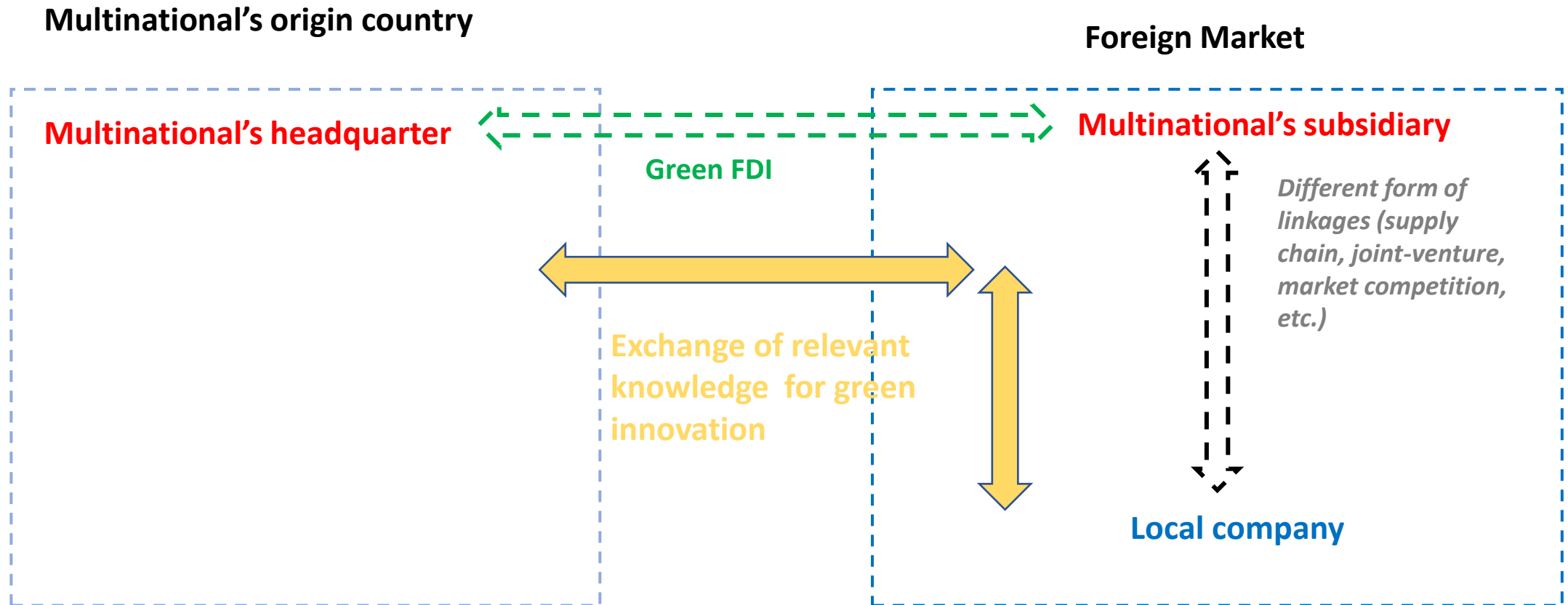
First applicant	Firms	MNEs	MNEs % of total	MNEs % of firms	Individuals	Universities	Others	Total
Biofuel	12468 (50.1)	629	2.5	5.0	6440 (25.9)	3293 (13.2)	2690 (10.8)	24891 (7)
Geothermal	2642 (52.1)	105	2.1	4.0	1813 (35.8)	271 (5.3)	344 (6.8)	5070 (1)
Hydro	16225 (42.2)	5347	13.9	33.0	16603 (43.1)	1717 (4.5)	3932 (10.2)	38477 (11)
Marine	2240 (24.2)	1	0.0	0.0	4686 (50.6)	1401 (15.1)	935 (10.1)	9262 (3)
Solar hybrid	480 (42.8)	2	0.2	0.4	339 (30.2)	173 (15.4)	129 (11.5)	1121 (0)
Solar PV	78133 (72.6)	20942	19.5	26.8	12055 (11.2)	10242 (9.5)	7143 (6.6)	107573 (31)
Solar thermal	33699 (45.2)	898	1.2	2.7	30659 (41.1)	4318 (5.8)	5878 (7.9)	74554 (22)
Waste fuel	11790 (53.4)	1933	8.7	16.4	5976 (27.0)	2118 (9.6)	2211 (10.0)	22095 (6)
Wind	27221 (46.1)	9094	15.4	33.4	23413 (39.7)	4326 (7.3)	4055 (6.9)	59015 (17)
Total	184898 (54.0)	38951	11.4	21.1	101984 (29.8)	27859 (8.1)	27317 (8.0)	342058 (100)

