Multinationals and the Green Transition

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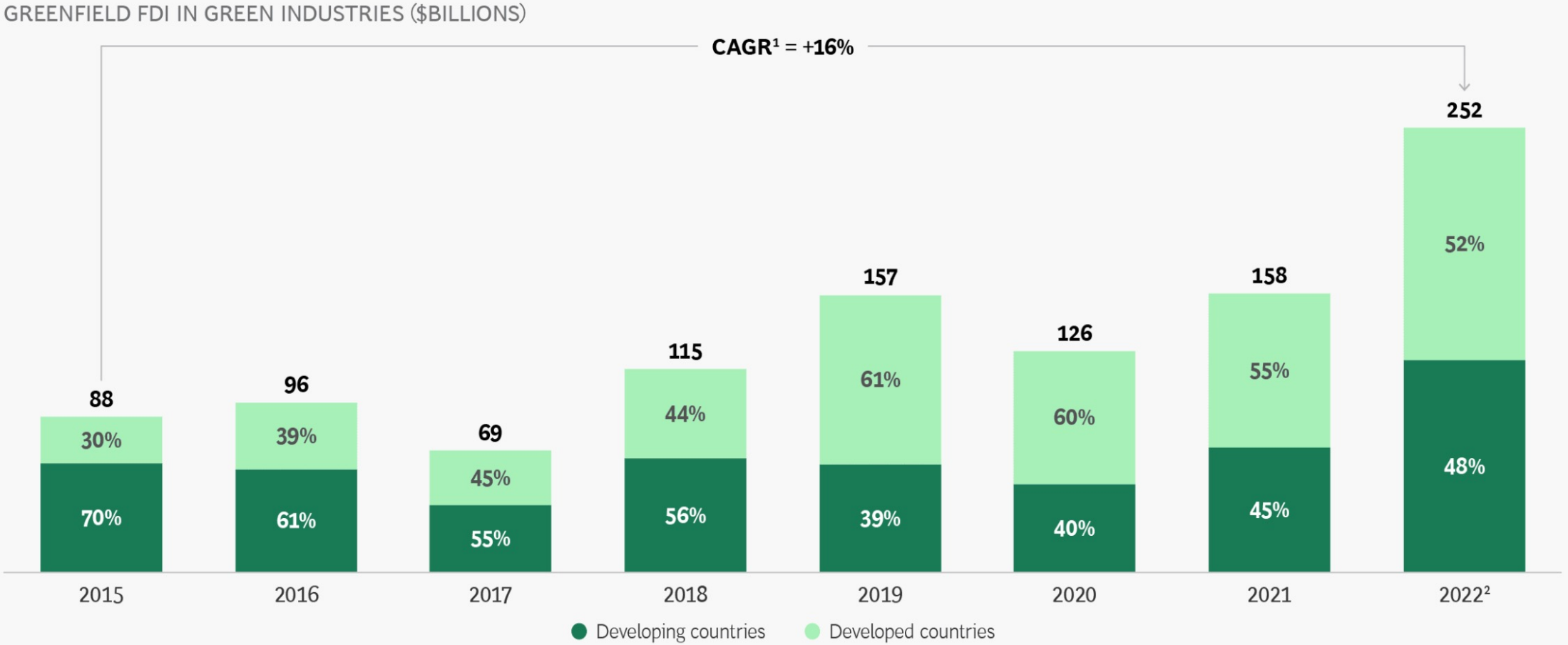
Multinationals and the environment
A dangerous liaison

Multinational enterprises (MNEs) can have both positive and negative effects on the green transformation

MNEs are often associated with environmental wrongdoing and for organizing globally to avoid environmental regulations.

MNEs can contribute to diffuse environmentally friendly knowledge and to increase green innovation.

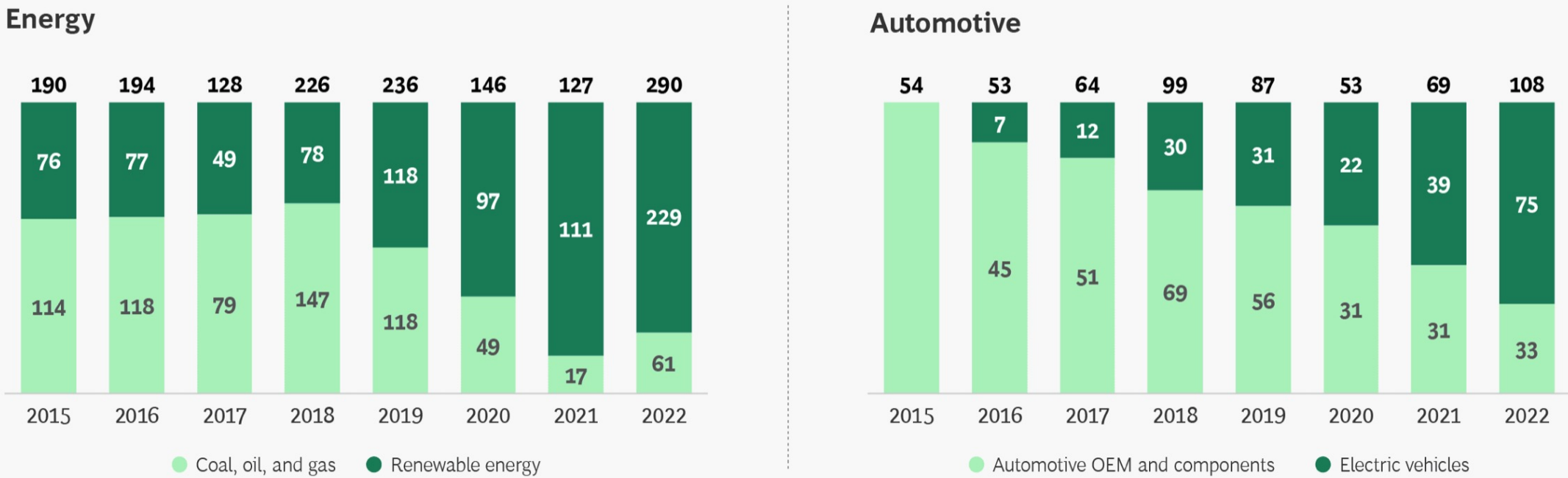
Exhibit 1 - Green FDI Flows Are Rising, but Since 2019 Most Go to Developed Countries



Note: Graph presents greenfield FDI projects CapEx. Numbers include announced and opened greenfield FDI projects in the environmental technology cluster, electric vehicles and renewable energy (green FDI). 2022 figures present data until Q3 2022.
[1]CAGR = compounded annual growth rate. [2]2022 figures present data until Q3 2022.

