Greenfield Foreign Direct Investments and Regional Environmental Technologies

22 March 2021

Abstract

This paper builds on (eco-)innovation geography and international business studies to investigate the effects of greenfield Foreign Direct Investments (FDIs) on regional specialisation in environmental technologies. Combining the OECD-REGPAT and the fDi Markets datasets with respect to 1,050 European NUTS3 regions over the period 2003-2014, we find that FDIs can positively impact on regions' specialisation in green technologies. This effect is statically significant when FDIs occur in industries wherein environmental patents represent a relatively high share of total inventive activities (green FDIs), and it is further reinforced if such foreign investments involve R&D activities. We also find that the relatedness of environmental technologies to pre-existing regional specialisations exerts a negative moderating effect on the role of green R&D FDIs in shaping environmental patenting patterns. In particular, green R&D FDIs have a larger effect in regions whose prior knowledge base is highly unrelated to environmental technologies. This result is consistent with the idea that MNEs inject the host region with external knowledge, which makes the development of green-technologies less place-dependent.

JEL codes: O31, O33, R11, R58

Keywords: green regional specialisation; FDIs; environmental technologies.

1 Introduction

Environmental sustainability is nowadays an inescapable priority, giving rise to mounting concerns for the development of “green technologies”, capable to reduce pollution and economize the use of natural resources. While early studies paid little attention to the geography of such technologies (Truffer and Coenen, 2012), recent research has emphasized that environmental innovations (EIs) have an important regional dimension: spatial and relational proximities, urbanisation and agglomeration economies, local networks and institutional set-ups contribute to make EIs unevenly distributed in space (Cooke, 2011; 2012; Horbach 2014; Gibbs and o’Neill, 2017; Barbieri et al 2016; Montresor and Quatraro, 2019; Santoalha and Boschma, 2021; Consoli et al., 2019).

Regions are differently equipped to eco-innovate for a number of reasons. Among the drivers of the regional capacity to eco-innovate and eventually specialize in green technologies, inward Foreign Direct Investments (FDIs) and the activities of multinational enterprises (MNEs) have surprisingly received little attention so far. Some evidence of global patterns in the regional development of green technologies and of environmental upgrading into Global Value Chains has been recently obtained (De Marchi and Gereffi, 2018; De Marchi et al., 2020). However, research about the impact of FDIs on regional green inventive activities has been rather scanty so far: the evidence about the impact of MNEs on local EIs is mainly based on case-studies and national surveys, whose insights are useful but not always generalizable (Cainelli et al., 2012; Chiarvesio et al., 2014). This lack of empirical research limits our understanding of the patterns through which FDIs may affect the capacity of regions to develop and/or employ new technologies to transition towards the green-economy (Truffer and Coenen, 2012). In particular, a number of largely unexplored issues need to be addressed when dealing with the effects of FDIs on the green specialisation of regions. Does the green nature of FDIs affect regional EI? Does the R&D intensity of FDIs matter for a green regional technological specialisation? Could FDIs enable regions to shift from non-green to green-tech specialisations, thus acting as “agents of structural change” in the green domain? Do FDIs interfere with the recombinatory processes of related knowledge through which EIs emerge at the regional level (e.g. by Montresor and Quatraro, 2019)?

This is the set of novel research questions that the present paper tackles by combining the OECD-REGPAT and the fDi Markets datasets with reference to 1,050 European NUTS3 regions over the period 2003-2014. Our results show that the patterns of regional specialisation in green technologies is correlated with the geographical distribution of FDIs, but in a somewhat specific way. First, we find that FDIs as a whole have a non-significant impact on the green specialisation of regions. This may reflect a wide heterogeneity in FDIs, which needs to be investigated. Second, the impact of foreign capital injections on the green specialisation of regions turns out positive and significant when FDIs occur in industries that have a "green technological footprint" – that is industries wherein environmental patents represent a relatively high share of total inventive activities. Third, the effect of green FDIs is further reinforced if they involve R&D activities, which possibly increase the local knowledge base directly and favour the occurrence of green inventions. Fourth, green FDIs in R&D activities favour the persistence of specialisation in environmental technologies in the case of regions that already exhibit such a specialisation, while in general they do not facilitate a switch (from non-green) to green-tech specialisation. However, this finding holds true for average levels of relatedness of green technologies to the pre-existing specialisations of the region. Instead, green FDIs in R&D activities can positively impact on the regions' switch to green-tech specialisation, provided that the pre-existing technological specialisations of the region are highly unrelated to green technologies.

The rest of the paper is structured as follows. Section 2 positions the paper in the different streams of literature it relates to. Section 3 illustrates the empirical application, and Section 4 discusses the results. Section 5 concludes.

2 Background literature and research questions

Although initially developed in a-spatial framework, the analysis of green technologies and eco-innovations (EIs) has been recently enriched with several regional characterizations (Truffer and Coenen, 2012). On the one hand, research on the determinants of EIs has shown that their unfolding is affected by several region-specific features (Horbach, 2014; Leoncini et al., 2016; Antonioli et al., 2016; Arranz et al., 2019; Giudici et al., 2019). On the other hand, the literature on technological diversification has shown that green technologies, like most other technologies, develop in a path- and place-dependent way, conditionally on the existing (regional) knowledge-base (Van den Berge and Weterings, 2014; Tanner, 2016; Barbieri et al., 2020a; Colombelli and Quatraro, 2019; Corradini, 2019; Barbieri and Consoli, 2019; Montresor and Quatraro, 2019; Consoli et al., 2019; Santoalha and Boschma, 2021).

