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

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September 2020

*Abstract*

There is mounting agreement that the global economy is at the nascent stage of a green transformation. In response, global lead firms are seeking to enhance their capabilities for sustainable innovation and many have begun to globalise their green efforts. But to what extent and how (if at all) do green foreign direct investments contribute to the deepening of such sustainability capabilities? In this article, we find that the answer to this question is threefold. First, green foreign direct investments enhance the overall sustainability orientation of multinationals. Not only do they have a greening effect on the overall technology base, they also have a specialisation effect so that multinationals increase their specialisation in specific green technologies. Second, green foreign direct investments have a significant positive impact on the degree and quality of multinationals' innovative capacity in sustainability-oriented technology fields. This means that multi-technology corporations tend to stretch their innovation capabilities in a more sustainability-oriented direction overall, while at the same time deepening their innovation capabilities around specific green technologies. Third, the mode of the globalisation process matters: in the long run, green foreign direct investments in the form of newly established subsidiaries contribute more to innovativeness and greening than do acquisitions of foreign firms. These findings have important implications for policies to enhance sustainability transitions.

**Keywords:** Foreign Direct Investments, Global Connectedness, Green Innovation, Multinational Enterprises, Renewable Energy, Sustainability Transitions

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## 1 Introduction

It is well established that multinational enterprises (MNEs) transfer technologies and knowledge from their headquarters to foreign affiliates across the globe (Dunning, 2001; Rugman and Verbeke, 2001) and a wealth of research has shown that, depending on conditions such as policies and domestic absorptive capacities, host economies may benefit from significant knowledge spillovers from foreign direct investments (FDI) (Blomstrom and Kokko, 1998). With a focus on green sectors, MNEs contribute to sustainability transitions as sustainability-relevant knowledge is transferred internationally through foreign direct investments (Glachant and Dechezleprêtre, 2017; Golub et al., 2011; Sarkodie and Strezov, 2019).

In this paper we do not examine knowledge diffusion from home economies and headquarters to host economies and subsidiaries; on the contrary we focus on the reverse causality, investigating how green foreign direct investment (GFDI), identified as those undertaken by firms with some degree of green innovative activity, affect MNEs' sustainability-oriented innovative capacity. Our empirical analysis is concentrated on GFDI in renewable energies (GFDI). [4] These comprise only a subset of sustainability-relevant technologies, but a crucial one given the specific urgency of addressing dangerous climate change in the context of human induced transgression of planetary boundaries (Rockström et al., 2009). Energy production accounts for 72% of all greenhouse gas emissions (WRI, 2020). Therefore, tackling the negative environmental effects of the global energy system has never been more pressing. Accelerating the process of innovation to make renewable energy technologies efficient, affordable, secure and available for all, bringing a much broader range of new technologies and solutions to market as soon as possible is indeed a priority for public and private actors (Stern, 2007). The potential of multinational enterprises in being not only part of the environmental problem but also of the solution is gradually acknowledged in policy, but it is surprisingly absent in academic research, in particular in the field of international business (Kolk and van Tulder, 2010). So, in this article we plan to

[4] We follow Glachant and Dechezleprêtre (2017) and consider investors in green technology fields with at least one patent in renewable energy technologies.

contribute filling this knowledge gap, by addressing the following main research question: *To what extent and how (if at all) do GFDIs contribute to the deepening of sustainability-oriented innovative capacity in multinational enterprises?* We use the term 'deepening' deliberately because, as already clarified, we concentrate our analysis on firms which already have some experience in green innovative activity. This issue is important for policy and practice because sustainability-oriented MNEs – both environmental pure-players (e.g. lead firms specialised in renewable energy industries) and multi-technology conglomerates (Granstrand, 2004) with green business lines – have the potential to play a crucial role in sustainability transitions (Ansah and Sorooshian, 2019; Hart, 2013).

Through cross-country empirical analysis, we seek answers to three sets of subsidiary questions:

- *The greening and specialisation effect:* To what extent and how do GFDIs affect the sustainability-orientation of MNE knowledge bases? Do they drive an expansion of the variety of green technologies or a specialisation in distinct sustainability-related technology domains?
- *Green innovativeness*: How do GFDIs influence MNEs sustainability-oriented innovation capability? What does it mean for the quantity and quality of green innovations?
- *FDI entry mode:* Does it matter whether REFDIs take the form of newly established subsidiaries or of acquisitions of existing firms in the host economy? Do acquisitions of existing green firms or do greenfield investments provide a more effective route to the greening of MNEs?

To address these questions, the paper is structured as follows. In the next section, we review the relevant literature about how the enterprise-level, investment-driven globalisation process influences the innovative capacity of green lead firms. Given that there is only scant knowledge about this issue, we seek insights from (a) the literature on sustainability transition, specifically the subset of papers which addresses the role of multinational enterprises, (b) the international business literature which examines the contributions of MNEs to sustainable development and (c) the literature which investigates green FDI explicitly. On this basis, we carve out the specific knowledge gaps addressed in this paper.

Then *Section 3* describes the sources of data and explain the methods of our analysis. There is no established framework or methodology to examine the 'reverse' innovation and greening effect of GFDIs and therefore we elaborate our research steps in some detail. We draw on foreign direct investment and patent data from 1997 and 2013 and study statistically the differential effect on innovation in firms that made green FDIs as compared similar firms that did not undertake foreign investments. To address the first set of research questions about the greening effect we investigate the specialization and variety of the green patents filed after the overseas green investments. To study green innovativeness, we examine the quantity and quality of the green patents filed after the green foreign investment by the multinational enterprise. As for the third question, we test separately for the different impact of greenfield investments and cross-border acquisitions.

The findings of our empirical analysis are presented in *Section 4*. GFDIs generate a greening effect (i.e. an increase of the share of green patents in investors' patent portfolios) and have a positive impact on innovation (as measured by patenting activity) in the first five years after the investment. Furthermore, the effects of greenfield GFDIs become larger and larger year by year while cross-border acquisitions only have short-term effects on innovativeness and on the specialisation across renewable energy technologies.

Finally, *Section 5* outlines the main findings, laying out the contributions to the literature, discussing the policy implications and outlining areas for further research.

## 2 The literature

In recent years there has been a surge in the literature on concepts such as 'sustainability transitions' (Geels, 2011; Markard et al., 2012), 'green transformations' (Han et al., 2020; Schmitz, 2015) and more broadly on 'decarbonization' of energy systems and economies (Loftus et al., 2015; Rockström et al., 2017). In their effort to understand advances and setbacks towards environmentally sustainable transformation of economic systems, a striking feature of this literature is the absence of focus on the role of firms, and in particular of multinational enterprises. This is despite a general acknowledgement that knowledge at firm-level will contribute at system-level change (Smink et al., 2015) and the recognition in both policy and academic circles that dynamics related to the environmental behaviour of large private firms are crucial for the transition to a green economy (Hanni et al., 2011).

In this paper, the entry-point into the wider debate on sustainability is the role that multinational enterprises in the field of renewable energies can play through the deepening of their sustainability-relevant innovation capabilities. This is pertinent because the ability to develop innovation capabilities which can advance green technologies is key to the green transformation. In the next phase of the energy transition (Markard, 2018), innovation activities are fundamentals and should be centred on improvements in both core technologies (solar PV panels, wind turbines etc) and adjacent functions (distribution, transmission, storage), being dependent on changing landscape developments such as increased technology maturation (Nature Energy, 2017), accelerated deployment (WRI, 2020) and emergence of new complementary technologies such as batteries and smart grids (Kolokotsa et al., 2019).

