
DO GREEN FOREIGN DIRECT INVESTMENTS INCREASE THE INNOVATIVE CAPABILITY OF MNE SUBSIDIARIES?

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MOTIVATION



- The acceleration of green technology transfer is a cornerstone of the United Nations Framework Convention on Climate Change (UNFCCC), which has adopted a range of governance frameworks, such as the Technology Needs Assessments (TNA) and the Climate Technology Centre and Network (CTCN), to fast-track the green transition.
- Knowledge transfer within MNEs is an important channel, possibly driving the diffusion of green technologies, and overcoming the lack of knowledge, which is often reported as a key barrier to achieving the green energy transition, especially in less developed countries.

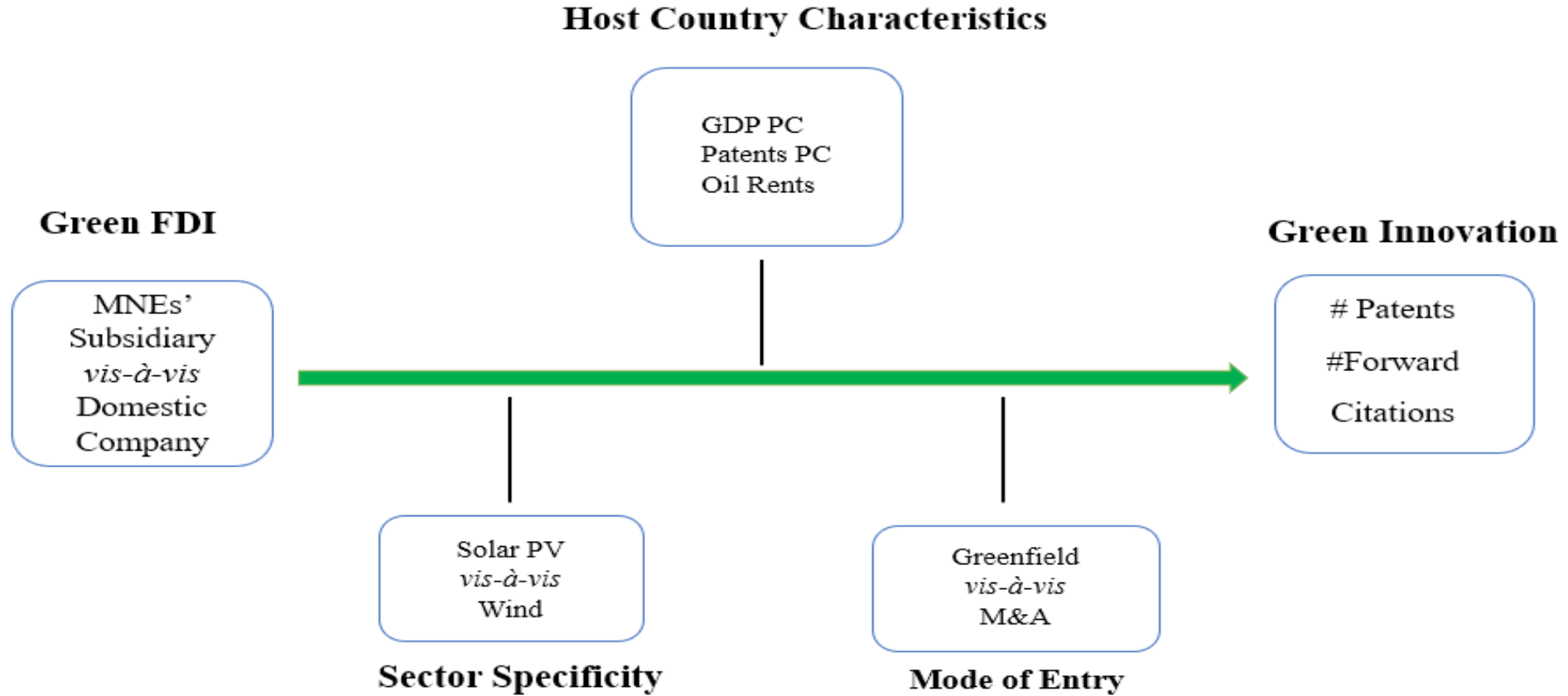


BACKGROUND LITERATURE



- **Knowledge transfer in the MNE-subsidary relationship** is widely investigated but there is limited evidence on green technologies.
 - **Noailly and Ryfisch (2015)** investigate the internationalization of green R&D by studying the patenting activity of 1,200 MNEs and finding that around 18% of the patents are developed by their affiliates.
 - **De Marchi et al (2022)** based on CIS in 14 European countries suggest that subsidiaries have an advantage of foreignness in green innovation with respect to domestic firms.
 - **Castellani et al. (2022)** show that greenfield FDI in Europe contribute to regional specialization in environmental technologies, especially in industries with previous capabilities in specific green technologies.

OUR CONCEPTUAL FRAMEWORK



RESEARCH QUESTIONS



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

- Whether and how the degree of knowledge transfer and innovative capability development in subsidiaries depends on
 - **the host country characteristics?**
 - **the specific technology?**
 - **the mode of entry chosen by the MNE?**



DATASET



- **Green FDI**s are investments undertaken by MNEs with at least one patent in **renewable energy technologies** (subset of Y20E: **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.
