



Green FDI and Technological Spillovers in the Host Economies

Roberta Rabelotti
Università di Pavia

with Vito Amendolagine & Dalila Ribaudò

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Motivation

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

Two examples

 Vestas

is a global leader in wind technologies based in Aarhus (Denmark):

- Its patents are cited by foreign inventors located in 43 countries;
- From 1997 to 2020 it has done 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**
POWERING A GREENER TOMORROW

is a global leader in wind technologies, based in Pune (India)

- Its patents are cited in 22 different countries;
- From 1997 to 2020 it has done 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) in 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)

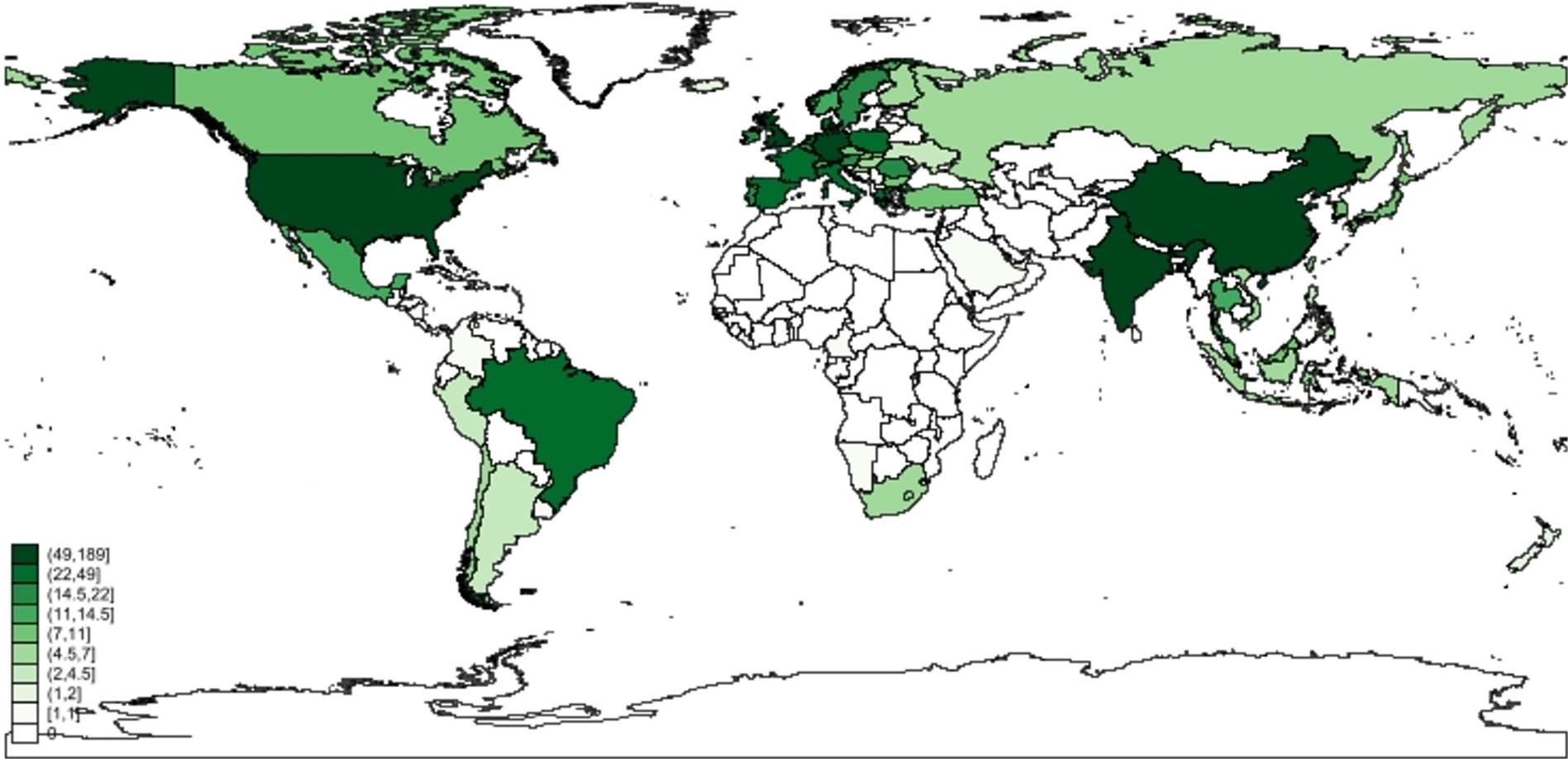
Methodology: how green FDI are identified