Exhibit 2 - Growth of Green FDI Projects in Energy and Automotive

GREENFIELD INVESTMENTS, SHARE OF GREEN PROJECTS 2015–2022 ($BILLIONS)



Source: fDi Markets, a service from The Financial Times Limited [2022]. All Rights Reserved.
Note: Graph presents greenfield FDI projects CapEx. Numbers include announced and opened greenfield FDI projects. 2022 figures present data until Q3 2022. Electric vehicles covered since January 2015.
[1]OEM = original equipment manufacturer.

MNEs as a green knowledge spreader via green foreign direct investments (FDI)

1. How to identify green FDI?
2. Green FDI impact on the green innovative capacity of the investors?
3. Green FDI impact on the green innovative capacity of their subsidiaries?
4. Green FDI impact on the green innovative capacity of the host countries?

Green FDI and technological spillovers in the host economies

Vito Amendolagine,
Roberta Rabellotti & Dalila Ribaudo

How to identify green FDI?

1. Identify all patents in PATSTAT "*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 (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) in ORBIS and Zephir;
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.

The database include 1217 FDI (from 2003 to 2015, recently updated to 2022)

Green FDI: home and host countries

Home countries

	Entry mode		
	Greenfield (%)	M&As (%)	Total (%)
Income level			
High income	840 (95.02)	385 (91.7)	1225 (93.94)
Lower middle income	10 (10.13)	7 (1.7)	17 (1.30)
Upper middle income	34 (3.85)	28 (6.6)	62 (4.76)
Region			
East Asia & Pacific	193 (21.83)	67 (15.95)	260 (19.94)
Europe & Central Asia	555 (62.78)	247 (58.81)	802 (61.5)
Latin America & Caribbean	7 (0.79)	4 (0.95)	11 (0.84)
Middle East & North Africa	4 (0.45)	3 (0.71)	7 (0.54)
North America	115 (13.00)	94 (22.39)	209 (16.03)
South Asia	10 (1.15)	5 (1.19)	15 (1.15)
Total	884 (100)	420 (100)	1304 (100)

Host countries

	Entry mode		
	Greenfield	M&As	Total
Income level			
High income	624 (70.58)	355 (84.52)	979 (75.08)
Lower middle income	85 (9.62)	14 (3.33)	99 (7.59)
Upper middle income	175 (19.80)	51 (12.15)	226 (17.33)
Region			
East Asia & Pacific	214 (24.20)	42 (10.00)	256 (19.63)
Europe & Central Asia	503 (56.90)	268 (63.80)	771 (59.13)
Latin America & Caribbean	36 (4.07)	34 (8.10)	70 (5.37)
Middle East & North Africa	11 (1.25)	3 (0.71)	14 (1.07)
North America	40 (4.53)	60 (14.29)	100 (7.67)
South Asia	75 (8.48)	11 (2.62)	86 (6.60)
Sub-Saharan Africa	5 (0.57)	2 (0.48)	7 (0.53)
Total	884 (100)	420 (100)	1304 (100)

Green FDI impact on the green innovative capacity of investors

- Innovation in renewable energies is crucial to increase their **economic competitiveness** and **sustainability** relative to fossil fuels.
- MNEs are key actors in R&D and therefore they have an important role to play in the green innovation process.

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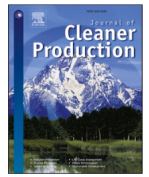

Green foreign direct investments and the deepening of capabilities for sustainable innovation in multinationals: Insights from renewable energy

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Research questions

How do green FDI impact on investors' green innovative capacity?

- on the number and quality of their green patents?
- on their specialization in green technologies ?
- on the variety of their green patents ?

Empirical methodology

- To address a possible bias of self-selection, we adopt a 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. Counterfactual sample of non-investors with similar *ex-ante* probabilities to undertake FDI with a logit model (the counterfactual sample share the same time distribution as the investments by the proportional random investment time assignment as in Chari et al 2012);
2. With the sample including both investors and non-investors selected by propensity score matching, we estimate the following equation:

$$\Delta y_{i,j,x,t+s} = \alpha + \beta\, FDI_{i,j,x,t} + \gamma_j + \delta_x + \vartheta_t + \varepsilon_{i,t},$$

where g_j, d_x, and q_t are fixed effects for industry, home country and deal year s=0,**1,2,3,4,5**.

4 output variables

1. *Green Intensity:* % of green patents in total investor' patent portfolio after the deal
2. *Green Specialization:* Herfindhal index measuring the concentration in green patents after the deal
3. *Green Patents:* # of investor's green patents after the deal
4. *Forward citations:* # of forward citations to investor's green patents after the deal

Greening Effect and Green Innovativeness

Table 3

Propensity score matching difference-in-difference estimators.