At the broad level, the knowledge gap we address is whether and how the globalisation of firms, through GFDIs, affects the deepening of their green innovative capabilities. To specify the research gap(s) further, we seek insights from the literature on green FDIs and innovation. This literature comprises both the international business literature which, rather surprisingly, has only seen a moderate interest in energy and climate change (Kolk et al., 2017) as well as the climate and sustainability literature dealing with the role of private sector innovation (Dechezleprêtre et al., 2011).

## 2.1 Global connectedness and green dynamic capabilities

Our starting point is the global connectedness hypothesis advanced in a recent article by Maksimov et al. (2019). The main proposition is that 'global connectedness' (Turkina and Van Assche, 2018) helps MNEs to cultivate the dynamic capabilities (Teece, 2014) needed to improve environmental sustainability. According to Maksimov et al. (2019), ‘dynamic green capabilities' are accumulated in MNEs because connectedness provides direct access to relevant green knowledge pools in the global economy and it strengthens routines for integrating new green knowledge in the firm. Compared to 'non-globalised' firms, '*MNEs* *are in a better position to be proactive rather than cautious in environmental sustainability and should be able to make the transition from ''avoiding harm'' to ''doing good'' more easily than other firms*' (Maksimov et al., 2019). In this paper, we explore the notion that MNEs are in a better position than other firms to go green by advancing sustainable technologies.

Aguilera-Caracuel et al. (2012) put forth a very similar thesis in an effort to understand whether international experience helps firms to be green. They draw on a knowledge-based approach in the effort to understand how international experience (i.e. exports) and organisational learning capability influence proactive environmental strategies. Interestingly, they find that exporting in itself does not create a greener profile of the firm. However, a more focused practise of environmental diversification internationally is positively related to a proactive environmental strategy in the firm and, anticipating Maksimov et al. (2019), the positive relationship between international environmental diversification and environmental proactivity is moderated by organisational learning capabilities (Aguilera-Caracuel et al., 2012). Chiarvesio et al. (2015) confirm that exporting does not support green innovation; nevertheless, being foreign subsidiary or undertaking FDI do have positive effects. In other words, the knowledge acquired by firms, being part of (diversified) international groups, augments their environmental strategies, particularly in presence of strong organizational capabilities.

In this respect, MNEs sustainability profile is important and can be significantly shaped by the extent of environmental innovation. Firms differ on the basis of their *green intensity*, which is the relative 'degree' of greenness, in other words the strength of their sustainability focus, for operational purposes defined as the ratio of green innovation efforts in renewable energies to overall innovation endeavours in the enterprise.

In this paper, we include in the empirical analysis two types of green multinationals which are distributed along an analytical continuum. At the one extreme, there are *multi-technology corporations* whose main innovation (and commercial) focus is not exclusively on green technologies but who do also undertake some sustainability-oriented innovation activities. In terms of their contribution to address the challenges of the green transformation and given their overall significant innovation capacity[5], what matters for multi-technology corporations is more likely to be the degree to which they move along the greenness dimension through FDI to improve their sustainability profile ('going greener'). These multi-technology corporations (Granstrand et al., 1997; Patel and Pavitt, 1997) may be able to integrate and leverage different knowledge domains from distinct application areas (Lema, 2010; Teece, 2014) for green advancement, for example by utilising cross-subsidiary linkages in order to enrich sustainability-oriented technologies (Maksimov et al., 2019).

At the other end of the continuum, there are *green pure players* which are specialised firms having green technologies as their main focus (Santaló and Becerra, 2006). For pure players, given their dominant green profile, the key issue is whether they deepen their innovation capacity as they increase their global connectedness: they may either diversify their efforts across several green technologies or they may focus on some specific technologies, in other words they may differ in terms of *green specialisation*. Their type of greenness can range from highly specialised to highly diversified and can be defined as the scope of green technologies which are subject to innovation efforts in the firm. A common way to devise such connectedness is to locate affiliates abroad, often in specialised clusters with cumulatively developed knowledge stocks. They establish their subsidiaries or make their acquisitions with strategic intent to enter in green local ecosystems, developing local connections to key sustainability-relevant firms as well as other stakeholders (Kolk et al., 2017; Turkina and Van Assche, 2018).

In this paper, we test the effect of RE FDI on *green intensity*, *green specialization* and *green innovativeness*, but before doing that we first seek further insights from the literature regarding the possible effects of FDI on these types of greening. To do so, it is also necessary to go beyond the specific, and rather limited, literature on green MNEs, examining the general international business literature.

[5] Based on the EU R&D Industrial R&D Investment Scoreboard, among the *multi-technology* corporations included in our sample, there are many companies included in the list of the R&D global spenders, such as Siemens, General Electric, Panasonic and LG (accessed April 22nd 2020).

## 2.2 FDI and the knowledge base of the firm: a greening effect?

To our knowledge, there is not a literature which examines specifically whether and how FDIs affect the sustainability-orientation of MNE knowledge bases. Maksimov et al. (2019) examine how global connectedness can help MNEs becoming more environmentally sustainable by focusing on the international spread of MNE sales (also considering sales from overseas subsidiaries), but they do not focus on FDI.

In pondering the possible greening effect of FDI we are informed by the MNE literature which examines how FDI impacts on the knowledge base of firms, in particular with respect to technological specialisation versus diversification. The key insight is that FDI is positively associated with increased diversification of MNE knowledge bases. For example, in a longitudinal study, Cantwell and Piscitello (2000) find that FDI and technological diversification are significantly correlated and that the positive effect on diversification increases over time, i.e. from 1900 and up until the turn of the millennium. They attribute this effect to access to new-to-firm knowledge domains through the establishment of R&D foreign subsidiaries and to the fact that undertaking R&D abroad may release resources at home to engage in new areas of research. Echoing the connectedness hypothesis, they argue that diversification is achieved thanks to the formation of internationally integrated networks operating within MNEs and achieving competitiveness through asset creation and acquisitions in specialised locations. Hence, this is consistent with the idea that MNEs may build dynamic green capability by tapping into clusters specialised in environmental technologies. A study by Blomkvist et al. (2014) also confirms these findings adding that internationalisation through FDI only increases knowledge base diversification through acquisitions of foreign firms, whereas newly established subsidiaries do not have the same effect. Having in mind these findings, in our empirical analysis, we investigate if they do hold in the specific context of green FDIs and their impact on green innovative capabilities.

Overall, we would expect that green FDI will increase the overall greening of MNE profiles, enhancing the propensity to engage in new and emerging, environmentally friendly technologies, thereby by concentrating a larger share of green content in the knowledge base as opposed to non-green content. This is because of the overall 'green race' in the global economy, which has been shown to be occurring across countries and sectors, and which implies that green competitiveness is key to success in international markets (Fankhauser et al., 2013). Moreover, the literature would suggest that green FDI will enhance the diversification of the green knowledge base itself. In other words, we could expect that green FDI will increase the propensity to engage in a larger variety of green technologies thereby diversifying the green knowledge base itself. In general, MNEs are more involved in international co-innovation than domestic firms and they may be better able to diversify their green knowledge base than are firms which do not engage in FDI. This notion is supported by Zhou et al. (2016) who found that green pure players (in the wind energy sector) have more diverse knowledge bases when their innovation process is strongly based on international networks, as it happens to European and some Indian MNEs as compared to less networked firms such as Chinese firms.