As in Amendolagine et al. (2021) and Amendolagine et al. (2023)

1. Identify all patents in “*technologies or applications for mitigation or adaptation against climate change*” (EPO classification: **Y02E category**);
2. Focus on **technologies related to energy generation** from renewable and non-fossil sources, i.e. **wind, solar, hydro, geothermal, marine, waste, biofuel** (DOCDB families);
3. Select among them, all the green patents **with a firm as applicant**;
4. Identify among the **firms with at least one green patent**, those with at least one foreign subsidiary (>50% ownership);
5. Textual search on the foreign subsidiaries’ business activity to select only FDIs aimed at establishing or acquiring subsidiaries related to the **production or distribution of renewable energies**.

Green FDI in 66 countries (1997-2020)

Green FDI

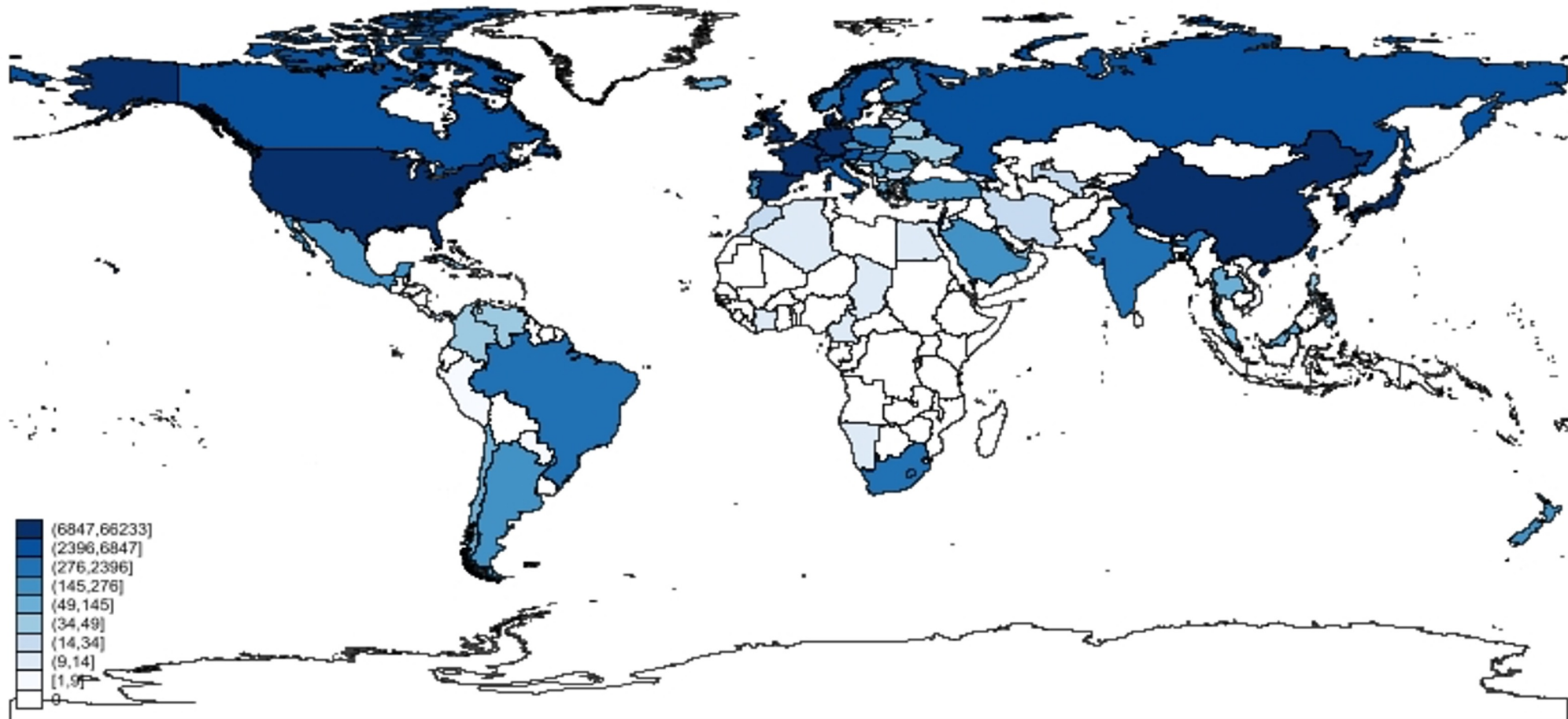


Dataset

- Based on PATSTAT: (non-self) **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 FDI of the investor i in country j ;
- Time span of green FDI: 1997-2020
- Two sub-samples for **solar** and **wind** technologies.