	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	#Obs.
Greening effect							
Green Intensity	0.0215	0.0522***	0.0517***	0.0366**	0.0234	0.0457***	5589
	(0.0138)	(0.0129)	(0.0146)	(0.0158)	(0.0174)	(0.0155)	
Green Specialization	0.0195	0.0549***	0.0575**	0.0552**	0.0328	0.0666***	5589
	(0.0206)	(0.0205)	(0.0237)	(0.0251)	(0.0257)	(0.0246)	
Green innovativeness							
Green Patents	0.1340***	0.2028***	0.2707***	0.3014***	0.3085***	0.3431***	5589
	(0.0411)	(0.0466)	(0.0582)	(0.0616)	(0.068)	(0.067)	
Forward Citations	0.0242	0.1134	0.1007	0.0483	0.0413	0.0681	5589
	(0.067)	(0.0730)	(0.0826)	(0.0830)	(0.0834)	(0.0755)	

Matching by kernel algorithm with common support.

Outputs equal to $\ln(1+Y_{t+s})-\ln(1+Y_{t-1})$, where s = 0,1,2,3,4,5.

All regressions include fixed effects for investors country, investor NACE 2-digit sector and year of investment. Standard errors are clustered at investor level and reported in parentheses.

* p-value< 0.10, ** p-value< 0.05, *** p-value 0.010.

Greening effect

- Green FDIs enhance the green intensity of investors' patent portfolios, which means that the share of RE patents increases in the investors' total patent portfolio in the first five years after the investment:
  - There is an increase in the green innovative activity in multinationals.
- GFDIs increase the specialization in specific renewable energy technologies:
  - MNEs deepen their innovative capabilities in the technologies such as solar or wind in which they already have most of their green patents.

Green innovativeness

- GFDIs increase the green innovativeness of investors in terms of number of green patents (forward citations has a positive but not significant coefficient)

The greening effect

- In the sample there are two types of MNEs:
  - Multi-technology corporations with 50% or fewer green patents in their portfolio, which accounts for most investors and investments. Examples are Siemens, General Electric, Samsung.
  - Pure green players with more than 50% of their patents in renewable energies (Y02E subgroup), which accounts for around 25% of total investments. Examples are Vestas, Yingly Energy.
- Green FDI increase the green specialization also in multi-technology corporations.

Table 1
Investors' green intensity (# and%).

	Firms	GFDI	Greenfield Investments	Acquisitions
Multi-technology corporations	375 (78)	923 (76)	683 (76)	240 (76)
Green pure players	103 (22)	294 (24)	219 (24)	75 (24)
Total	478 (100)	1217 (100)	902 (100)	315 (100)

Authors' elaborations.

The mode of entry: greenfield investments vs. acquisitions

Table 4
Propensity score matching difference-in-difference estimators Greenfield Investments and Acquisitions.

		t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	#Obs.
Greening effect								
Green Intensity	Greenfield Investments	0.0312	0.0440**	0.0599***	0.0562***	0.0563***	0.0632***	4232
		(0.0200)	(0.0190)	(0.0200)	(0.0191)	(0.0198)	(0.0182)	
	Acquisitions	0.0118	−0.0037	−0.0123	−0.0046	−0.0301	−0.0322	4211
		(0.0263)	(0.0249)	(0.0303)	(0.0281)	(0.0366)	(0.0329)	
Green Specialization	Greenfield Investments	0.0651**	0.0616**	0.0710**	0.1040***	0.0969***	0.1244***	4232
		(0.0264)	(0.0293)	(0.0303)	(0.0312)	(0.0316)	(0.0302)	
	Acquisitions	0.0049	0.0630	0.0082	0.0495	−0.0323	−0.0178	4211
		(0.0402)	(0.0427)	(0.0423)	(0.0457)	(0.0499)	(0.0528)	
Green innovativeness								
Green Patents	Greenfield Investments	0.1120**	0.1989***	0.2454***	0.3544***	0.3759***	0.4245***	4232
		(0.0464)	(0.0627)	(0.0719)	(0.0801)	(0.0894)	(0.0889)	
	Acquisitions	0.1459*	0.1895**	0.1220	0.1509	0.1102	0.0488	4211
		(0.0788)	(0.0862)	(0.0958)	(0.1014)	(0.1126)	(0.1146)	
Forward Citations	Greenfield Investments	0.0800	0.0238	0.1321	0.1405	0.1983**	0.2323***	4232
		(0.0840)	(0.1003)	(0.1022)	(0.0900)	(0.0950)	(0.0881)	
	Acquisitions	−0.0891	−0.0031	−0.2135	−0.2155	−0.3498*	−0.3535*	4211
		(0.1544)	(0.1788)	(0.1418)	(0.1780)	(0.1850)	(0.1967)	

Matching by kernel algorithm with common support.
The outputs are equal to $\ln(1+Y_{t+s})-\ln(1+Y_{t-1})$, where $s = 0,1,2,3,4,5$.
All regressions include fixed effects for investor country, investor NACE 2-digit sector and year of investment.
Standard errors are clustered at investor level and reported in parentheses.
* p-value< 0.10, ** p-value< 0.05, *** p-value 0.010.

The mode of entry matters

- Newly established subsidiaries contribute more to green innovativeness and the greening effect than acquisitions of foreign firms.
- Firms that make green greenfield investments file more green patents (and these patents are cited more) than firms that make acquisitions.
- When Green FDI takes the form of an acquisition of an existing company, there are only short-term effects on the MNEs green innovativeness.
- In terms of policy implications this implies that greenfield investments must be preferred to acquisitions for the purpose of accelerating the green transition.

Key takeaways

- We show that green foreign direct investments increase the green specialization of large multinational conglomerates.
- Given the fact that the world's largest and most influential manufacturers have a multi-technology nature, this insight is good news from the perspective of the green transformation.
- If the largest MNEs increasingly devote their innovative activities to making green technologies more efficient, affordable and accessible, their contribution to the green transformation could be significant.

GFDI impact on the green innovative capacity of their subsidiaries?