From **Amendolagine, Lema, Rabellotti, J. Cleaner Production, 2021.**

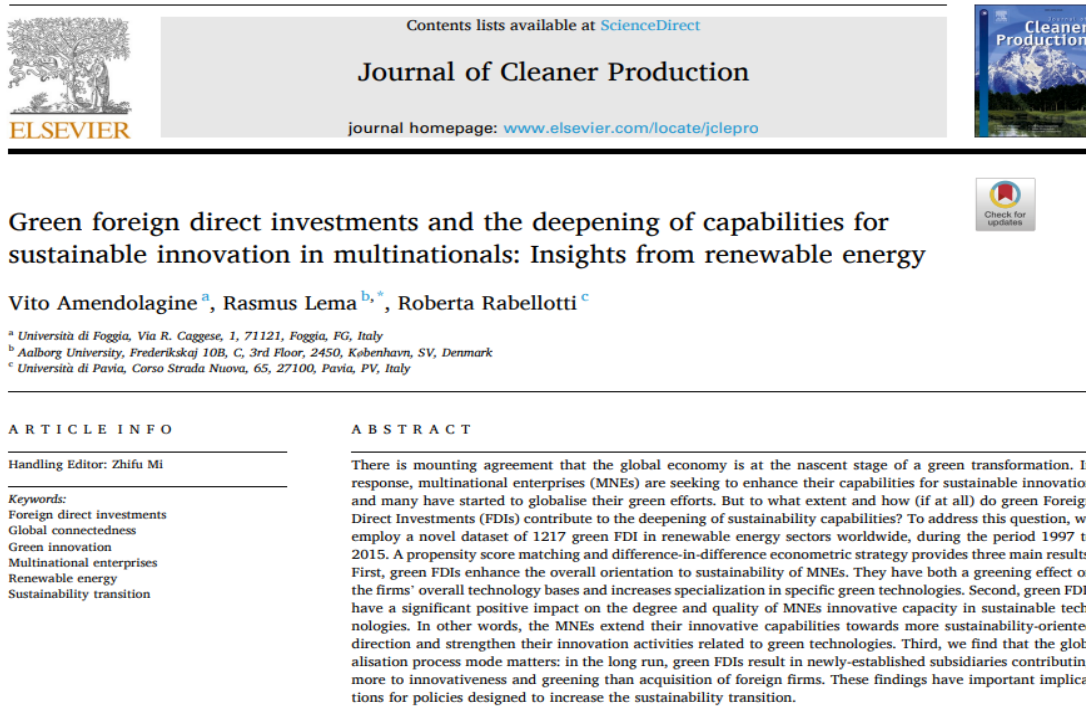
Fonte dati: PATSTAT

N.B. Many Multinationals's green patents are produced at the foreign subsidiary level (Noailly & Ryfish, 2015)

Green FDI and Green Knowledge Transfer

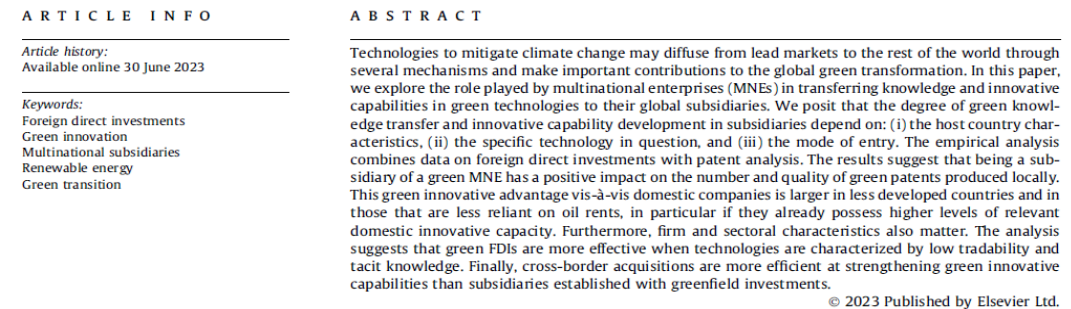


Green FDI effects on innovation in renewables-related technology



Effect at the Multinational' headquarter level

Effect on multinationals' foreign subsidiary



Effect at the Multinational' heaquarter level

Renewable energies and MNEs

MNEs invest in renewable energies for:

- a) accessing new expanding markets;
- b) improving their reputation;
- c) increasing their efficiency by improving their management of natural resources (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013; Chayapa et al., 2018; de Azevedo-Rezende et al, 2019);

Outward green FDI

- **Main determinants** for advanced economies' MNEs (Hanni et al, 2011):
 - *saturation of domestic markets;*
 - *rise of domestic production costs*
- In case of **Chinese outward FDI**, technology and knowledge acquisition is one of the main motivations (Curran et al., 2017);
- In a study on **Italian manufacturing companies**, Chiarvesio et al. (2015) show that investing abroad has a positive impact on investors' green technologies, since international markets offer access to advanced knowledge useful for green innovation;
- In a case study of a **Danish company and its Indian first-tier supplier**, Hansen et al. (2019) observe initially a unidirectional flow of knowledge from the multinational to the Indian supplier and in a later stage, a bidirectional knowledge flow, since the Danish headquarter starts sourcing new knowledge from the subsidiary.

Research questions

- **How do green outward FDI impact on investors' green innovations?**
 - how do impact on the number and quality of their green patents?
 - how do impact on their specialization in green technologies ?
 - how do impact on the variety of their green patents ?

The challenge to identify green FDI

- Following **Glachant and Dechezleprêtre** (2017) to identify green FDI:
 1. All patents in the technological category: “*technologies or applications for mitigation or adaptation against climate change*” (EPO classification: Y02 category);
 2. Focus on technologies related to energy generation from **renewable** and **non-fossil sources**, i.e. wind, solar, hydro, geothermal, marine, waste, biofuel (**Renewable Energy Technologies - RET patents** - DOCDB families);
 3. Among them, patents with a firm as applicant;
 4. We consider foreign subsidiaries of firms with at least one green patent (>50% ownership);
- **Textual search** on the descriptions of foreign subsidiaries’ business activity in order to select only FDIs aimed at establishing or acquiring subsidiaries related to the production or distribution of renewable energies;
- 1217 FDI (from 2003 to 2015) disaggregated by mode of entry: 315 acquisitions & 956 greenfield investments;
- Data sources: **PATSTAT**; **Orbis** ; **Zephyr**

Green FDI: home and host countries

Home countries

Country	# FDI (%)	# greenfield (%)	# acquisitions (%)
Low/middle income country	69 (5.7)	44 (4.9)	25 (7.9)
High income country	1148 (94.3)	858 (95.1)	290 (92.1)
Germany	222 (18.2)	178 (19.7)	44 (14.0)
USA	170 (14)	104 (11.5)	66 (21.0)
Japan	126 (10.3)	105 (11.6)	21 (6.7)
Denmark	120 (9.9)	97 (10.7)	23 (7.3)
France	109 (9.0)	85 (9.4)	24 (7.6)
Spain	62 (5.1)	48 (5.3)	14 (4.4)
Italy	45 (3.7)	36 (4.0)	9 (2.9)
Taiwan	40 (3.3)	36 (4.0)	5 (1.3)
China	36 (3.0)	29 (3.2)	7 (2.2)
Others	287 (23.5)	184 (20.41)	102 (32.7)
Total	1217 (100)	902 (100)	315 (100)