- # GREEN FDI's 1,055 (73% GREENFIELD INVESTEMENTS and 27% M&As)
- 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**
- **Counter sample:** 6,276 DOMESTIC COMPANIES (in the same sectors/countries of the subsidiaries)
- Period of the analysis: 2003-2015

METHODOLOGY



- **Negative binomial model** (Piperopoulos et. al., 2018)
- **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
- **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
- **Subsamples**
 - **Wind & Solar** (vs. domestic companies)
 - **Greenfield investments & M&As** (vs. domestic companies)

RESULTS: Full sample

| | 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 | -0.859*** | -0.049 | 0.188 | 0.377 | 0.705*** | 0.552** | 1.167*** | 1.154*** | 1.202*** | 1.510*** | 2.115*** | 2.187*** |
| 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*** |
| 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 |
| 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*** |
| BIG_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** |
| 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** |
| 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*** |
| 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 |
| INDUSTRY F.E. | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| DEAL YEAR F.E. | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| # Obs. | 7331 | 7331 | 7331 | 7331 | 7331 | 7331 | 7331 | 7331 | 7331 | 7331 | 7331 | 7331 |

RESULTS - FULL SAMPLE



- Subsidiaries **outperform comparable domestic companies** with respect to # of green patents & # of forward citations.
→ **Subsidiaries have a green innovation advantage with respect to domestic companies**
- **Pre-deal knowledge base** (# of patents up to one year before the investment) is **negatively and significantly** related to the **post-deal green** innovative performance.
→ Barbieri et al. (2020) and Orsatti et al. (2020) show that the larger the accumulated patenting experience, the lower the probability to creatively recombine ex-ante knowledge in green patents.

RESULTS: 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 - 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.**