- If MNEs positively spur green knowledge though their subsidiaries across countries at different levels of development, they can contribute kickstarting the green transition.

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Do green foreign direct investments increase the innovative capability of MNE subsidiaries?

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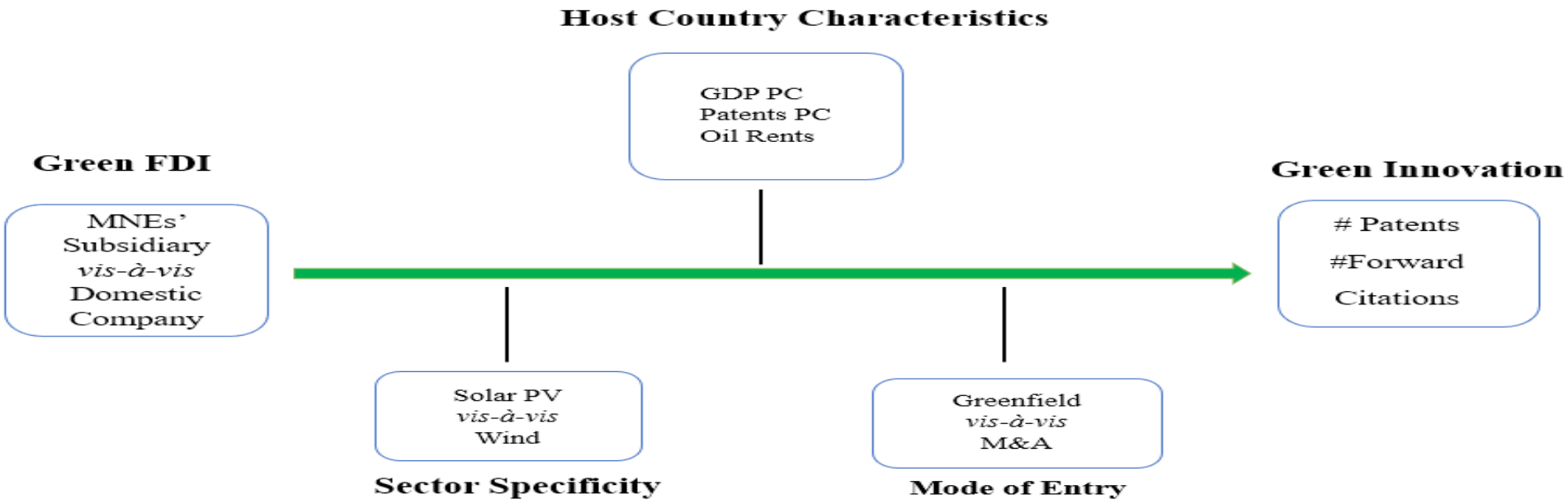
Research question

To what extent are MNEs contributing to increase the green innovative capabilities of their subsidiaries vis-à-vis domestic companies?



Methodology

- **Negative binomial model** (Piperopoulos et. al., 2018)
- **Counter sample:** 6,276 DOMESTIC COMPANIES **with at least one patent in RE technologies** (in the same sectors/countries of the subsidiaries)
- **Output variables**
  - # of green patents (DOCDB families) up to 5 years after the investment
  - # forward citations (average) to green patents up to 5 years after the investment
  - Patents are attributed to subsidiaries if at least one inventor is from the same country of the subsidiary (Stiebale, 2016): 1,410 SUBSIDIARIES' PATENTS IN RE
- **Main independent variable:** Dummy 1= MNE subsidiary 0 = domestic company
- **Moderating factors:** Host country-specific characteristics (GDP per capita; # of patents per capita in the country; oil rents %GDP)
- **Controls:** SIZE, AGE, PRE-DEAL KNOWLEDGE BASE
- **Fixed effects:** NACE 2-digit sector and deal year

Table 2
Full sample.

	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	−0.859***	−0.049	0.188	0.377	0.705***	0.552**	1.167***	1.154***	1.202***	1.510***	2.115***	2.187***
	(0.262)	(0.262)	(0.249)	(0.263)	(0.245)	(0.274)	(0.375)	(0.352)	(0.399)	(0.361)	(0.357)	(0.376)
PATENT PORTFOLIO STOCK LAG 1 (LN)	−0.690**	−0.614***	−0.626***	−0.145	−0.518**	−0.172	−1.029***	−1.056***	−1.099***	−1.049***	−1.026***	−0.666***
	(0.306)	(0.171)	(0.211)	(0.144)	(0.208)	(0.166)	(0.187)	(0.167)	(0.260)	(0.365)	(0.234)	(0.257)
AGE (LN)	−0.314***	−0.249***	−0.189***	−0.244***	−0.087	−0.156*	−0.072	−0.414***	−0.281***	−0.226**	−0.125	−0.003
	(0.071)	(0.071)	(0.072)	(0.074)	(0.072)	(0.086)	(0.085)	(0.077)	(0.087)	(0.090)	(0.092)	(0.097)
MIDDLE SIZE	0.093	0.173	0.066	0.138	0.105	0.934***	−0.127	−0.150	0.021	−0.040	0.015	0.815***
	(0.165)	(0.182)	(0.169)	(0.181)	(0.208)	(0.221)	(0.204)	(0.214)	(0.230)	(0.249)	(0.244)	(0.264)
LARGE_SIZE	0.350*	0.088	0.308	0.398**	0.405**	1.064***	−0.313	0.067	−0.487**	−0.154	0.507**	0.741**
	(0.188)	(0.200)	(0.199)	(0.193)	(0.206)	(0.241)	(0.232)	(0.241)	(0.230)	(0.280)	(0.250)	(0.345)
COUNTRY GDP PC (LN)	0.106	0.010	0.029	0.150*	−0.004	−0.081	0.250***	0.305***	0.255***	0.458***	0.360***	0.228**
	(0.068)	(0.063)	(0.069)	(0.077)	(0.072)	(0.074)	(0.083)	(0.083)	(0.089)	(0.104)	(0.083)	(0.092)
COUNTRY PATENT PC (LN)	0.131	0.466***	0.265	0.422**	0.764***	1.062***	0.384*	−0.032	0.242	−0.165	0.353	0.921***
	(0.148)	(0.154)	(0.166)	(0.170)	(0.195)	(0.206)	(0.202)	(0.218)	(0.248)	(0.196)	(0.242)	(0.260)
OIL RENTS (% GDP)	−0.049	−0.061	−0.082*	−0.063	−0.023	0.011	−0.145***	−0.074*	−0.156***	−0.012	−0.064	0.192
	(0.043)	(0.038)	(0.042)	(0.053)	(0.038)	(0.055)	(0.046)	(0.043)	(0.050)	(0.068)	(0.043)	(0.133)
INDUSTRY FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
DEAL YEAR FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
CONSTANT	−19.082	−20.876***	−21.553	−22.229	−20.192***	−20.596***	−21.540***	−27.152	−36.194	−31.572	−23.094***	−27.666
		(1.222)	.	.	(0.858)	(1.914)	(1.409)	(9090.162)	(8447873.262)	.	(0.613)	(125.124)
LNALPHA	2.462***	2.838***	2.788***	2.870***	2.983***	3.171***	4.048***	4.087***	4.148***	3.996***	4.044***	4.177***
	(0.164)	(0.101)	(0.107)	(0.113)	(0.112)	(0.110)	(0.071)	(0.072)	(0.081)	(0.082)	(0.084)	(0.097)
OBSERVATIONS	7331	7331	7331	7331	7331	7331	7331	7331	7331	7331	7331	7331