Host countries

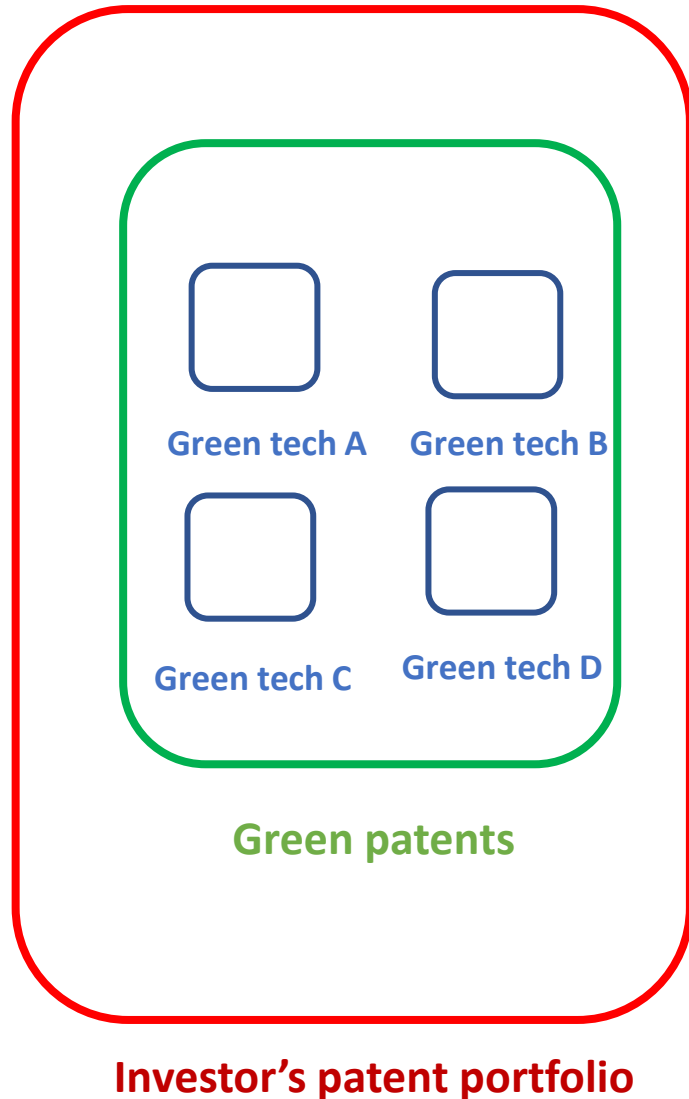
	# FDI (%)	# greenfield (%)	# acquisitions (%)
Low/middle income	341 (28.0)	294 (32.6)	47 (14.9)
High income	876 (72.0)	608 (67.4)	268 (85.1)
Europe and Central Asia	697 (57.3)	493 (54.7)	204 (64.8)
East Asia and Pacific	249 (20.5)	228 (25.3)	21 (6.7)
South Asia	80 (6.6)	74 (8.2)	6 (1.9)
Latin America and Caribbean	71 (5.8)	40 (4.3)	31 (9.8)
North America	97 (8.0)	48 (5.3)	49 (15.6)
MENA	13 (1.1)	10 (1.1)	3 (0.9)
SSA	10 (0.8)	9 (1)	1 (0.3)
UK	174 (14.3)	131 (14.5)	43 (13.6)
China	101 (8.3)	95 (10.5)	6 (1.9)
Germany	101 (8.3)	64 (7.1)	37 (11.8)
USA	87 (7.2)	43 (4.8)	44 (14.0)
India	80 (6.6)	74 (8.2)	6 (1.9)
Italy	44 (3.6)	25 (2.8)	19 (6.0)
Netherlands	44 (3.6)	37 (4.1)	7 (2.2)
Spain	41 (3.4)	31 (3.4)	10 (3.2)
Australia	40 (3.3)	34 (3.8)	6 (1.9)
France	39 (3.2)	28 (3.1)	11 (3.5)
Others	466 (38.3)	340 (37.7)	126 (40.0)
Total	1217 (100)	902 (100)	315 (100)

FDI distribution according to the main RET specialization of investors*

Main technological specialization	# FDI (%)	# greenfield (%)	# acquisitions (%)
Wind	400 (32.9)	313 (34.7)	87 (27.6)
Solar photovoltaic	379 (31.1)	285 (31.6)	94 (29.8)
Solar thermal	195 (16.0)	138 (15.3)	57 (18.1)
Biofuel	95 (7.8)	60 (6.7)	35 (11.1)
Hydro	75 (6.2)	55 (6.1)	20 (6.3)
Waste	63 (5.2)	44 (4.9)	19 (6.0)
Geothermal	8 (0.7)	5 (0.6)	3 (1.0)
Marine	1 (0.1)	1 (0.1)	0 (0.0)
Solar hybrid	1 (0.1)	1 (10.1)	0 (0.0)
Total	1217 (100)	902 (100)	315 (100)

* RET technology with the largest number of patents

Outputs



We study the causal effect of green FDI on the growth rate (up to 5 years after the deal) of four variables:

- ***Green patents:*** # of RET patents (Amendolagine et al., 2018; Stiebale, 2016);
- ***Forward citations:*** # of forward citations to RET patents (Giuliani et al., 2016);
- ***Green specialization:*** % of RET patents in total investor' patent production (Frankhauser et al., 2013; de Azevedo-Rezende et al. 2019; Aguilera-Caracuel & Ortiz-de-Mandojana, 2013);
- ***Green concentration:*** Herfindhal index measuring the concentration of patents across renewable energy technologies (Quintana-García and Benavides-Velasco, 2008).

Empirical methodology

- The estimation of the FDI causal effect on the investors can suffer from self-selection problems
 - Larger, more efficient and more innovative companies are more likely to undertake FDIs (Helpman et al., 2004);
 - The decision to undertake a (green) FDI might depend on the past (green) patenting activity of investors
- **Propensity score matching** combined with **Dif-in-Dif estimators** (Debaere, 2010; Stiebale & Trax, 2011; Stiebale, 2013, Cozza et al., 2015; Stiebale, 2016), based on two steps:
 1. We build a counterfactual sample of non-investors with similar *ex-ante* probabilities to undertake FDI with a logit model ;
 2. With the sample including both investors and non-investors selected by propensity score matching, the second step consists of estimating the following equation:
$$\Delta y_{i,j,x,t+s} = \alpha + \beta \text{ GREEN FDI}_{i,j,x,t} + \gamma_j + \delta_x + \vartheta_t + \varepsilon_{i,t},$$
where γ_j , δ_x , and ϑ_t are fixed effects for industry, home country and deal year $s=0,1,2,3,4,5$.