### 2.3 Green innovativeness

From the international business literature, we know that internationalisation of firms is positively associated with innovativeness in general (Cassiman and Golovko, 2018; Castellani and Zanfei, 2007; Siedschlag and Zhang, 2015). Maksimoiv et al (2019) extends the 'connectedness thesis' to 'green innovativeness', which is measured by as whether or not a firm has policy on emission reduction, natural resource reduction and environmental product innovation. In this study we are able to push this thesis further by examining the quantity and quality of green patenting in MNEs. By doing so, we are able to draw on the general literature which examines the relationship between the FDI mode(s) of internationalisation on the one hand and innovativeness on the other (Cantwell, 2017). It is clear from this literature that the innovativeness effect is mediated by the type of international investments, in particular whether investments are focused on overseas production or on research and development (Penner-Hahn and Shaver, 2005). In a study on the energy industry, covering both 'black' and 'green' energy, Hurtado-Torres et al (2018) find that overseas R&D investments increase MNE's innovative output, in particular if they are geographically distributed. Echoing the connectedness thesis, this finding suggests that overseas R&D

investments enhance MNEs' capacity of technological learning as well as their benefits from R&D externalities.

There are indications that similar patterns may exist in the specific case of green innovation. For example, Noailly & Ryfisch (2015), in line with the connectedness hypothesis, find that a large share of green patents produced worldwide is the output of MNEs' cross-border R&D activities, which allow them to exploit both the demand advantages originated from stricter environmental regulation in lead-markets as well as the acquisition of specific foreign capabilities in green technologies. A number of studies indicates that internationalisation increases the propensity of firms to introduce products or processes that reduce environmental impact. This conclusion is also derived by Chiarvesio et al. (2015) in a study on Italian firms specializing in medium- and low-tech industries. They find that subsidiaries which are part of a multinational enterprise have a greater propensity to implement green innovations because they can tap into global flows of knowledge.

Aguilera Caracuel et al. (2016) find that SMEs with higher degrees of internationalisation acquire more effectively innovation capabilities and that they pay special attention to the development of a proactive environmental strategy. Similarly, Melane-Lavado et al. (2018) compare SMEs with and without FDI and find that the former are more innovative overall but also focus more their innovative process on sustainability-relevant domains of knowledge.

In this study, we enhance the existing literature examining whether this conclusion can also be derived in the case of green FDIs. We would therefore expect that green FDI will increase green innovativeness (Chiarvesio et al., 2015; Melane-Lavado et al., 2018; Noailly and Ryfisch, 2015), measured as both the quantity of green patents and their technological value proxied by forward citations (Giuliani et al., 2016; Stiebale, 2016).

### 2.4 The FDI mode of entry

As mentioned, research on the 'global connectedness' thesis has so far mainly examined exporting as the mode of entry into foreign markets (Aguilera-Caracuel et al., 2012; Maksimov et al., 2019). Instead, it has scarcely focused on foreign direct investment as an expansion strategy for multinationals and how that relates to innovativeness and greening (Chiarvesio et al., 2015). However, the international business literature has a long tradition of research seeking to understand the effectiveness of foreign direct investments as a mode of entry and making the key distinction between acquisition of foreign firms and greenfield establishment of foreign subsidiaries (Buckley and Casson, 2009; Meyer, 2001). A subset of this literature has sought to examine the relationship between the FDI mode of entry and innovativeness in MNEs ( Blomkvist et al., 2014; Stiebale, 2013; Zander, 1999).

Two main conclusions emerge from this literature. First, the literature shows that the impact of overall innovativeness on internationalisation is augmented if it takes place through acquisitions (Blomkvist et al., 2014). Foreign subsidiaries account for a large share of the new technologies introduced in the MNEs, particularly when they are set up by cross-border acquisitions (Zander, 1999). The effects are established for both output variables (patents and product innovations) as well as for input variables (measurable innovation efforts) and are stronger in high-tech industries (Stiebale, 2013).

Second, the literature on international business has highlighted that foreign subsidiaries, both greenfield investments and acquisitions, contribute to overall innovativeness in MNE networks, but there is still a gap when it comes to understand whether subsidiaries are able to contribute over longer time periods to the strategic renewal of the MNE. In this respect, and with reference to greenfield establishments, Blomkvist et al (2010) highlight the importance of 'superstar subsidiaries' which stand out from the network and provide a long term contribution to innovativeness. Similarly, Hansen et al. (2020) show that technological capabilities generally increase over time in greenfield subsidiaries, but strategic renewal - the development of sustained competitiveness in new technology fields - is limited to selected subsidiaries in the network.

Both observations lead to the expectation that acquisitions of existing foreign firms and their integration into the MNE network are effective in the short run, enabling rapid diversification into new green technology fields as compared to new foreign venture creation. Depending on absorptive capacities (Amendolagine et al. 2018; Cohen & Levinthal, 1990), integration in existing centres of excellences in environmental technologies may provide a fast-track to cooperate in green innovation, to acquire new green technology expertise as well as to create synergies with existing technologies for strategic renewal in the green economy. Greenfield investments, on the other hand, may benefit green innovativeness over longer time periods but the real impact on greening trajectories may be only confined to a few green subsidiaries. Testing these expectations empirically shed new light on the global connectedness thesis by verifying which particular modes of investments may be more effective for green deepening and specialisation in MNEs.

# 3 Data and methodology

## 3.1 The dataset

The empirical analysis is focused on green foreign direct investments in renewable energies, whose identification requires some caution because there could be relevant investments in industries, which are not normally identified as renewable energy industries, such as 'Production and Electricity'. To overcome identification problems, we have followed the approach adopted by Glachant and Dechezleprêtre (2017) who define the volume of climate-change related FDIs considering all foreign subsidiaries hold by companies with at least one climate change-related technology patent.

In this study, we match Orbis and PATSTAT databases to identify firms with at least one patent in a sub-set of the technological category denominated *Technologies or applications for mitigation or adaptation against climate change,* available in the European Patent Office (EPO) classification. In particular, we consider the Y02E subgroup, including *Climate change mitigation technologies in energy generation, transmission and distribution* and focus on two main areas: *Energy generation through renewable energy sources* and *Technologies for the production of fuel of non-fossil origin*. In other words, we undertake our empirical analysis on wind, solar, geothermal, marine energy, hydropower, biomass and fuel from waste.[6]

[6] Y02E code covers energy sources that are alternatives to fossil fuels. It also covers technologies for using sustainable fossil fuels for energy generation, as well as more efficient transmission and distribution technologies, and enabling technologies for alternative energy sources. There are seven main technical areas, divided into over 200 sub-categories. We consider two of these areas and include the following IPC (International Patent Classification) codes: geothermal energy (Y02E10/1), hydro energy (Y02E10/2), marine

To avoid possible double counting, we use DOCDB families.[7] Figure 1 represents the geography of innovation in renewable energy technologies worldwide between 1970 and 2018, showing a strong concentration of RE patents in developed countries (US and EU) and some emerging economies, such as Brazil, China, Russia, South Africa, Turkey. 91% of patents are originated in high income countries and USA (7.7%), South Korea (7.6%), Germany (6.5%) and China (5.4%) are the top 4 patenting countries. Table A.1 (in Appendix A) provides some additional information about the geographical distribution of RE patents in the different energies.