FDI subsidiaries = 1,055. # Domestic companies = 6,276. Robust standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01″.

Full sample

- Subsidiaries outperform comparable domestic companies with respect to # of green patents & # of forward citations.

→Subsidiaries have a green innovative advantage with respect to domestic companies

Table 3
Interaction terms (full sample).

	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***
	(0.864)	(0.845)	(1.202)	(0.734)	(0.574)	(0.593)	(0.789)	(0.818)	(0.922)	(0.791)	(0.686)	(0.650)
PATENT PORTFOLIO STOCK LAG 1 (LN)	−0.728**	−0.746***	−0.699***	−0.169	−0.575***	−0.255	−0.978***	−1.018***	−1.030***	−0.986***	−1.343***	−0.826***
	(0.293)	(0.194)	(0.242)	(0.150)	(0.215)	(0.178)	(0.181)	(0.171)	(0.265)	(0.311)	(0.247)	(0.237)
AGE (LN)	−0.323***	−0.254***	−0.187**	−0.239***	−0.087	−0.175**	−0.077	−0.419***	−0.297***	−0.252***	−0.211**	−0.042
	(0.070)	(0.075)	(0.077)	(0.073)	(0.071)	(0.085)	(0.084)	(0.077)	(0.087)	(0.090)	(0.093)	(0.097)
MIDDLE SIZE	0.094	0.153	0.036	0.123	0.073	0.945***	−0.104	−0.122	0.037	−0.087	0.145	0.848***
	(0.163)	(0.180)	(0.165)	(0.181)	(0.204)	(0.219)	(0.205)	(0.210)	(0.232)	(0.246)	(0.240)	(0.269)
LARGE SIZE	0.368**	0.121	0.331*	0.403**	0.435**	1.162***	−0.298	0.139	−0.461**	−0.136	0.634**	0.895***
	(0.186)	(0.202)	(0.200)	(0.193)	(0.208)	(0.240)	(0.235)	(0.246)	(0.230)	(0.278)	(0.255)	(0.339)
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***
	(0.068)	(0.061)	(0.064)	(0.075)	(0.078)	(0.083)	(0.087)	(0.088)	(0.098)	(0.119)	(0.093)	(0.117)
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*
	(0.148)	(0.156)	(0.168)	(0.174)	(0.200)	(0.211)	(0.199)	(0.219)	(0.250)	(0.202)	(0.246)	(0.262)
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
	(0.043)	(0.039)	(0.045)	(0.055)	(0.042)	(0.056)	(0.049)	(0.044)	(0.053)	(0.070)	(0.048)	(0.171)
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*****
	(0.288)	**(0.240)**	**(0.344)**	**(0.221)**	**(0.180)**	**(0.179)**	**(0.224)**	**(0.219)**	**(0.249)**	**(0.241)**	**(0.220)**	**(0.189)**
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*****
	(0.925)	**(0.900)**	**(0.896)**	**(0.770)**	**(0.844)**	**(0.869)**	**(1.156)**	**(1.123)**	**(1.261)**	**(1.091)**	**(1.076)**	**(1.137)**
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**
	(0.115)	**(0.127)**	**(0.138)**	**(0.120)**	**(0.099)**	**(0.147)**	**(0.206)**	**(0.204)**	**(0.190)**	**(0.247)**	**(0.168)**	**(0.237)**
INDUSTRY FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
DEAL YEAR FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
CONSTANT	−20.379	−21.262***	−19.904***	−21.323**	−20.276***	−20.766	−22.385***	−24.177	−35.701	−19.287***	−24.453***	−32.564
	.	(2.125)	(1.223)	(9.381)	(0.975)	.	(3.576)	.	.	(0.834)	(0.987)	(7659.261)
LNALPHA	2.456***	2.816***	2.766***	2.865***	2.977***	3.160***	4.043***	4.072***	4.139***	3.985***	3.991***	4.120***
	(0.160)	(0.097)	(0.111)	(0.115)	(0.112)	(0.110)	(0.071)	(0.072)	(0.080)	(0.082)	(0.082)	(0.098)
OBSERVATIONS	7331	7331	7331	7331	7331	7331	7331	7331	7331	7331	7331	7331

FDI subsidiaries = 1,055. # Domestic companies = 6,276. Robust standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01″.