MNEs green patents citations in 94 countries

Foreign forward citations to MNEs' green patents



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 (where there are not investments from α).

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

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

of forward citations to all green patents by the investor i based in country j , cumulated up to year t

- All estimations include investor, host country and year fixed effects, errors are clustered at the investor level

Independent Variables

- **# of green FDI** by investor i in country j at year t
- **Dummy variable** taking value 1 for country j where the investor has at least one investment at the year of the first investment, and 0 otherwise
- **Cumulative Green Patents** $_{i,j,t}$: cumulative # of green patents owned by investors i up to year t
- **Green Patents Age** $_{i,j,t}$: share of the cumulative # of green patents owned by investor i up to year t in a citable age (i.e. 4-6 years)
- **Green Patents** $_{i,t}$ # of green patents by investor i at time t
- $\gamma_i, \delta_j, \theta_t$ fixed effect for investor i , country j , year t .
- $s=0,1,2,3$

Macro-level mediating factors

- **GDP per capita** (World Bank)
- **OECD Environmental Policy Stringency Index (EPS)**: degree to which environmental policies fix an explicit or implicit price on polluting or environmentally harmful behavior. It ranges from from 0 (not stringent) to 6 (highest degree of stringency)

Preliminary results



Work in
Progress

Forward spillovers: intensive margin

Cumulative Green Patents	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)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Green Patents Age	1.279*** (0.097)	1.281*** (0.098)	1.274*** (0.098)	1.257*** (0.097)	1.279*** (0.097)	1.282*** (0.098)	1.275*** (0.098)	1.258*** (0.097)	1.279*** (0.097)	1.281*** (0.098)	1.274*** (0.098)	1.257*** (0.097)
# FDIs	0.134** (0.054)											
# FDIs (t-1)		0.121** (0.055)										
# FDIs (t-2)			0.123*** (0.046)									
# FDIs (t-3)				0.128*** (0.050)								
# Greenfield FDIs					0.074 (0.071)							
# Greenfield FDIs (t-1)						0.094 (0.073)						
# Greenfield FDIs (t-2)							0.098* (0.058)					
# Greenfield FDIs (t-3)								0.108* (0.062)				
# M&As									0.225*** (0.080)			
# M&As (t-1)										0.167** (0.079)		
# M&As (t-2)											0.168** (0.072)	
# M&As (t-3)												0.166** (0.072)
F.E. (target country, investor, year)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	81240	77855	74470	71085	81240	77855	74470	71085	81240	77855	74470	71085

Forward spillovers: extensive margin

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Cumulative Green Patents	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)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Green Patents Age	1.280*** (0.097)	1.282*** (0.098)	1.274*** (0.098)	1.258*** (0.097)	1.279*** (0.097)	1.282*** (0.098)	1.275*** (0.098)	1.258*** (0.097)	1.280*** (0.097)	1.281*** (0.098)	1.274*** (0.098)	1.257*** (0.097)
FDIs Dummy	0.105 (0.067)											
FDIs Dummy (t-1)		0.071 (0.061)										
FDIs Dummy (t-2)			0.082 (0.054)									
FDIs Dummy (t-3)				0.088 (0.054)								
Greenfield FDIs Dummy					-0.003 (0.094)							
Greenfield FDIs Dummy (t-1)						0.002 (0.088)						
Greenfield FDIs Dummy (t-2)							0.024 (0.077)					
Greenfield FDIs Dummy (t-3)								0.036 (0.077)				
M&As Dummy									0.252** (0.104)			
M&As Dummy (t-1)										0.176* (0.097)		
M&As Dummy (t-2)											0.178** (0.085)	
M&As Dummy (t-3)												0.178** (0.085)
F.E. (target country, investor, year)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	81240	77855	74470	71085	81240	77855	74470	71085	81240	77855	74470	71085