Table 1 reports a disaggregation of RE patents by type of first applicants, pointing to the relevance of firms in general and multinationals in particular, in each technology. Overall, firms are the main applicants (54%), followed by individuals (29.8%). Multinationals represent 11.4% of all RE applicants with larger shares in solar PV (19.5%), wind (15.4%) and hydro (13.9%) technologies. Furthermore, we can also notice that RE patents applied by MNEs are more concentrated across some technologies: around 80% are in solar (PV, thermal and hybrid) and wind technologies.

Among all the firms with at least one patent in renewable energy technologies identified in PATSTAT, we focus our empirical analysis on multinationals, i.e. firms with at least one foreign subsidiary, as reported by ORBIS. To account for the different possible mode of entry, in ZEPHYR, a companion database of ORBIS, we also identify foreign subsidiaries established through a cross-border acquisition. Consequently, all the remaining foreign subsidiaries are considered as greenfield investments (Stiebale,2013). As common in the literature about foreign investments and innovation(Guadalupe et al., 2012; Stiebale, 2016, 2013), we include in our sample only investments with at least 50% ownership. Furthermore, we undertake a number of manual checks to strengthen the robustness of our sample. First, we carry out a textual search on the description of the foreign subsidiaries' business activity to check

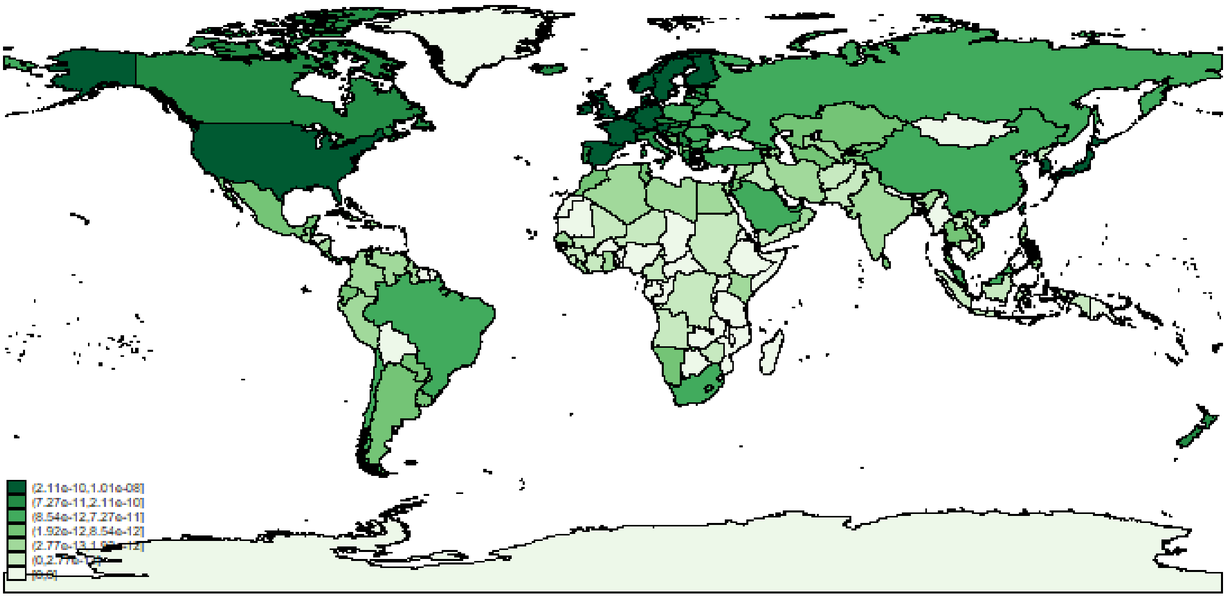
energy (Y02E10/3), solar thermal energy (Y02E10/4), solar photovoltaic energy (Y02E10/5), solar thermal-PV hybrid ((Y02E10/6), wind energy (Y02E10/7), biofuels (Y02E50/1), fuel from waste (Y02E50/3). More information is available at https://www.epo.org/news-issues/issues/classification/classification.html (accessed 8 January 2020).

[7] DOCDB is the EPO's master documentation database with worldwide coverage (more than 100 patent offices). We only consider patents filed from 1970 onwards given that we include investments since 1997.

whether they are actually in the field of production and/or distribution of renewable energies.[8] Second, we clean the dataset from investments in tax havens[9], less likely to be related with technology seeking purposes. The final dataset includes 1217 foreign direct investments specialised in biofuel, geothermal, hydro, marine, solar, waste fuel and wind.

**Figure 1. Geography of innovation in renewable energies**

**(# of RE patents scaled by population size, in millions, 1970-2018)**




Authors' elaborations

**Table 1. Applicants of RE patents (# and %) (1970-2018)**

| First applicant | Firms # (%) | MNEs (#) | MNEs % over total | MNEs % over firms | Individuals # (%) | Universities # (%) | Others # (%) | Total # (%) |
|---|---|---|---|---|---|---|---|---|
| Biofuel | 12468 (50.1) | 629 | 2.5 | 5.0 | 6440 (25.9) | 3293 (13.2) | 2690 (10.8) | 24891 (100) |
| Geothermal | 2642 (52.1) | 105 | 2.1 | 4.0 | 1813 (35.8) | 271 (5.3) | 344 (6.8) | 5070 (100) |
| Hydro | 16225 (42.2) | 5347 | 13.9 | 33.0 | 16603 (43.1) | 1717 (4.5) | 3932 (10.2) | 38477 (100) |
| Marine | 2240 (24.2) | 1 | 0.0 | 0.0 | 4686 (50.6) | 1401 (15.1) | 935 (10.1) | 9262 (100) |
| Solar hybrid | 480 (42.8) | 2 | 0.2 | 0.4 | 339 (30.2) | 173 (15.4) | 129 (11.5) | 1121 (100) |
| Solar PV | 78133 (72.6) | 20942 | 19.5 | 26.8 | 12055 (11.2) | 10242 (9.5) | 7143 (6.6) | 107573 (100) |
| Solar thermal | 33699 (45.2) | 898 | 1.2 | 2.7 | 30659 (41.1) | 4318 (5.8) | 5878 (7.9) | 74554 (100) |
| Waste fuel | 11790 (53.4) | 1933 | 8.7 | 16.4 | 5976 (27.0) | 2118 (9.6) | 2211 (10.0) | 22095 (100) |

[8] The key words used are: "wind", "solar", "PV", "photovoltaic", "biofuel", "waste", "marine energy", "marine power", "hydro energy", "hydro power", "geothermal", "renewable", "non-fossil", "non-fossil", "biodiesel", "biogas", "biomass".

[9] Based on the OECD list of tax havens available at: http://www.oecd.org/countries/monaco/jurisdictions-committed-to-improving-transparency-and-establishing-effective-exchange-of-information-in-tax-matters.htm (accessed on January 7 2020).