Interaction terms

- **GDP per capita**
  - Relative to domestic companies the subsidiaries of multinationals are more innovative when the GDP per capita is lower.

→ In less developed countries being a subsidiary it really makes a difference!

- **Patents per capita**
  - The advantage of being a subsidiary is larger in more innovative countries

→ better absorptive capacity

- **Oil Rents (% GDP)**
  - In oil-reliant countries, subsidiaries engage less in green innovative activity

→ the resource curse hypothesis.

Solar vs. Wind

Wind

	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

	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***

Sector specificity

- **Wind** subsidiaries outperform domestic companies in both outputs;
- **Solar** subsidiaries outperform domestic companies only in forward citations;

→ Knowledge is more tacit in wind and more codified in solar!

→The subsidiaries' advantage in terms of patent quality is larger in wind than in solar PV.

Mode of entry

Greenfield FDI

	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

	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*** **

Mode of entry

- Greenfield investments outperform domestic companies in terms of forward citations, but not in terms of # of patents.
- M&A perform better in terms of both output variables, i.e., the amount and quality of innovation.

→ Greenfield subsidiaries rely mostly on foreign investors' knowledge;

→ Acquired companies combine parent's knowledge with an easier access to local knowledge.

→ **The gap between subsidiaries and domestic companies in terms of innovative capability is larger in case of acquisitions than in greenfield investments.**

Key takeaways

- Subsidiaries of green MNEs are more innovative than domestic firms with similar characteristics.
- The green innovative advantage is larger in less developed countries, in particular when they already possess high levels of relevant domestic innovative capacity, as exemplified by the cases of China and India.
- Firm-level and sectoral characteristics also matter.
  - Green FDI is more effective when technologies are characterized by low tradability and uncodified knowledge, as in wind compared to solar PV industries.
  - Cross-border acquisitions are more efficient at establishing green innovative capabilities than newly established greenfield subsidiaries.

Policy implications

- Foreign direct investments should become more central in the policy discourse as **channels to transfer knowledge**
- From the home country point of view, governments should encourage and sustain firm green internationalisation considering that it helps green innovation, sustaining the green transformation.
- From the host country point of view, especially in the Global South, should focus on attracting green FDI to boost local green innovation, enhancing the adaptation of green innovative solutions to local needs and the creation of new global green solutions.
- The increasing adoption of **screening investment frameworks** may be detrimental to green innovation that can speed up the green transformation worldwide.
- Considering intellectual property in green industries, there is mounting consensus about the need to treat green technologies, especially in renewable energy, as essential global public goods.

Limitation!!!
We don’t measure knowledge spillovers in the host economies!

Green FDI and technological spillovers in the host economies

Vito Amendolagine,

Roberta Rabellotti & Dalila Ribaudo

- Extending Branstetter (2006), who finds that Japanese FDIs in the USA increase the likelihood of domestic firms to license Japanese technology, and the licensing leads to an increase in their innovative activity, we will test a negative binomial model with two outputs:
  - # of citations of foreign investors' green patents by the green patents applied in the host economy;
  - # of co-patents in green technologies applied by green foreign investors, their subsidiaries and other local companies.
- Moderating factors: FDI mode of entry (greenfield or cross-border acquisition); technology specialization of foreign investors (solar or wind); technological and economic development level of the host economy; direction of green FDI: i.e., North-South or South-North.

Thank You!

robertarabellotti.it

Table 2
Distribution of GFDI based on investors' technological specialization (# and%).

Main technological specialization	GFDI	Greenfield Investments	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)

Authors' elaborations.

Logit – PSM scores

- Based on Stiebale (2016) we include the following regressors at t-1:
  - ✓ patent_portfolio_L1: log of patent stock
  - ✓ n_green_patents_L1: log of the number of RET patents applied for at one year before the deal;
  - ✓ Age: log of the investor's age at the year of the deal;
  - ✓ pre_sample_patent_avg: average number of patents produced before 2003
  - ✓ pre_sample_patent_d: dummy taking value 1 if at least 1 patent was produced before the deal and 0 otherwise
- Controls: size, legal status, FDI experience, technological dispersion of green patents, green patent share in patent portfolio

	(1)	(2)	(3)
	any FDI	greenfield	acquisition
patent_portfolio_L1	0.1978***	0.2128***	0.1125**
	(0.0487)	(0.0462)	(0.0551)
green_specialization_L1	0.4614	0.3766	0.2834
	(0.2978)	(0.3330)	(0.5059)
n_green_patents_L1	0.5633***	0.1673*	0.1668
	(0.1281)	(0.0876)	(0.1091)
fdi_exp_L1	0.4267***		
	(0.0470)		
greenfield_fdi_exp_L1		0.3306***	
		(0.0552)	
acquisition_fdi_exp_L1			0.4785***
			(0.1182)
green_tech_concentration_L1	-0.5658***	-0.5032**	-0.0961
	(0.2113)	(0.2101)	(0.2715)
PLC_form	0.9745***	0.8885***	0.5066**
	(0.1791)	(0.1922)	(0.2102)
age	-0.1818***	-0.2179***	0.0200
	(0.0698)	(0.0675)	(0.0959)
size middle	-0.0788	0.2229	-1.1950
	(0.6112)	(0.7976)	(1.1136)
size big	1.8690***	1.7516**	1.7068***
	(0.5585)	(0.7655)	(0.5484)
size_very_big	4.2920***	4.1006***	3.7256***
	(0.5447)	(0.7307)	(0.5354)
pre_sample_patent_avg	0.0006	-0.0001	-0.0001
	(0.0006)	(0.0001)	(0.0001)
pre_sample_patent_d	-0.7567***	-0.5940***	-0.8156***
	(0.2276)	(0.2098)	(0.3051)
Constant	-2.1534*	-0.2188	-18.1184***
	(1.2812)	(1.3851)	(1.2139)
Observations	6833	6570	6437
ll	-1.1e+03	-1.1e+03	-6.8e+02

Logit estimator. All regressions include fixed effects for investor country, investor NACE 2-digit sector, and deal year. Standard errors (clustered at investor level) are reported in parentheses. * p-value< 0.10, ** p-value< 0.05, *** p-value 0.010

Table 4
Interaction terms (full sample) with dummy for China and India.