PSM-DID results (1)

Green patents

	any fdi		greenfield		acquisition	
	Beta	s.e.	Beta	s.e.	Beta	s.e.
t	0.1340***	(0.0411)	0.0319	(0.0335)	0.1274***	(0.0463)
t+1	0.2028***	(0.0466)	0.1136***	(0.0412)	0.1322**	(0.0526)
t+2	0.2707***	(0.0582)	0.1738***	(0.0493)	0.0723	(0.0616)
t+3	0.3014***	(0.0616)	0.2363***	(0.0513)	0.0505	(0.0589)
t+4	0.3085***	(0.0680)	0.2630***	(0.0555)	0.0659	(0.0625)
t+5	0.3431***	(0.0670)	0.3280***	(0.0604)	0.0461	(0.0685)

Forward citations

	any fdi		greenfield		acquisition	
	Beta	s.e.	Beta	s.e.	Beta	s.e.
t	0.1426	(0.0869)	0.0360	(0.0756)	0.1467	(0.0938)
t+1	0.2590***	(0.0948)	0.2089**	(0.0843)	0.1424	(0.1130)
t+2	0.3352***	(0.1171)	0.2954***	(0.0965)	0.0828	(0.1326)
t+3	0.3040***	(0.1171)	0.4016***	(0.0937)	0.0277	(0.1258)
t+4	0.3264***	(0.1238)	0.3886***	(0.1025)	0.0474	(0.1357)
t+5	0.3479***	(0.1137)	0.5046***	(0.1048)	0.0197	(0.1404)

PSM-DID results (2)

Green specialization

	any fdi		greenfield		acquisition	
	Beta	s.e.	Beta	s.e.	Beta	s.e.
t	0.0215	(0.0138)	0.0215**	(0.0104)	0.0197*	(0.0117)
t+1	0.0522***	(0.0129)	0.0236*	(0.0122)	0.0332**	(0.0163)
t+2	0.0517***	(0.0146)	0.0361***	(0.0131)	0.0174	(0.0161)
t+3	0.0366**	(0.0158)	0.0309**	(0.0132)	0.0247	(0.0152)
t+4	0.0234	(0.0174)	0.0290**	(0.0128)	0.0185	(0.0197)
t+5	0.0457***	(0.0155)	0.0352***	(0.0132)	0.0236	(0.0165)

Green concentration

	any fdi		greenfield		acquisition	
	Beta	s.e.	Beta	s.e.	Beta	s.e.
t	0.0195	(0.0206)	0.0307*	(0.0163)	0.0188	(0.0190)
t+1	0.0549***	(0.0205)	0.0496***	(0.0181)	0.0259	(0.0230)
t+2	0.0575**	(0.0237)	0.0526***	(0.0194)	0.0141	(0.0247)
t+3	0.0552**	(0.0251)	0.0590***	(0.0207)	0.0102	(0.0248)
t+4	0.0328	(0.0257)	0.0606***	(0.0205)	0.0044	(0.0268)
t+5	0.0666***	(0.0246)	0.0767***	(0.0199)	0.0076	(0.0258)

Conclusions

- Green FDIs have a positive and increasing impact on both the **quantity** and the **quality** of green patents in the 5 years after the investment;
- FDIs enhance the **greening** of investors' patent portfolios;
- FDIs increase the **concentration** in specific renewable energy technologies;
- **Greenfield FDI** follow a similar pattern;
- **Cross-border acquisitions** have only short-term effects on the quantity of green patents and on the share of green patents in investors' patent portfolios.

Effect of Green FDI at the foreign subsidiary level

RESEARCH QUESTION

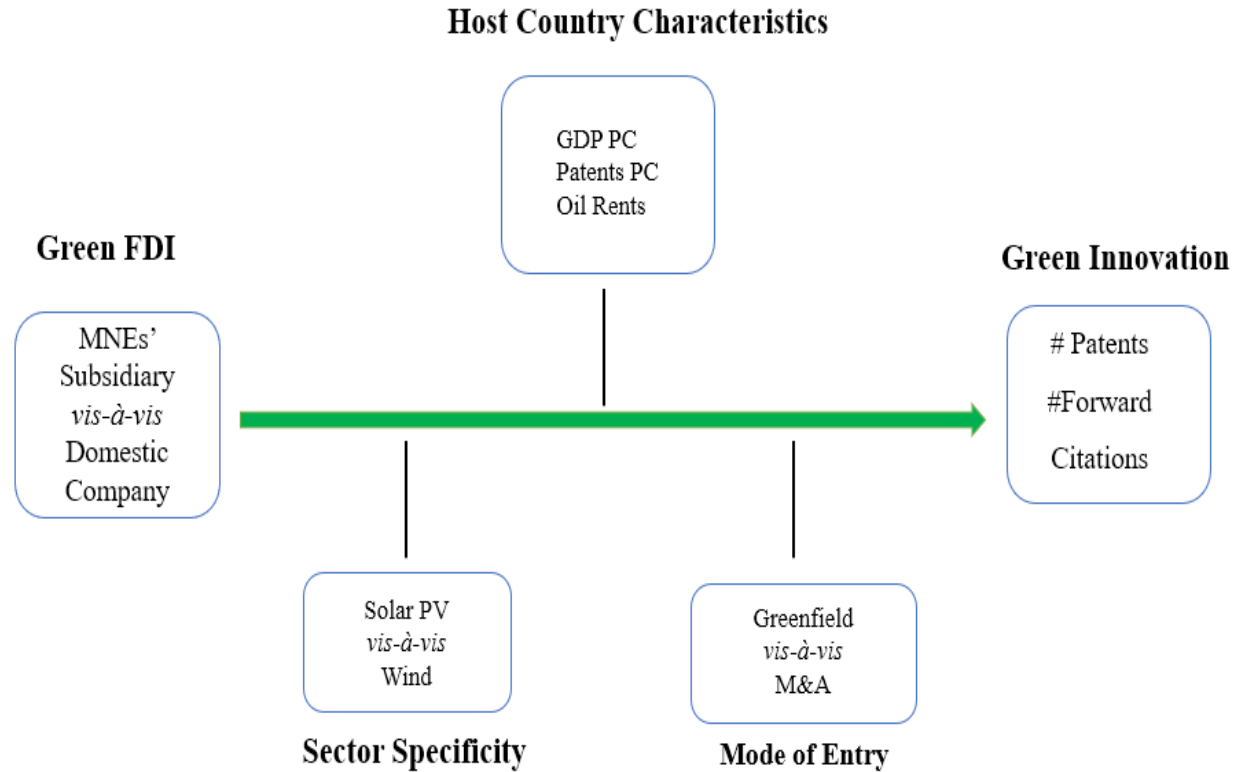
To what extent do MNEs, through their FDIs in RE technologies, sustain the increase of innovative capabilities in green innovation in their subsidiaries vis-à-vis domestic companies?