RESULTS: 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*** |

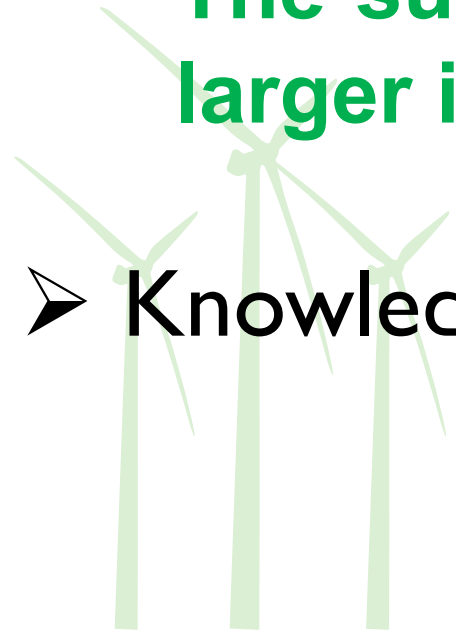
Solar

| | 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*** |

RESULTS: SECTOR SPECIFICITY



- **Wind** subsidiaries outperform domestic companies in both outputs;
 - **Solar** subsidiaries outperform domestic companies only in forward citations;
 - **The subsidiaries' advantage in terms of patent quality is larger in wind than in solar PV.**
- Knowledge is more tacit in wind and more codified in solar!



RESULTS: 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*** |

RESULTS: 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.
 - **The gap between subsidiaries and domestic companies in terms of innovative capability is larger in case of acquisitions than in greenfield investments.**
 - Greenfield subsidiaries rely mostly on foreign investors' knowledge;
 - Acquired companies combine parent's knowledge with an easier access to local knowledge.

KEY TAKEAWAYS



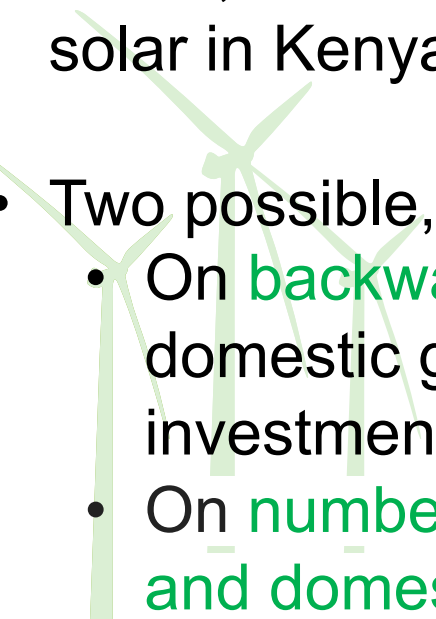
1. Subsidiaries of green MNEs are more innovative than domestic firms with similar characteristics.
2. This green innovative advantage is larger in less developed countries (and in those that are less reliant on oil rents), in particular if they already possess higher levels of relevant domestic innovative activity, as exemplified by the cases of China and India.
3. 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

- Countries can **attract green FDI** to enhance their green innovative capacities.
- Policies attracting green FDI should go hand in hand with measures **encouraging knowledge spillovers from MNE subsidiaries to domestic companies**, such as policies including local content requirements and training of the local workforce.
- Green technology transfer should take a more central role in the WTO around the TRIMS agreement, accounting for the public goods nature of green technologies, to support their global diffusion through FDI.
- International organizations, such as the UNFCCC, should direct **more attention to FDI as a key channel for green technology transfer**.



We don't measure knowledge spillovers in the host economies!

- Numerous studies have shown that, although the extent of spillover may vary, it is likely that some degree of spillover will inevitably occur due to various mechanisms.
 - Case-study research shows that knowledge spillovers from green FDI take place across various RE technologies and developing countries (e.g. Hansen and Ockwell, 2014 on biomass power technologies in Malaysia and Hansen and Hansen, 2020 on China; Lema et al., 2018; Baker and Sovacool, 2017; Davy et al., 2021 on wind and solar in Kenya and South Africa).
 - Two possible, complementary, analyses:
 - On **backward citations of green patents in the host economies**, exploring whether domestic green patents are more likely to cite investors' patents after the investments (see Branstetter, 2006);
 - On **number and quality of green technologies co-patented by MNEs subsidiaries and domestic companies** (see de Araújo et al., 2019).
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Thank You!



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VARIABLES

■ DATABASES

- ORBIS → firm-level dataset
- PATSTAT → patent-level data
- WORLD BANK, UNCTAD, OECD → country-level data

MODERATING FACTORS

- Host country-specific characteristics: GDP per capita, # of patents registered in the country per capita, and oil rents (%GDP)

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