Wind: intensive margin

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Cumulative Green Patents	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)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Green Patents Age	1.055*** (0.100)	1.058*** (0.101)	1.057*** (0.100)	1.055*** (0.100)	1.055*** (0.100)	1.058*** (0.101)	1.058*** (0.100)	1.055*** (0.100)	1.057*** (0.100)	1.060*** (0.101)	1.059*** (0.100)	1.055*** (0.100)
# FDIs	0.144** (0.067)											
# FDIs (t-1)		0.163*** (0.055)										
# FDIs (t-2)			0.153*** (0.051)									
# FDIs (t-3)				0.133*** (0.051)								
# Greenfield FDIs					0.132 (0.086)							
# Greenfield FDIs (t-1)						0.176*** (0.066)						
# Greenfield FDIs (t-2)							0.153*** (0.055)					
# Greenfield FDIs (t-3)								0.145*** (0.051)				
# M&As									0.192** (0.090)			
# M&As (t-1)										0.149* (0.085)		
# M&As (t-2)											0.174** (0.087)	
# M&As (t-3)												0.116 (0.094)
F.E. (target country, investor, year)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	28104	26933	25762	24591	28104	26933	25762	24591	28104	26933	25762	24591

Wind: extensive margin

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Cumulative Green Patents	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)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Green Patents Age	1.056***	1.059***	1.059***	1.056***	1.056***	1.059***	1.059***	1.055***	1.057***	1.060***	1.059***	1.055***
	(0.100)	(0.101)	(0.100)	(0.100)	(0.100)	(0.101)	(0.100)	(0.100)	(0.100)	(0.101)	(0.100)	(0.100)
FDIs Dummy	0.094											
	(0.093)											
FDIs Dummy (t-1)		0.118*										
		(0.071)										
FDIs Dummy (t-2)			0.129**									
			(0.065)									
FDIs Dummy (t-3)				0.104								
				(0.065)								
Greenfield FDIs Dummy					0.102							
					(0.096)							
Greenfield FDIs Dummy (t-1)						0.136*						
						(0.072)						
Greenfield FDIs Dummy (t-2)							0.123**					
							(0.060)					
Greenfield FDIs Dummy (t-3)								0.119**				
								(0.058)				
M&As Dummy									0.133			
									(0.171)			
M&As Dummy (t-1)										0.117		
										(0.143)		
M&As Dummy (t-2)											0.179	
											(0.125)	
M&As Dummy (t-3)												0.106
												(0.137)
F.E. (target country, investor, year)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	28104	26933	25762	24591	28104	26933	25762	24591	28104	26933	25762	24591

Solar: intensive margin

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Cumulative Green Patents	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)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Green Patents Age	1.250***	1.260***	1.258***	1.243***	1.250***	1.260***	1.259***	1.244***	1.249***	1.259***	1.258***	1.243***
	(0.114)	(0.115)	(0.115)	(0.115)	(0.114)	(0.115)	(0.115)	(0.115)	(0.114)	(0.115)	(0.115)	(0.115)
# FDIs	0.136** (0.061)											
# FDIs (t-1)	0.109 (0.071)											
# FDIs (t-2)	0.095 (0.065)											
# FDIs (t-3)	0.092 (0.061)											
# Greenfield FDIs					0.044 (0.095)							
# Greenfield FDIs (t-1)					0.082 (0.108)							
# Greenfield FDIs (t-2)					0.087 (0.096)							
# Greenfield FDIs (t-3)					0.060 (0.088)							
# M&As									0.230** (0.105)			
# M&As (t-1)									0.142 (0.100)			
# M&As (t-2)									0.107 (0.088)			
# M&As (t-3)									0.134 (0.083)			
F.E. (target country, investor, year)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	53112	50899	48686	46473	53112	50899	48686	46473	53112	50899	48686	46473

Solar: extensive margin

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Cumulative Green Patents	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)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Green Patents Age	1.250***	1.260***	1.258***	1.243***	1.250***	1.260***	1.259***	1.244***	1.250***	1.259***	1.258***	1.243***
	(0.114)	(0.115)	(0.115)	(0.115)	(0.114)	(0.115)	(0.115)	(0.115)	(0.114)	(0.115)	(0.115)	(0.115)
# FDIs	0.198** (0.083)											
# FDIs (t-1)	0.121 (0.082)											
# FDIs (t-2)			0.104 (0.072)									
# FDIs (t-3)					0.105* (0.061)							
# Greenfield FDIs					0.066 (0.129)							
# Greenfield FDIs (t-1)					0.053 (0.120)							
# Greenfield FDIs (t-2)							0.058 (0.108)					
# Greenfield FDIs (t-3)									0.032 (0.090)			
# M&As									0.320*** (0.118)			
# M&As (t-1)									0.195 (0.120)			
# M&As (t-2)											0.159 (0.105)	
# M&As (t-3)											0.197** (0.093)	
F.E. (target country, investor, year)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	53112	50899	48686	46473	53112	50899	48686	46473	53112	50899	48686	46473