BACKGROUND LITERATURE

- **Transfer of technology globally through investment-centered value chains**, as firms sought to exploit knowledge in foreign subsidiaries as part of a broader trend toward internationalization of R&D;
- **Some limited evidence on green technologies**
 - Noailly and Ryfisch (2015) assess the internationalization of R&D by studying the patenting activity of 1,200 MNEs and find that around 18% of the patents are developed by their affiliates.
 - Based on innovation survey data about MNE subsidiaries in Spain, Konara et al. (2021) find that affiliates with parent MNEs from countries with stricter environmental policies engage in environmental innovations to a greater extent.
 - Evidence of positive green innovation gap between MNEs' subsidiaries and domestic companies (Chiarvesio et al., 2015; De Marchi et al., 2022)
 - At the regional level in Europe, Castellani et al. (2022) show that greenfield FDIs contribute to the regional specialization in environmental technologies, especially in industries with previous capabilities in specific green technologies.

CONCEPTUAL FRAMEWORK

- ❖ Level of **development and innovative capacity of the host country** →
 - ❖ domestic companies have less opportunities to connect to global innovation networks (Un, 2011 and 2016).
 - ❖ different degrees of absorptive capacity (Amendolagine, Piscitello, Rabellotti, 2021).
 - ❖ Reliance on fossil fuel exports can be a 'curse' (Awijen et al. 2022)
- ❖ **Wind & Solar PV** differ in the way they transfer knowledge within-firm (Binz et al., 2017; Quitzow et al., 2017).
- ❖ **Greenfield Investments & M&As** (Blomqvist et al 2014; Li, 2022).



DATASET

Green FDI dataset

- The same as in Amendolagine, Lema, Rabellotti (J. Cleaner Production, 2021)
- Green FDI are defined as investments undertaken by firms with at least one patent in renewable energy technologies (subset of Y20E Technology class: **geothermal, hydro, marine, solar thermal, solar PV, solar thermal-PV hybrid, wind, biofuels, fuel from waste**).
 - Subsidiaries' main business activities focus on production/distribution of renewable energy.
 - We drop FDI for which we do not have information on subsidiaries
 - # GREEN FDI 1,055 (73% GREENFIELD INVESTMENTS)
- **# SUBSIDIARIES' PATENTS IN RE: 1,410**
 - Patents are attributed to subsidiaries if at least one inventor is from the same country of the subsidiary (Stiebale, 2016)
- **Countersample**
 - # DOMESTIC COMPANIES (in the same sectors/countries of subsidiaries): 6,276
- Period of the analysis: 2003-2015

METHODOLOGY

- **Output variables**
 - # of green patents (DOCDB families) in RE up to 5 years after the investment
 - # forward citations (average) to green patents up to 5 years after the investment.
- **Negative binomial model** (Piperopoulos et. al., 2018)
- **Main independent variable:** Dummy 1= MNE subsidiary 0 = domestic company
- **Moderating factors:** Host country-specific characteristics (GDP per capita; # of patents registered in the country per capita, oil rents %GDP)
- **Subset of green FDIs:**
 1. Wind
 2. Solar
 3. Greenfields
 4. M&As
- **Countersample** of domestic companies selected in the same sectors/countries of subsidiaries

VARIABLES

■ DATABASES

1. ORBIS → firm-level dataset
2. PATSTAT → patent-level data
3. WORLD BANK, UNCTAD, OECD → country-level data

CONTROL VARIABLES

- Subsidiaries' SIZE → two dummy variables (1= medium or large company and 0 otherwise)
- Subsidiaries' AGE → difference between the deal year and the company's establishment year
- Pre-deal Knowledge base (# of patents up to one year before the investment)
- NACE 2-digit sector and deal year fixed effects

RESULTS 1/4 → FULL SAMPLE

[illegible]

RESULTS 2/4 → FULL SAMPLE with interaction terms

	OUTPUT: # green patents						OUTPUT: # forward citations to green patents					
	t	t+1	t+2	t+3	t+4	t+5	t	t+1	t+2	t+3	t+4	t+5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FDI SUBSIDIARY	-2.042**	-1.498*	-1.182	0.017	0.143	0.242	1.730**	2.486***	2.081**	3.302***	3.251***	2.770***
COUNTRY GDP PC (LN)	0.062	-0.035	-0.030	0.115	-0.028	-0.070	0.331***	0.403***	0.324***	0.496***	0.577***	0.440***
COUNTRY PATENT PC (LN)	0.101	0.360**	0.192	0.395**	0.648***	0.892***	0.301	-0.157	0.166	-0.084	0.070	0.491*
COUNTRY OIL RENTS (%GDP)	-0.037	-0.050	-0.079*	-0.054	-0.038	0.003	-0.153***	-0.049	-0.143***	0.006	-0.079	0.139
FDI SUBSIDIARY * COUNTRY GDP PC	0.334	0.254	0.277	0.083	-0.079	-0.263	-0.390*	-0.660***	-0.445*	-0.233	-1.292***	-0.966***
FDI SUBSIDIARY * COUNTRY PATENT PC	0.471	2.111**	1.530*	0.548	2.030**	2.918***	1.286	2.467**	1.403	-1.777	6.497***	5.463***
FDI SUBSIDIARY * COUNTRY OIL RENTS	-0.070	-0.086	-0.024	-0.109	0.074	-0.071	-0.070	-0.604***	-0.253	-0.858***	-0.064	-0.193

RESULTS 3/4

Wind specialized investor subsample

	OUTPUT: # green patents						OUTPUT: # forward citations to green patents					
	t	t+1	t+2	t+3	t+4	t+5	t	t+1	t+2	t+3	t+4	t+5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FDI SUBSIDIARY	-0.197	0.986***	1.888***	1.503***	2.309***	2.410***	3.827***	3.742***	5.139***	3.731***	4.654***	3.288***

Solar specialized investor subsample

	OUTPUT: # green patents						OUTPUT: # forward citations to green patents					
	t	t+1	t+2	t+3	t+4	t+5	t	t+1	t+2	t+3	t+4	t+5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FDI SUBSIDIARY	-0.079	-0.717	0.078	-0.169	-0.167	1.440***	3.491***	2.985***	2.933***	1.688**	2.908***	3.561***