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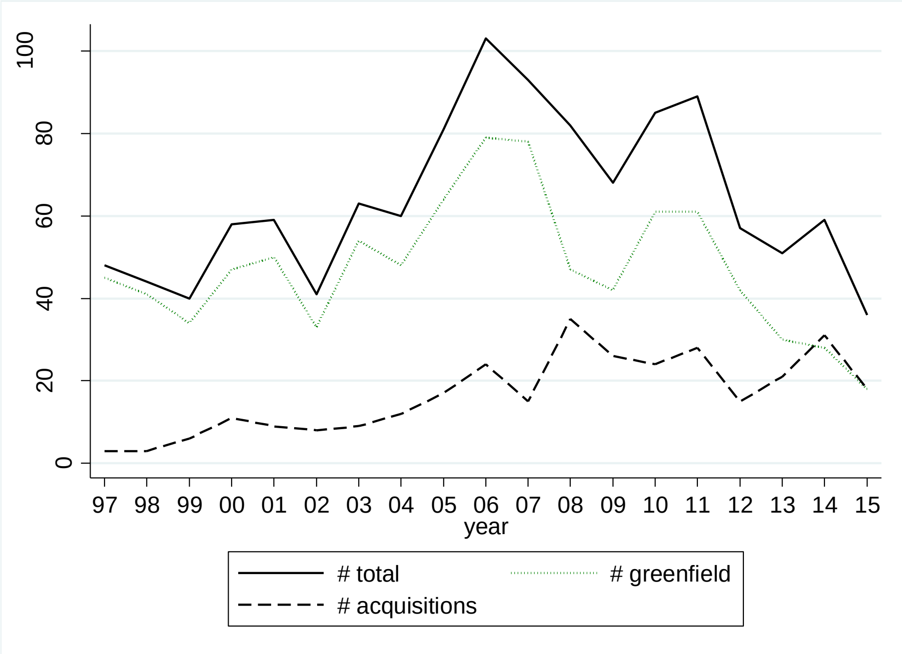
|---|---|---|---|---|---|---|---|---|
| Wind | 27221 (46.1) | 9094 | 15.4 | 33.4 | 23413 (39.7) | 4326 (7.3) | 4055 (6.9) | 59015 (100) |
| Total | 184898 (54.0) | 38951 | 11.4 | 21.1 | 101984 (29.8) | 27859 (8.1) | 27317 (8.0) | 342058 (100) |

Authors' elaborations

Fig. 2 shows the trend of RE FDIs from 1997 to 2015, indicating an upward trend up to 2011, when they start decreasing. It should also be noted that acquisitions have increased all along the period, overcoming greenfield investments in 2014. Table A.2 and A.3 presents evidence about home and host countries. The main home countries are Germany (18%), USA (14%), Japan (10%) and Denmark (10%) and the four top host countries are the UK (175 deals), China and Germany (101 deals) and USA (87 deals).

Table 2 offers information about the investors' green intensity, measured in terms of the share of RE patents in the patent portfolio. *Multi-technology corporations* are those in which green patents are equal or less than 50% in the patent portfolio. In our sample, they represent the large majority of investors and investments. In *Pure green players* more than 50% of the patents are in the Y02E subgroup, identified above as renewable energies related. In terms of investments, they represent almost one fourth of the total. Table 3 shows the main technological specialization of investors, defined as the RE technology in which each multinational has the largest number of patents, and shows that the largest share of investments is in wind (33%), solar photovoltaic technologies (31%) and solar thermal technologies (16%). Among acquisitions, investments in solar photovoltaic (30%) exceed those in wind technologies (28%).

## Figure 2. Number of RE FDIs (1997-2015)




Authors' elaborations

## Table 2 – Investors' green intensity (# and%)

| | Firms (# & %) | RE FDI (# & %) | 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

## Table 3. RE FDIs distribution across investors' technological specialization (# and%)

| Main technological specialization | # RE FDI | # 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.

## 3.2 Methodology

In order to investigate the causal effects of RE FDIs on investors' innovative performance, we consider four different outputs calculated for up to five years after the investment:

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

The *Greening effect* is measured by two outputs:

- *Green Intensity* calculated as the share of RE patents in the total investors' patent portfolios in a given year;
- *Green Specialization* estimated by Herfindhal index equals to zero when a firm applies for green patents only in one single technology and becoming close to one when a firm applies for patents in many different renewable energy technologies (Quintana-García and Benavides-Velasco, 2008).

*Green Innovativeness* is also estimated by two variables:

- *Green Patents* calculated as the number of RE patents applied by investors in a given year (Amendolagine et al., 2018; Stiebale, 2016);
- *Forward Citations*, an indicator for patent value, measured as the number of forward citations to the RE patents applied by the investors in a given year (Gambardella et al., 2008; Giuliani et al., 2016).

The estimation of the FDI impact on the investors is affected by possible endogeneity and reverse causality. There is a problem of self-selection because larger, more efficient and more innovative firms are more likely to undertake FDIs (Helpman et al., 2004). In other words, the green patenting activity of MNEs with respect to firms without foreign investments might be independent on their decision to undertake such investments. In order to address this potential selection bias, the FDI causal effects is tested with a propensity score matching estimation combined with difference in differences estimators (Cozza et al., 2015; Debaere et al., 2010; Stiebale, 2016, 2013; Stiebale and Trax, 2011). Accordingly, we build a counterfactual sample of companies without foreign investments but with similar *ex-ante* probabilities to undertake FDIs. The probability to undertake FDIs is estimated with a logit model that yields the propensity scores used to match investors and non-investors, based on several firm characteristics, including controls for innovation activity before the investment, such as the level of overall green innovativeness, green intensity and green specialization. The results of the logit model are presented in Appendix B.

With a sample including both investors and non-investors selected by propensity score matching, we estimate the causal impact of RE FDIs on the investors' patenting activity, also by introducing the distinction between cross-border acquisitions and greenfield investments, with the following equation:

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

where $\delta_x$, $\vartheta_t$, $\varepsilon_{i,t}$, and are fixed effects for the investors' industry, home country and year of investment.

## 4 Green foreign direct investments, the greening effect and green innovativeness

The empirical analysis addresses three sets of research questions: first we investigate whether and how overseas green investments impact on the specialization and the variety of the green patents; second, we examine the quantity and quality of the green patents filed by the multinational enterprises after the green foreign investments and third, we test for the different impact of greenfield investments and cross-border acquisitions.

Table 4 shows the results of propensity score matching difference-in-difference (DiD). The DiD allows to compare changes in the average outcomes for the two groups of firms – investors and non-investors - during a time period going from the year of the investment (t=0) up to five years (t= 1, 2,...,5) after. It presents the effects of investments on the *Greening effect*, measured by *Green Intensity* and *Green Specialization* and on *Green innovativeness* measured by *Green Patents* and *Forward Citations*. All the outputs tested show a significant positive coefficient meaning that RE FDIs increase the likelihood of both the *Greening effect* and *Green innovativeness*, as discussed in what follows.

**Tab. 4. 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* | 0.1426 | 0.2590*** | 0.3352*** | 0.3040*** | 0.3264*** | 0.3479*** | 5589 |
| | (0.0869) | (0.0948) | (0.1171) | (0.1171) | (0.1238) | (0.1137) | |

Matching by kernel algorithm with common support. The outputs are equal to ln(1+Ys)-ln(1+Yt-1), where s=0,1,2,3,4,5. All regressions include fixed effects for investor's country, investor's 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.

## 4.1 Greening effect

In Table 4 the first two rows present the outputs used to measure the *Greening effect* - *Green Intensity* and *Green Specialization* - and the columns indicate how the impact of FDIs on these two indicators changes over time from t=0 up to t=5.

We find that RE foreign direct investments have a positive (and significant in year t= 1,2,3 and 5) impact on *Green Intensity*, which means that they increase the share of RE patents in the investors' total patent portfolio, in other words they increase the green innovation activity in multinationals. This is a major contribution to the literature about global connectedness because it indicates that undertaking green FDI, MNEs innovation activity becomes greener, therefore participating to advance sustainable technologies.