	OUTPUT: # green patents						OUTPUT: # forward citations to green patents					
	t (1)	t + 1 (2)	t + 2 (3)	t + 3 (4)	t + 4 (5)	t + 5 (6)	t (7)	t + 1 (8)	t + 2 (9)	t + 3 (10)	t + 4 (11)	t + 5 (12)
FDI SUBSIDIARY	−0.854* (0.469)	−0.627 (0.457)	−0.083 (0.438)	0.307 (0.474)	−0.044 (0.415)	−0.555 (0.422)	0.702 (0.548)	0.636 (0.553)	1.348** (0.654)	2.804*** (0.638)	−0.685 (0.543)	−0.208 (0.661)
PATENT PORTFOLIO STOCK LAG 1 (LN)	−0.737** (0.304)	−0.760*** (0.192)	−0.732*** (0.240)	−0.213 (0.147)	−0.701*** (0.220)	−0.342** (0.172)	−1.175*** (0.183)	−1.143*** (0.177)	−1.194*** (0.278)	−1.138*** (0.335)	−1.770*** (0.262)	−0.870*** (0.206)
AGE (LN)	−0.314*** (0.071)	−0.252*** (0.072)	−0.191*** (0.073)	−0.250*** (0.072)	−0.086 (0.069)	−0.187** (0.083)	−0.119 (0.082)	−0.417*** (0.076)	−0.259*** (0.085)	−0.204** (0.092)	−0.112 (0.089)	−0.005 (0.100)
MIDDLE SIZE	0.108 (0.163)	0.211 (0.178)	0.079 (0.163)	0.181 (0.179)	0.112 (0.197)	0.983*** (0.214)	0.013 (0.204)	−0.155 (0.214)	0.146 (0.239)	0.076 (0.239)	0.018 (0.232)	0.858*** (0.280)
LARGE SIZE	0.361* (0.184)	0.167 (0.198)	0.367* (0.195)	0.438** (0.187)	0.454** (0.205)	1.206*** (0.238)	−0.112 (0.231)	−0.013 (0.239)	−0.497** (0.228)	−0.083 (0.255)	0.496** (0.250)	0.845** (0.350)
CHINA&INDIA	−0.228 (0.294)	−0.175 (0.270)	0.179 (0.302)	−1.531*** (0.405)	0.041 (0.439)	−0.065 (0.420)	−0.011 (0.418)	−0.701* (0.361)	0.042 (0.361)	−2.898*** (0.488)	−1.844*** (0.441)	−0.499 (0.505)
MIDDLE INCOME_NO_CHINA&INDIA	−1.285*** (0.386)	−1.224*** (0.451)	−1.048*** (0.400)	−0.943** (0.384)	−0.593 (0.403)	−0.872** (0.408)	−2.874*** (0.548)	−2.618*** (0.413)	−3.112*** (0.779)	−2.651*** (0.491)	−3.209*** (0.554)	−4.355*** (1.290)
COUNTRY PATENT PC (LN)	0.027 (0.152)	0.263* (0.159)	0.129 (0.170)	0.262 (0.177)	0.610*** (0.197)	0.789*** (0.208)	0.394* (0.201)	−0.011 (0.220)	0.175 (0.249)	−0.286 (0.214)	0.056 (0.249)	0.500* (0.275)
OIL RENTS (%GDP)	0.007 (0.038)	0.006 (0.040)	−0.037 (0.042)	0.014 (0.047)	0.009 (0.048)	0.062 (0.067)	−0.070* (0.042)	0.068 (0.055)	−0.056 (0.048)	0.140* (0.074)	0.114* (0.067)	0.278 (0.249)
FDI SUBSIDIARY * CHINA&INDIA	**−0.143** **(0.753)**	**0.104** **(0.704)**	**−0.859** **(0.979)**	**1.051** **(0.700)**	**0.161** **(0.757)**	**1.341**** **(0.675)**	**0.752** **(0.778)**	**2.357***** **(0.832)**	**0.521** **(0.972)**	**1.568*** **(0.821)**	**4.258***** **(0.924)**	**2.856***** **(0.717)**
FDI SUBSIDIARY *MIDDLE INCOME_NO_CHINA&INDIA	**−15.862***** **(0.608)**	**−15.237***** **(0.624)**	**−17.774**** **(7.122)**	**−17.543***** **(1.802)**	**−3.917***** **(1.388)**	**−17.340***** **(0.656)**	**−20.925***** **(0.846)**	**−18.479***** **(0.607)**	**−18.406***** **(1.045)**	**−20.766***** **(0.741)**	**−3.159**** **(1.400)**	**−15.771***** **(1.642)**
FDI SUBSIDIARY * COUNTRY PATENT PC	0.478 (0.880)	2.056** (0.918)	1.178 (0.925)	0.295 (0.754)	1.595* (0.842)	2.369*** (0.833)	0.591 (1.113)	1.821 (1.198)	0.155 (1.287)	−2.323** (1.064)	5.426*** (1.028)	4.638*** (1.098)
FDI SUBSIDIARY * COUNTRY OIL RENTS	−0.042 (0.182)	−0.103 (0.225)	0.203 (0.285)	0.103 (0.172)	0.515* (0.264)	0.010 (0.217)	0.003 (0.230)	−0.644* (0.369)	−0.009 (0.357)	−0.385 (0.261)	0.529* (0.279)	−0.304 (0.346)
INDUSTRY FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
DEAL YEAR FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
CONSTANT	−20.342 .	−20.765 .	−21.118*** (2.053)	−18.721 .	−20.899 .	−20.763*** (2.517)	−19.884*** (0.971)	−18.678 .	−22.720 (36.383)	−18.015*** (0.982)	−23.703*** (1.020)	−29.230 (1476.619)
LNALPHA	2.435*** (0.164)	2.793*** (0.099)	2.732*** (0.108)	2.820*** (0.113)	2.953*** (0.112)	3.105*** (0.111)	4.001*** (0.071)	4.032*** (0.074)	4.082*** (0.080)	3.928*** (0.082)	3.951*** (0.082)	4.040*** (0.105)
OBSERVATIONS	7334	7334	7334	7334	7334	7334	7334	7334	7334	7334	7334	7334