RESULTS 4/4

Greenfield FDI subsample

	OUTPUT: # green patents						OUTPUT: # forward citations to green patents					
	t	t+1	t+2	t+3	t+4	t+5	t	t+1	t+2	t+3	t+4	t+5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FDI SUBSIDIARY	-1.134***	-0.133	-0.027	0.408	0.443	0.728*	1.119**	0.869**	0.397	1.920***	1.356***	1.895***

M&As subsample

	OUTPUT: # green patents						OUTPUT: # forward citations to green patents					
	t	t+1	t+2	t+3	t+4	t+5	t	t+1	t+2	t+3	t+4	t+5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FDI SUBSIDIARY	0.536	2.331*	2.244**	2.020	3.708***	3.416***	7.262***	7.417***	6.490***	7.227***	7.566***	6.646***

KEY Takeaways 1/2

- MNEs' subsidiaries gain additional green innovative capabilities compared to local firms and, they have the potential to enhance the development of green innovation in host countries

•  **Subsidiaries may become central contributors to the building of sustainability-oriented innovation systems.**

- **Green FDI could play a positive and significant role in transferring innovative knowledge** towards subsidiaries located in developing countries, where the green transition could otherwise be delayed by the adoption of a 'clean up later' model waiting for the environmental Kuznets curve to set in

•  **Encouraging findings due to the urgency of transferring knowledge and innovative capabilities to actors in developing countries.**

KEY Takeaways 2/2

- Combining this finding with the result about host country innovativeness, we can conclude that **MNEs are pivotal in boosting subsidiaries green innovative capacities in less developed countries with a high degree of general innovative capacity. (e.g., India).**
 - **Reliance on fossil fuel exports can be a 'curse'** (Awijen et al. 2022; Poudineh et al., (2018).)
 - In the **wind power industry**, because of the more tacit knowledge involved, knowledge transfer via **MNEs**, with dense global relationships inside the corporate network, has an important role to play in **knowledge diffusion**.
 - Substantial local rootedness is important for learning and knowledge diffusion to take place.
- ➡ • **Larger technological advantage of M&As with respect to greenfield investments.**

POLICY IMPLICATIONS

- Green innovation systems need to be strengthened and countries with weaker green innovative capabilities can attract green FDI to enhance their innovative capacities to contribute to the green transition.
- Need for national policy makers to **target FDI specifically in green technology sectors** to strengthen their innovative capacities not only to adapt technologies to local conditions, but more importantly to engage in innovation for developing new green solutions for the global market.
- International organizations should support the **building of innovation systems** aimed at increasing green innovative capacity to sustain global green transition and promote more technological variety in the market (i.e., reducing the control of green technologies by few advanced lead markets).
- **Green technology transfer should take a more central role in the WTO** around the TRIMS agreement, so that policy frameworks reflect the public goods nature of green technology and support the global diffusion of green technology through FDI.
- International organizations, such as the UNFCCC, should focus more on the **importance of FDI** as an important channel for low carbon technology transfer.

Green FDI and Technological Spillovers in the Host Economies

- Working paper -

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Motivation

- Multinational enterprises (**MNEs**) with green innovative capability can contribute to **diffuse environmentally friendly knowledge**.
 - Amendolagine, Lema, Rabellotti (2021) show that green **FDIs increase the green specialization of MNEs**.
 - Amendolagine, Hansen, Lema, Rabellotti & Ribaudó (2023) show that foreign **subsidiaries of green MNEs are more innovative** than domestic firms with similar characteristics.
- In this paper we investigate **whether green FDI affect the extent to which MNEs green patents are cited by patents in the host countries**, as a proxy of **forward technological spillovers**.

Two examples

- **Vestas wind Systems** is a global leader in wind technologies with the headquarter based in Aarhus (Denmark):
 - Renewable Energy (RE) related patents are cited by (*first*) foreign inventors located in 43 countries;
 - From 1997 to 2020 it undertook 37 green FDI in 21 different countries;
 - On average, **Vestas' green patents received 1054 citations in host countries**, and 176 citations in other countries.

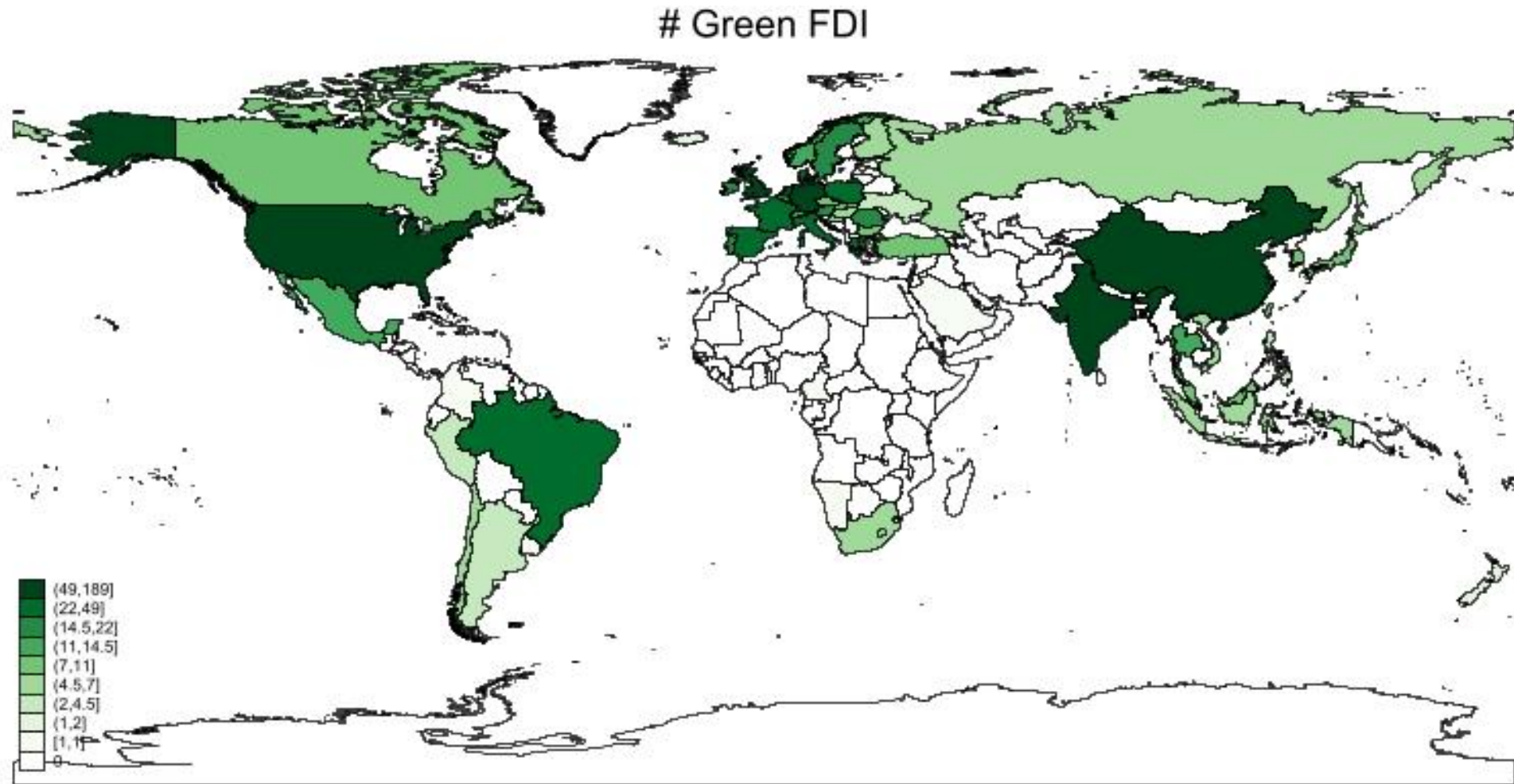
Suzlon is a global leader global leader in wind technologies, with the headquarter in Pune (India)