This result is even more relevant when we consider the prevalence in our sample of *multi-technology corporations* (Aguilera-Caracuel et al., 2012; Rezende et al., 2019). As seen in Table 2, in almost 80% of the investors the main innovation activity is not exclusively concentrated on green technologies and our finding indicates that undertaking green FDI makes their innovation capacity greener, enhancing their sustainability profile. This means that companies such as Siemens, General Electric, Panasonic, Samsung or LG, just to mention a few included in our sample, are becoming greener in their innovation activity when they undertake green FDIs. To use the terms adopted by Maksimov et al (2019), MNEs' starting points for 'going green' (changing their profile) and 'doing good' (investing in environmental innovations) may differ significantly. It is important to note that firms which have already a green profile (i.e. *pure green players*) enhance their green innovation capability by overseas engagement but it is really very good news for sustainability transition to find that *multi-technology corporations* do change their profiles moving towards a greener direction by undertaking REFDIs.

The second result about *Green Specialization* shows that green FDIs drive MNEs to focus their innovation activities on specific technological areas, and rather than expanding the variety of their green technological efforts, they are more likely to deepen their competencies in some specific green technologies. This contrasts to expectations based on the general existing evidence in the international business literature and indicate that green FDIs help MNEs to further develop specific innovative capabilities in the (few) technologies that are more likely to grow on a large scale, such as solar or wind, in which they already have accumulated the majority of their green patents (see Table 1). Previous empirical works on green innovation have emphasised that one of the key motivation for innovating is the need to adapt existing knowledge to consumers and regulations in foreign markets (Chiarvesio et al., 2015; Noailly and Ryfisch, 2015). Therefore, our finding about an increase in specialisation following green FDI points to innovation activity driven by the opportunity to exploit existing comparative advantages in terms of knowledge and experience aimed at expanding towards new markets and consumers (Hanni et al., 2011).

## 4.2 Green innovativeness

The two indicators at the bottom of Table 4 measure the quantity (*Green Patents*) and quality of innovative activity (*Forwards Citations*). As expected on the basis of the existing evidence (Chiarvesio et al., 2015; Melane-Lavado et al., 2018; Noailly and Ryfisch, 2015), we find a positive and increasing impact of REFDIs, meaning that the number of RE patents applied by investors significantly rises from the year of the investment up to five years after and besides, investors' patents are more and more cited, which can be considered as an indication of their growing technological importance. Therefore, green FDI are a significant determinant of green innovativeness, inducing more and more relevant innovation activities. This is important when we consider that our sample includes not only firms with established green profiles, the so called *green pure players*, but also - even to a larger extent - *multi-technology corporations*.

The learning process presented in Hansen et al. (2020) provides some qualitative support to explain the dynamics of these findings. In the case of a wind Danish company producing blades in India, they find that at the beginning the knowledge flows exclusively from the headquarter to the subsidiary but after some time and thanks to complementarities, the headquarters also starts to receive knowledge and the flows becomes bi-directional. This qualitative evidence could help in explaining the increasing effect found in the econometric analysis, confirming that it could take some time for the headquarters to absorb and assimilate the knowledge they can acquire through their investment activity. Furthermore, the positive effect of the overall value of green patents, proxied by the number of forward citations, suggests that green FDI are motivated by a genuine intent to invest in innovation rather than by a strategy aimed at acquiring intellectual property rights (Stiebale, 2016).

## 4.3 FDI mode of entry

Table 5 introduces the distinction by mode of entry and shows that for greenfield investments the findings are very similar to those described above for the outputs of the full sample. This does not hold instead for acquisitions because coefficients are significant only for one of the outputs: *Green Patents*. This coefficient is significant from the year of the investment to year 3 and both significance and magnitude decrease over time, meaning that the impact of green acquisitions on the number of green patents has short-term effects only. This result is in line with the expectation that acquisitions of existing firms are effective in the short run and represent an efficient way for rapidly entering into new green technology fields. In particular for multi-technology corporations, acquisitions of existing firms may offer a fast-track to embed in clusters of excellences in environmental technologies, providing quick access to relevant knowledge about green innovation. This indicates that acquisitions are mainly aimed at acquiring technological assets with an immediate impact on MNEs' innovation capacity but with limited changes in their longer-term innovation activity (Nocke and Yeaple, 2008).

Therefore, while greenfield investments seem to drive the general result about the dynamic effect discussed in paragraph 4.2 (see the case of the Danish wind company producing blades in a greenfield-type subsidiary in India), acquisitions offer quick wins but less opportunities for knowledge access in the long run.

**Tab. 5. 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 | 0.0338 | 0.0230 | 0.0264 | 0.0303 | 0.0058 | 0.0246 | 4742 |
| | | (0.0237) | (0.0264) | (0.0272) | (0.0255) | (0.0311) | (0.0306) | |
| *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 | 0.0379 | 0.0554 | 0.0315 | 0.0624 | -0.0063 | 0.0077 | 4742 |
| | | (0.0356) | (0.0411) | (0.0403) | (0.0420) | (0.0431) | (0.0445) | |
| ***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 | 0.2012*** | 0.2060** | 0.1711* | 0.1774* | 0.1697 | 0.0981 | 4742 |
| | | (0.0693) | (0.0839) | (0.0939) | (0.0979) | (0.1062) | (0.1048) | |
| *Forward Citations* | Greenfield Investments | 0.1441 | 0.1875 | 0.3490** | 0.4274*** | 0.4877*** | 0.5488*** | 4232 |
| | | (0.1052) | (0.1364) | (0.1495) | (0.1469) | (0.1529) | (0.1492) | |
| | Acquisitions | 0.2059 | 0.2365 | 0.0555 | 0.0331 | 0.0385 | -0.1005 | 4742 |
| | | (0.1623) | (0.1876) | (0.1731) | (0.1848) | (0.1977) | (0.1913) | |

Matching by kernel algorithm with common support. The outputs are equal to ln(1+Ys)-ln(1+Yt-1), where s=0,1,2,3,4,5. All regressions include fixed effects for investor's country, investor's 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.

## 5 Conclusions

MNEs are often associated with corporate environmental wrongdoing (Fiaschi et al., 2020; Giuliani, 2018) as they organise globally to avoid environmental regulations and use accumulated corporate power to sustain outdated technologies and slow down the green transformation (Kolk and Pinkse, 2008; Smink et al., 2015). To be sure, the influence of multinationals on the green transformation is complex and multifaceted and in this paper we contribute to an important debate about whether and how multinational firms can reduce 'environmental harm' and increase 'environmental help' by deepening their sustainability-oriented innovation capabilities. We do so by focusing on a particular determinant in this respect: the role of green FDIs.

Our key findings are as follows. First, GFDIs enhance the 'greening' of the overall technology base of the multinationals, also increasing their specialisation in specific green technologies. Second, these investments have a significant positive impact on the degree and quality of multinationals' innovative capacity in sustainability-oriented technology fields. Third, the mode of the globalisation process matters: in the long run, newly established subsidiaries contribute more to innovativeness and greening than does acquisitions of foreign firms.

Our overall results are positive in nature, affirming expectations about the beneficial relationship between internationalisation and greening. These expectations are informed by a nascent but still scattered body of academic literature which has begun to focus on MNE internationalisation and greening, but not specifically on FDI (Aguilera-Caracuel et al., 2012; Maksimov et al., 2019). We contribute to this literature by showing that foreign investments do indeed help to deepen sustainability-oriented innovation capabilities in multinational enterprises, thereby having a similar effect as other forms of internationalisation such as exporting and foreign licensing. These insights bare also relevant to the international organisations that are paying increasing attention to GFDI but have so far mainly relied on descriptive statistics (Golub et al., 2011; UNCTAD, 2016; UNEP, 2017).