Forward spillovers & macro conditions (intensive margin)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# FDIs * GDP per capita	-0.000** (0.000)								-0.000** (0.000)			
# FDIs * GDP per capita (lag 1)		-0.000 (0.000)								-0.000 (0.000)		
# FDIs * GDP per capita (lag 2)			-0.000* (0.000)								-0.000 (0.000)	
# FDIs * GDP per capita (lag 3)				-0.000** (0.000)								-0.000* (0.000)
# FDIs * Env. Pol. Index					0.064 (0.056)				0.082 (0.070)			
# FDIs * Env. Pol. Index (lag 1)						0.046 (0.074)				0.036 (0.089)		
# FDIs * Env. Pol. Index (lag 2)							0.057 (0.063)				0.042 (0.073)	
# FDIs * Env. Pol. Index (lag 3)								0.074 (0.053)				0.066 (0.060)
F.E. (target country, investor, year)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	73986	70898	67810	64722	73104	70058	67012	63966	66096	63342	60588	57834

Forward spillovers & macro conditions (extensive margin)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
FDIs dummy * GDP per capita	-0.000*								-0.000*			
	(0.000)								(0.000)			
FDIs dummy * GDP per capita (lag 1)		-0.000*								-0.000		
		(0.000)								(0.000)		
FDIs dummy * GDP per capita (lag 2)			-0.000**								-0.000*	
			(0.000)								(0.000)	
FDIs dummy * GDP per capita (lag 3)				-0.000***								-0.000**
				(0.000)								(0.000)
FDIs dummy * Env. Pol. Index					0.082				0.104			
					(0.059)				(0.071)			
FDIs dummy * Env. Pol. Index (lag 1)						0.102*				0.095		
						(0.060)				(0.070)		
FDIs dummy * Env. Pol. Index (lag 2)							0.104*				0.086	
							(0.054)				(0.062)	
FDIs dummy * Env. Pol. Index (lag 3)								0.114**				0.096*
								(0.045)				(0.052)
F.E. (target country, investor, year)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	73986	70898	67810	64722	73104	70058	67012	63966	66096	63342	60588	57834

Preliminary conclusions

- **Green FDI**s are important drivers of innovation in green technologies;
- Their **impact is not limited to the MNEs' boundaries** (Amendolagine et al., 2021) and at level of subsidiaries (Amendolagine et al., 2023)
- **Green FDI**s increase **forward technological spillovers in the host countries, enhancing green innovative activities**;
- Their impact is stronger in case of **cross-border acquisitions** rather than in greenfield investments and in the **wind industry** with respect to the the solar sector.
- Their impact is more evident in **developing economies** and in countries with **stricter environmental policy**.



robertarabellotti.it

Backward spillovers: intensive margin

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Green Patents	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)
# FDIs	-0.101 (0.233)											
# FDIs (t-1)		0.101 (0.330)										
# FDIs (t-2)			0.036 (0.283)									
# FDIs (t-3)				-0.350 (0.230)								
# Greenfield FDIs					0.133 (0.335)							
# Greenfield FDIs (t-1)						0.417 (0.473)						
# Greenfield FDIs (t-2)							-0.219 (0.477)					
# Greenfield FDIs (t-3)								-0.294 (0.365)				
# M&As									-0.471 (0.368)			
# M&As (t-1)										-0.504* (0.282)		
# M&As (t-2)											0.263 (0.421)	
# M&As (t-3)												-0.454** (0.226)
F.E. (target country, investor, year)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	13680	13110	12540	11970	13680	13110	12540	11970	13680	13110	12540	11970

Backward spillovers: extensive margin

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
# Green Patents	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)	0.003*** (0.001)
FDIs Dummy	-0.084 (0.330)											
FDIs Dummy (t-1)		-0.089 (0.712)										
FDIs Dummy (t-2)			0.236 (0.376)									
FDIs Dummy (t-3)				-0.348 (0.270)								
Greenfield FDIs Dummy					0.262 (0.453)							
Greenfield FDIs Dummy (t-1)						0.529 (1.092)						
Greenfield FDIs Dummy (t-2)							-0.081 (0.663)					
Greenfield FDIs Dummy (t-3)								-0.175 (0.441)				
M&As Dummy									-0.245 (0.357)			
M&As Dummy (t-1)										-0.781*** (0.265)		
M&As Dummy (t-2)											0.478 (0.432)	
M&As Dummy (t-3)												-0.474* (0.272)
F.E. (target country, investor, year)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	13680	13110	12540	11970	13680	13110	12540	11970	13680	13110	12540	11970