- Its RE patents are cited in 22 different countries;
- From 1997 to 2020 it undertook 10 green FDI in 8 different countries;
- On average, **Suzlon's green patents received 135 citations in host countries**, and 81 citations in other countries.

The literature

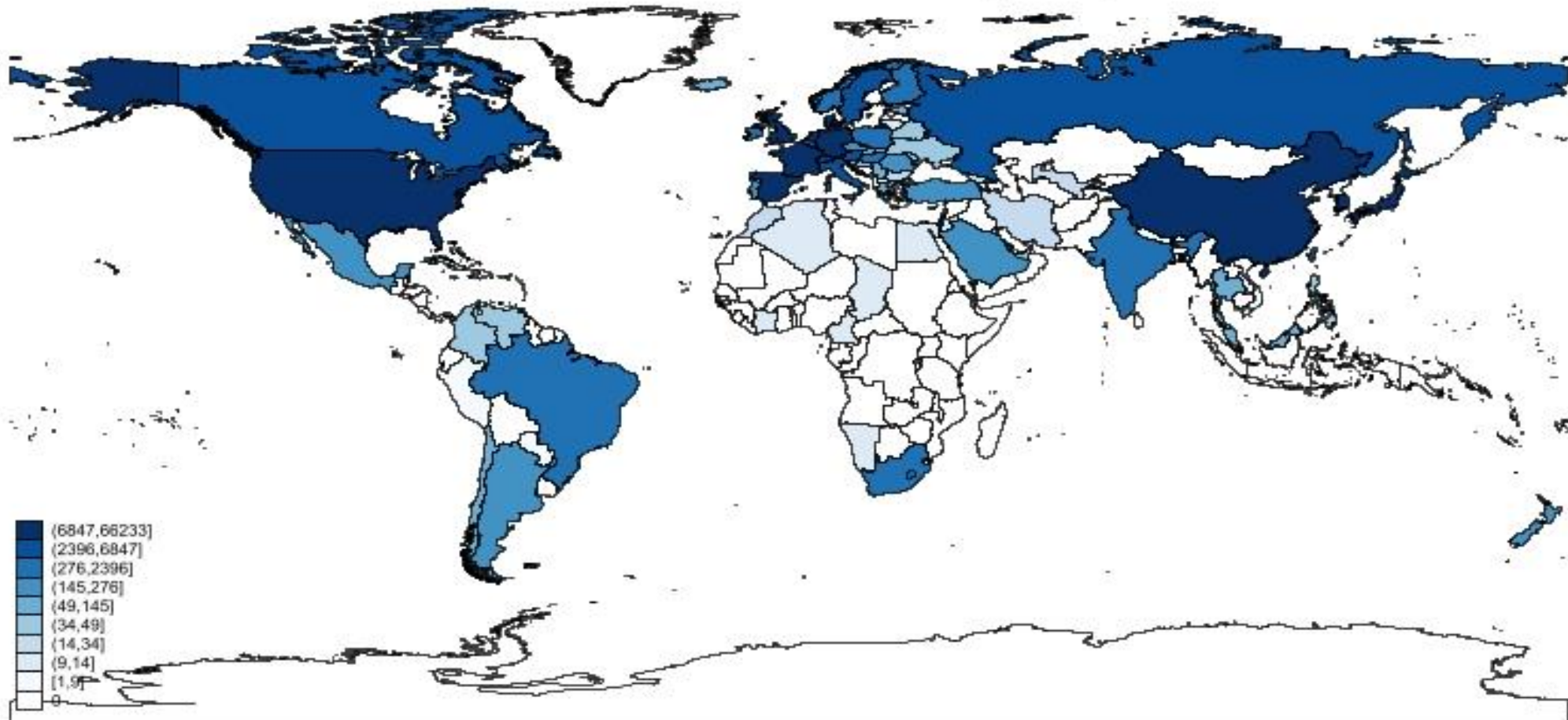
- Green FDI can enhance innovation in RE technologies in investors and in their foreign subsidiaries (Amendolagine et al., 2021, 2023)
 - Results are conditioned by **development/innovation level of the host economies**, FDI type (greenfield/acquisitions); RE technology (solar/energy).
- **FDIs can generate spillovers** in destination economies, boosting productivity (Javorcik, 2004; Gong, 2023) and innovation (**Branstetter**, 2006; Grafstrom, 2018; Tan et al., 2022) of local economies
- **The impact of green technologies on subsequent inventions is larger** and more pervasive with respect to non-green technologies (Dechezleprêtre et al., 2014; Barbieri et al, 2020)

Green FDI in 66 countries (1997-2020)



MNEs green patents citations in 94 countries

Foreign forward citations to MNEs' green patents



Dataset: construction

- Based on PATSTAT: **forward citations to green patents owned** by green investors and their subsidiaries;
- For each investor i , we consider all the countries j where **foreign citations to their green patents are based**, according to the address of the **first inventor**.
- For each country j , we consider:
 - the number of forward citations to green patents of the investor i by the first inventor based in country j ;
 - the number of green FDI of the investor i in country j ;
- Time span of green FDI:1997-2020
- Two sub-samples for **solar** and **wind** technologies;

Dataset: an example

Investor α undertook two investments in 1998 in country A (**host country**) and its green patents are cited in countries A and B (no investment took place here).