It unsurprising that GFDI increases the sustainability-orientation of 'green pure players' i.e. MNEs that focus specifically on environmental technologies. This only confirms the established insights that FDI (of any kind) supports the innovativeness of MNEs

(Amendolagine et al., 2018). Since the pure players in our sample are expected to have a focus on green innovation, this effect is expected. However, our revelation that GFDIs increase the overall sustainability focuses of multi-technology corporations, which constitute the bulk of our sample, is novel. In particular, we show that GFDIs increase the green specialisation of such firms. Given the fact that the world's largest and most influential manufacturers have a multi-technology nature, this insight is not trivial and good news for sustainability transition. If large multinationals are increasingly devoting their innovation activities to make renewable energy technologies more efficient, affordable and accessible their contributions to sustainability and energy transition could be remarkable.

Furthermore, our study shows that incremental internationalisation is related with superior (more) green innovation compared to fast internationalisation. Firms that make GFDI in the form of 'greenfield' investments file more green patents (and these patents are cited more) than firms that make GFDI in the form of acquisitions of foreign green innovators. In other words, there may be may be few shortcuts to corporate greening efforts thorough internationalisation. Rather, sustainable corporate greening is more sustainable when built incrementally in foreign subsidiaries.

The impact of outward GFDI on sustainability-oriented innovation has so far be overlooked as a mechanism to support the green transformation both in the policy arena as well as in the international business literature. In terms of policy, our findings indicate that governments should encourage and sustain internationalisation in environmentally friendly domains because this will help green transformations, sustaining the decarbonization of energy systems in the specific domain of renewable energies. The potential impact on green innovation should also be accounted for in the implementation of the screening investment frameworks which have gained momentum around the world in recent years. The rising political concerns in terms of security issues may be at detriment of innovation activities which can contribute to the green strategies that numerous countries are enforcing in these days.

In terms of further research, it would be highly relevant to investigate further the differences between green pure payer and multi technology corporations. In the analysis we carry out in this paper we take this as a control dimension only. However, further research should examine in detail whether multi-technology MNEs behave in a significantly different as compared to green pure players and whether they have specific advantage un undertaking globally orientated green innovation. To which extent are the results we show in this paper dependent on the starting point of green specialization? Under which conditions, the 'greening' of multinationals is more effective?

Moreover in future analysis, the 'reverse causality' involved in home-host capability transfer should also further investigated. Knowing more about under which conditions can subsidiaries absorb investors' knowledge and develop their own innovation capabilities could be very important to help policy makers to understand how to maximize the gains from inward GFDI. Adding key firm-level characteristics such as absorptive capacity and intensity in green R&D of foreign subsidiaries would allow to understand more deeply the micro mechanisms for knowledge transfer within the multinationals as well the spillover on the hosting countries and regions.

## Acknowledgments

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# Appendix A

**Tab. A1. Main origins of patent applications (by first applicant country): 1970-2018**

| | *Biofuel* | *Geothermal* | *Marine* | *Solar Hybrid* | *Solar PV* | *Solar Thermal* | *Waste* | *Wind* | *Total* |
|---|---|---|---|---|---|---|---|---|---|
| Low-middle income* | 2269 (9.1) | 355 (7.0) | 963 (10.4) | 55 (4.9) | 2443 (2.3) | 10980 (14.7) | 2028 (9.2) | 6559 (11.1) | 31182 (9.1) |
| High-income* | 22622 (90.9) | 4715 (93.0) | 8299 (89.6) | 1066 (95.1) | 105130 (97.7) | 63574 (85.3) | 20067 (90.8) | 52456 (88.9) | 310876 (90.9) |
| USA | 3671 (14.7) | 525 (10.4) | 703 (7.6) | 23 (2.0) | 10313 (9.6) | 4351 (5.8) | 988 (4.5) | 4324 (7.3) | 26468 (7.7) |
| South Korea | 1579 (6.3) | 582 (11.5) | 508 (5.5) | 83 (7.4) | 1126 (12.2) | 2416 (3.2) | 1116 (5.1) | 4073 (6.9) | 26092 (7.6) |
| Germany | 1118 (4.5) | 548 (10.8) | 363 (3.9) | 54 (4.8) | 5221 (4.8) | 5838 (7.8) | 1288 (5.8) | 6102 (10.3) | 22192 (6.5) |
| China | 1198 (4.8) | 258 (5.1) | 420 (4.5) | 47 (4.2) | 1680 (1.6) | 8473 (11.4) | 1530 (6.9) | 3118 (5.3) | 18493 (5.4) |
| Japan | 566 (2.3) | 78 (1.5) | 62 (0.7) | 8 (0.7) | 8098 (7.5) | 752 (1.0) | 222 (1.0) | 1137 (1.9) | 11268 (3.3) |
| Taiwan | 115 (0.5) | 37 (0.7) | 204 (2.2) | 16 (1.4) | 3547 (3.3) | 1363 (1.8) | 34 (0.1) | 1016 (1.7) | 6734 (2.0) |
| France | 650 (2.6) | 124 (2.4) | 308 (3.3) | 18 (1.6) | 1241 (1.2) | 1893 (2.5) | 349 (1.6) | 1146 (1.9) | 6595 (1.9) |
| Russia | 365 (1.5) | 74 (1.5) | 194 (2.1) | 0 (0.0) | 327 (0.3) | 859 (1.2) | 161 (0.7) | 1490 (2.5) | 5644 (1.7) |
| Spain | 152 (0.6) | 17 (0.3) | 186 (2.0) | 9 (0.8) | 262 (0.2) | 1058 (1.4) | 73 (0.3) | 1057 (1.8) | 3173 (0.9) |
| UK | 309 (1.2) | 35 (0.7) | 290 (3.1) | 3 (0.3) | 557 (0.5) | 421 (0.6) | 134 (0.6) | 716 (1.2) | 3154 (0.9) |
| Denmark | 275 (1.1) | 7 (0.1) | 58 (0.6) | 0 (0.0) | 54 (0.1) | 92 (0.1) | 71 (0.3) | 1692 (2.9) | 2285 (0.7) |
| Others | 14893 (59.8) | 2785 (54.9) | 5966 (64.4) | 860 (76.2) | 75147 (58.7) | 47038 (63.1) | 16129 (73.0) | 33144 (56.2) | 209960 (61.4) |
| Total | 24891 (100) | 5070 (100) | 9262 (100) | 1121 (100) | 107573 (100) | 74554 (100) | 22095 (100) | 59015 (100) | 342058 (100) |

* Based on the World Bank classification (accessed on January 7 2020). Source: Authors' elaboration on PATSTAT

Table A.2. RE FDIs: home countries (# and %)

| Country | # RE FDIs | # greenfield FDIs | # 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) |

Authors' elaborations.

Table A.3. RE FDIs destination (# and %)

| | # RE FDIs | # greenfield investments | # 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) |
| Other countries | 466 (38.3) | 340 (37.7) | 126 (40.0) |
| Total | 1217 (100) | 902 (100) | 315 (100) |

Authors' elaborations.