FDI subsidiaries = 1,058. # Domestic companies = 6,276. Robust standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

Table 9
Robustness test for host-country environmental policy.

	OUTPUT: # green patents						OUTPUT: # forward citations to green patents					
	t (1)	t + 1 (2)	t + 2 (3)	t + 3 (4)	t + 4 (5)	t + 5 (6)	t (7)	t + 1 (8)	t + 2 (9)	t + 3 (10)	t + 4 (11)	t + 5 (12)
FDI SUBSIDIARY	−0.779*** (0.256)	−0.077 (0.262)	0.151 (0.249)	0.299 (0.270)	0.693*** (0.252)	0.404 (0.272)	0.860** (0.361)	0.797** (0.343)	0.319 (0.400)	1.318*** (0.366)	2.121*** (0.372)	1.880*** (0.377)
PATENT PORTFOLIO STOCK LAG 1 (LN)	−0.704** (0.301)	−0.655*** (0.174)	−0.679*** (0.219)	−0.198 (0.143)	−0.607*** (0.221)	−0.273 (0.170)	−1.002*** (0.181)	−1.100*** (0.172)	−1.095*** (0.259)	−1.155*** (0.367)	−1.113*** (0.244)	−0.774*** (0.269)
AGE (LN)	−0.290*** (0.066)	−0.271*** (0.071)	−0.215*** (0.072)	−0.308*** (0.078)	−0.111 (0.075)	−0.246*** (0.086)	−0.202** (0.085)	−0.483*** (0.079)	−0.479*** (0.096)	−0.301*** (0.091)	−0.123 (0.097)	−0.049 (0.100)
MIDDLE SIZE	0.057 (0.155)	0.217 (0.176)	0.132 (0.171)	0.238 (0.177)	0.164 (0.212)	1.074*** (0.224)	−0.005 (0.201)	−0.034 (0.211)	0.093 (0.224)	0.117 (0.243)	0.043 (0.248)	0.924*** (0.267)
LARGE SIZE	0.313* (0.185)	0.112 (0.196)	0.363* (0.201)	0.500*** (0.192)	0.462** (0.207)	1.157*** (0.239)	−0.245 (0.224)	0.186 (0.232)	−0.134 (0.240)	0.029 (0.281)	0.431* (0.254)	0.656** (0.331)
COUNTRY GDP PC (LN)	0.046 (0.069)	0.040 (0.070)	0.077 (0.073)	0.246*** (0.081)	0.067 (0.083)	0.079 (0.087)	0.570*** (0.083)	0.474*** (0.091)	0.740*** (0.118)	0.718*** (0.129)	0.624*** (0.100)	0.551*** (0.108)
COUNTRY PATENT PC (LN)	0.225* (0.136)	0.477*** (0.156)	0.279 (0.171)	0.406** (0.173)	0.740*** (0.199)	1.100*** (0.212)	0.062 (0.184)	−0.124 (0.208)	−0.131 (0.244)	−0.293 (0.202)	0.138 (0.243)	0.502** (0.244)
OIL RENTS (%GDP)	0.031 (0.055)	0.005 (0.054)	−0.029 (0.058)	−0.182** (0.085)	−0.054 (0.074)	−0.034 (0.115)	−0.008 (0.072)	0.113 (0.079)	0.032 (0.107)	0.071 (0.090)	0.227 (0.183)	0.233 (0.178)
ENVIRONMENTALLY RELATED TAX REVENUE (%GDP)	0.166* (0.089)	−0.044 (0.100)	0.009 (0.087)	−0.145 (0.098)	−0.070 (0.100)	−0.194* (0.108)	−0.520*** (0.100)	−0.111 (0.106)	−0.575*** (0.124)	−0.532*** (0.120)	−0.408*** (0.124)	−0.517*** (0.157)
INDUSTRY FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
DEAL YEAR FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
CONSTANT	−20.259 .	−21.262*** (5.628)	−21.041*** (1.448)	−21.614 .	−20.311*** (2.758)	−20.343*** (0.780)	−19.519*** (0.951)	−25.264 .	−25.329 .	−25.077 .	−22.190*** (0.806)	−24.782 .
LNALPHA	2.443*** (0.159)	2.818*** (0.101)	2.755*** (0.107)	2.831*** (0.114)	2.976*** (0.116)	3.140*** (0.114)	3.986*** (0.072)	4.029*** (0.072)	4.030*** (0.081)	3.915*** (0.084)	3.966*** (0.085)	4.114*** (0.100)
OBSERVATIONS	7131	7131	7131	7131	7131	7131	7131	7131	7131	7131	7131	7131

FDI subsidiaries = 938. # Domestic companies = 6,133. Robust standard errors are in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.