Investor (i)	Country (j)	Year (t)	#Forward Citations	FDI
α	A	1997	#	0
α	A	1998	#	2
α	A			...
α	A	2020	#	0
α	B	1997	#	0
α	B	1998	#	0
α	B			..
α	B	2020	#	0

Forward Spillover

Similarly to Branstetter (2006), we estimate the following model:

$$\textit{Forward Citations}_{i,j,t} = \alpha + \beta_1 \textit{Cumulative Green Patents}_{i,t} + \beta_2 \textit{Green Patents Age}_{i,t} + \beta_3 \textit{Green FDI}_{i,j,t-s} + \gamma_i + \delta_j + \theta_t + \epsilon_{i,t,j}$$

- **Forward Citations**_{i,j,t} number of forward citations to all green patents by investor *i* based in foreign country *j*, cumulated up to year *t*
- **Green FDI** is the number of Green FDI by investor *i* at time *t* in country *j*

Control Variables

- **Cumulative Green Patents** $_{i,j,t}$ is the cumulative number of green patents owned by investors i up to year t
- **Green Patents Age** $_{i,j,t}$ is the share of the cumulative number of green patents owned by investor i up to year t in a citable age (i.e. 4-6 years)
- $\gamma_i, \delta_j, \theta_t$ are fixed effect for, respectively, investor i , country j , year t .
- $s=0,1,2,3$

Main preliminary results

- Green FDI enhance forward spillovers
 - Up to the third year after the investment
 - More evidence of the effect for wind technologies.
 - No significant interaction with macro-level factors.



Baseline

	(1)	(2)	(3)	(4)	(5)	(6)
Green FDI	0.113**					0.120**
	(0.052)					(0.051)
L. Green FDI		0.104*			0.110**	0.110**
		(0.054)			(0.054)	(0.055)
L2.Green FDI			0.125***		0.129***	0.127***
			(0.048)		(0.049)	(0.049)
L3.Green FDI				0.141***	0.140***	0.138***
				(0.048)	(0.049)	(0.049)
Observations	71926	68901	65900	62896	62896	62896

Output:

- #Forward citations in the host country

Controls:

- Investor's patent experience, patent stock age, innovation, fdi experience;
- Host country's GDP pc, green energy consumption intensity, patent pc.

Solar Technology

	(1)	(2)	(3)	(4)	(5)	(6)
Green FDI	0.143**					0.157**
	(0.063)					(0.062)
L. Green FDI		0.122*			0.131*	0.130*
		(0.073)			(0.073)	(0.072)
L2.Green Fdl			0.107		0.110*	0.108*
			(0.067)		(0.065)	(0.066)
L3.Green FDI				0.096	0.094	0.093
Obs.	40629	38926	37223	35520	35520	35520

Wind Technology

	(1)	(2)	(3)	(4)	(5)	(6)
Green FDI	0.109*					0.105
	(0.063)					(0.066)
L. Green FDI		0.120**			0.121**	0.125**
		(0.052)			(0.055)	(0.058)
L2.Green Fdi			0.134***		0.141**	0.138**
			(0.051)		(0.056)	(0.055)
L3.Green FDI				0.109**	0.111*	0.111**
Obs.				(0.053)	(0.057)	(0.056)
	21619	20708	19813	18919	18919	18919

Interaction with host country's characteristics (Innovation)

	(1)	(2)	(3)	(4)	(5)	(6)
Green FDI #						
patents_pc	-0.001					-0.001
	(0.002)					(0.002)
L.Green FDI #						
L.patents_pc		-0.001			-0.001	-0.001
		(0.002)			(0.002)	(0.002)
L2.Green FDI #						
L2.patents_pc			-0.001		-0.001	-0.001
			(0.001)		(0.001)	(0.001)
L3.Green FDI #						
L3.patents_pc				0.000	0.000	0.000
				(0.001)	(0.001)	(0.001)
Observations	71926	68901	65900	62896	62896	62896

Similar result with other host country characteristics:

- GDP pc
- Green energy consumption intensity

Robustness: IV method

	(1)	(2)	(3)
	# Forward citation in the host country	Green FDI	Endogeneity test
Green FDI	3.431**		
	(1.520)		
Bartik Instrument		0.228***	
		(0.0822)	
ro parameter			-4.088***
			(1.539)
Constant	-7.323***	0.00216	
	(0.390)	(0.00163)	
Observations	80,808	80,808	80,808

Bartik instrument

- It uses the exposition of host countries to different types of FDI (i.e. acquisition or greenfields)

Controls:

- **Investor's** patent experience, patent stock age, innovation, fdi experience;
- **Host country's** GDP pc, green energy consumption intensity, patent pc.

What about Grey FDI?

	(1)	(2)	(3)	(4)	(5)	(6)
Grey FDI	-0.013					0.018
	(0.133)					(0.128)
L.Grey FDI		-0.006			-0.009	-0.011
		(0.100)			(0.096)	(0.085)
L2.Grey FDI			0.240		0.236*	0.237*
			(0.147)		(0.143)	(0.143)
L3.Grey FDI				0.170	0.159	0.160
				(0.123)	(0.125)	(0.124)
Observations	70664	67764	64889	62010	62010	62010

Controls:

- **Investor's** patent experience, patent stock age, innovation, fdi experience;
- **Host country's** GDP pc, green energy consumption intensity, patent pc.

Green FDI and electricity access

- **With Rosario Colangione (Foggia), Eika Kraemer (Johannesburg), Roberta Rabbellotti (Pavia), Dalila Ribaudo (Aston)**
- What is the impact of Green FDI on
 - Electricity access
 - Access to other utilities (phone, cell, internet, fuel cook)
 - Dataset of Green FDI to all African Country (data source: **Orbis Cross Border Investment**)
 - Data on local access to utilities will be sourced from **IPUMS database**.
 - Difference-in-Difference and spatial estimators.

Thanks for attention!

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