## Appendix B
## Logit analysis for the counterfactual sample

The variables included in the logit analysis to calculate propensity scores are presented in Table B1. The first set of regressors controls for the innovation activity of firms before the investment, introducing the following variables: a) the log of the total number of patents applied by the investor between 1970 to one year before the investment (*Patent stock t-1*); b) the log of the number of RE patents applied for one year before the investment (*Green patents t-1*); c) the share of RE patents in total investors' patent portfolios, calculated over total investors' patent portfolios at one year before the investment (*Green intensity _stock t-1*) and d) the technological concentration of green patents calculated over total investors' patent portfolio at one year before the investment (*Green specialization stock t-1*).

Furthermore, we introduce other characteristics that might affect the choice of investing abroad such as size[10] (*D middle size, D large size, D very large size*), investor's age at the year of the deal (*Age*), legal form (*D PLC*), past experience with foreign direct investments (*FDI experience*) distinguishing between greenfield investments (*Greenfield investments experience*) and cross-border acquisitions (*Acquisitions experience*). Finally, to control for unobserved firm-level fixed effects (Blundell et al., 2002), we include firms' innovation activity before 1997, which is the first year considered in our sample of investments (*Pre-sample patents* and D *pre-sample patents*).

Since our sample includes FDIs in different years, in order to assign counterfactual treatment dates to the firms included in the control group, we follow the procedure described in Chari et al (2012) and adopt the approach of proportional random investment time assignment so that the counterfactual sample has the same time distribution as the investments in the treated group.

[10] Following Orbis, "very large" companies are those meeting at least one of the following criteria: a) operating revenue larger/equal to €100 mln; b) total assets larger/equal to €200 mln; c) number of employees larger/equal to 1000; d) listed company. "Large" companies meet one of the following criteria: a) operating revenue equal/equal to €10 ml; b) total assets larger/equal to €20 mln; c) number of employees larger/equal to 150. "Medium" companies meet one of the following criteria: a) operating revenue equal/equal to €1 ml; b) total assets larger/equal to €2 mln; c) number of employees larger/equal to 15.

Table B2 reports the results of the logit regressions to calculate the *ex-ante* probability to undertake RE GFDIs (*Model 1*), greenfield investments (*Model 2)*, cross-border acquisitions (*Model 3*), RE GFDIs in high income host countries (Model 4), and RE GFDIs in low/middle income host countries (*Model 5*). The results show that the size of the patent portfolio and of the green patent portfolio before investing increase the likelihood of undertaking RE GFDIs. Moreover, the coefficient of the index of technological concentration in RE patents is negative and statistically significant implying that more diversification across different green technologies boost the probability of undertaking green FDIs. This might be explained by the explorative nature of investments that are more likely to be undertaken by companies with more technologically diversified patent portfolios (Quintana-García and Benavides-Velasco, 2008). The remaining results by large confirm existing evidence, showing that larger and younger firms, public limited companies and investors with previous experience are more likely to undertake green foreign investments (Cozza et al., 2015; Stiebale, 2016; Stiebale and Trax, 2011).

With the results of the logit models we calculate the propensity scores to match investors with non- investors with similar characteristics through the Kernel matching estimator with common support (Cozza et al., 2015)[11]. To test whether the matching is successful, we run t-tests on the difference of covariates' mean values between investors and non-investors before and after the matching, finding that after the matching the difference of covariates' mean values becomes not significant in most of the cases. Results of the t-tests are available on request.

[11] The matching uses the algorithm by Leuven and Sianesi (2003).

## Table B.1. - The variables

| Variable | Description | Mean | Standard Deviation | Min | Max |
|---|---|---|---|---|---|
| Patent stock t-1 | Log of the # of patents between 1970 and 1 year before the investment | 2.016 | 2.415 | 0 | 13194 |
| Green patents t-1 | Log of the # of RE patents between 1970 and 1 year before the investment | 0.220 | 0.676 | 0 | 6378 |
| Green intensity stock t-1 | Share of RE patents in investors' total patent portfolio between 1970 and 1 year before the investment | 0.240 | 0.369 | 0 | 1 |
| Green specialization stock t-1 | Herfindhal index measuring technological concentration of all RE patents after 1970 and up to 1 year before the investment | 0.468 | 0.474 | 0 | 1 |
| D middle size | =1 if firm is middle size | 0.245 | 0.430 | 0 | 1 |
| D large size | =1 if firm is large size | 0.182 | 0.386 | 0 | 1 |
| D very large size | =1 if firm is very large size | 0.293 | 0.455 | 0 | 1 |
| Age | Difference between the year of the investment and the year of incorporation | 2. 595 | 1. 203 | 0 | 5. 843 |
| D PLC | =1 if the firm is a PLC | 0.290 | 0.454 | 0 | 1 |
| FDI Experience | Log of the # of foreign subsidiaries | 0.566 | 1.817 | 0 | 10851 |
| Greenfield investments experience | Log of the # of greenfield investments | 0.427 | 1.283 | 0 | 7.113 |
| Acquisitions experience | Log of the # of cross-border acquisitions | 0.158 | 0.593 | 0 | 3.761 |
| Pre-sample patents | Average # of patents applied before 1997 | 53.564 | 597.721 | 0 | 12024.81 |
| D pre-sample patent | =1 if pre-sample patents >0 | 0.341 | 0.4742 | 0 | 1 |

## Table B.2. - Logit models

| | All RE FDIs | Greenfield Investments | Acquisitions |
|---|---|---|---|
| | (1) | (2) | (3) |
| Patent stock, t-1 | 0.1978*** | 0.1913*** | 0.1604** |
| | (0.0487) | (0.0544) | (0.0724) |
| Green patents, t-1 | 0.5633*** | 0.4877*** | 0.7573*** |
| | (0.1281) | (0.1345) | (0.1711) |
| Green intensity stock, t-1 | 0.4614 | 0.4482 | 0.6185 |
| | (0.2978) | (0.3448) | (0.4893) |
| Green specialization stock, t-1 | -0.5658*** | -0.6790*** | -0.4436 |
| | (0.2113) | (0.2377) | (0.3179) |
| D middle size | -0.0788 | 0.3167 | -1.2224 |
| | (0.6112) | (0.8433) | (1.1722) |
| D large size | 1.8690*** | 1.9163** | 1.9578*** |
| | (0.5585) | (0.8294) | (0.6184) |
| D very large size | 4.2920*** | 4.4347*** | 4.4049*** |
| | (0.5447) | (0.7983) | (0.6270) |
| Age | -0.1818*** | -0.2022*** | -0.0932 |
| | (0.0698) | (0.0764) | (0.1064) |
| D PLC | 0.9745*** | 1.1310*** | 0.7159*** |
| | (0.1791) | (0.2034) | (0.2396) |
| FDI experience | 0.4267*** | | |
| | (0.0470) | | |
| Greenfield FDIs experience | | 0.6054*** | |
| | | (0.0726) | |
| Acquisitions experience | | | 1.3534*** |
| | | | (0.2004) |
| Pre-sample patents | 0.0006 | 0.0007 | 0.0004 |
| | (0.0006) | (0.0006) | (0.0004) |
| D Pre-sample patents | -0.7567*** | -0.6805*** | -0.7345** |
| | (0.2276) | (0.2445) | (0.3346) |
| Constant | -2.1534* | -1.3496 | -15.6909*** |
| | (1.2812) | (1.4773) | (1.5753) |
| Observations | 6833 | 6318 | 5698 |
| ll | -1.1e+03 | -8.8e+02 | -4.1e+02 |

Output variables are dichotomous variables taking on values 1 in case of RE FDI (model 1), greenfield investments (model 2) and acquisitions (model 3), and 0 otherwise. All regressions include fixed effects for investor's country, investor's 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.