Against this background, a few studies have addressed the role played by MNEs as drivers of firms' EIs at the regional level (e.g. Cainelli et al., 2012, Chiarvesio et al., 2014). Albeit with respect to some specific local contexts or/and by mainly using ad-hoc surveys, these studies highlight that the presence and operations of foreign subsidiaries within regions can work as an important boost to the EIs of the local firms. In the light of the increasing extent to which the development of regional technologies occurs in a global context (De Marchi et al., 2018), it becomes crucial to investigate whether these detected firm-level mechanisms work at a wider level across regions. Could we expect that inward FDIs augment the environmental knowledge-base of the hosting region to the point of favouring the region capacity to master, and specialise in, green-technologies?

2.1 The nature of inward FDIs and their effects on regional green-technological specialization

The "portfolio" of FDIs that could reach a region is heterogeneous, so that their impact on local EI is hard to predict in general. Empirical research largely reflects this indeterminacy, although most extant evidence has mainly addressed the impact of FDIs on environmental performance (e.g. emissions) rather than their effects on EIs as such (for recent surveys, see Zugravu-Soilita, 2017; Cole et al., 2017).

Two key dimensions of the heterogeneity of FDI when it comes to its relation with EI are: the degree to which FDI can be considered "green", and their R&D and innovation contents. First, the role of FDIs in contributing to regional EIs would apparently result less indeterminate when a focus is placed on what some recent literature has called *"green FDIs"*. Unfortunately, no single widely adopted definition of "green FDI" has been agreed upon in the literature. A recent report by Greeninvest (2017) provides a useful survey of various attempts to define the concept. Despite their differences, all definitions seem to point to environmentally-relevant sectors. Building on this literature, and considering that our analysis is specifically targeted at explaining innovation in green technologies, we will define Green FDIs as cross-border investments occurring in narrowly defined industries where new environmental technologies are most relevant. We refer to section 3.2.2 for details on how we operationalise this definition. We submit that FDI occurring in these industries are more likely to induce environmental innovation. Hence, regions that receive more FDIs in these industries can be expected to be better positioned in the development of green technologies. By contrast, non-green FDIs – that is FDIs accruing to industries that are not specialised in green technologies - are arguably more effective in pushing regions towards alternative (non-green) specialisations (Sawhney and Rastogi, 2015).

Green FDIs could increase the regional eco-innovativeness in a direct and an indirect way. On the one hand, subsidiaries of foreign MNEs investing in the region could *directly* affect the technological specialisation of the region towards green technologies, to the extent that MNEs are actually more involved in green innovation than local firms (Kaway et al., 2018). On the other hand, FDI could have *indirect* effects, by stimulating green innovation in the wider local economy, through the knowledge spillovers on domestic (regional) firms (competitors, suppliers and customers) (Ning et al., 2018).

The literature has found wide support for the direct effect of FDI on innovative activity as a whole (Castellani and Zanfei, 2006, Guadalupe et al., 2012, Stiebale, 2016), and some evidence has also been found on indirect effects (Castellani et al., 2015; Crescenzi et al., 2015, Papanastassiou et al., 2020). However, the evidence about these two potential effects on green innovation is scanty, sparse and mixed. The direct effect of FDIs on greening local innovation has been found to reflect several characteristics of both home and host countries (Marin and Zanfei, 2019; Carraro and Topa, 1994; Beise and Rennings, 2005; Costantini et al. 2017; Kawai et al. 2018; Hascic et al., 2012; Tatoglu et al. 2014; Noailly & Ryfisch, 2015). Some studies have also shown that foreign firms' inventive activities in green domains can contribute, indirectly, to increase the sustainability of domestic firms (Albornoz et al., 2009; Dechezleprêtre and Glachant, 2014: Cainelli et al., 2012), but still depending on a wide set of circumstances (Rezza, 2013; Tang, 2015), which cannot be easily reconciled with a straightforward interpretation.

Due to data limitation, disentangling direct and indirect effects empirically is beyond the scope of this paper.[1] However, one could venture saying that when MNEs carry out R&D in the host regions, while their activities are conducive to both direct and indirect effects on regional eco-innovation, the former effects are particularly likely. This leads to the second key dimension of heterogeneity of the nature FDI, which refers to *the functional activities* involved in FDIs. In fact, MNEs' strategic decision to invest in specific business activities – such as R&D, manufacturing and sales, or combinations thereof – is likely to influence the technological specialisation of the regions wherein FDIs are located. This is particularly the case of international investment decisions in the field of Research and Development (R&D) and of innovation activities, that is, FDIs through which MNEs pursue a "knowledge intensive" strategy (Papanastassiou et al., 2020). Indeed, also with respect to environmental technologies, R&D FDIs are likely to provide both a higher direct contribution to local innovation (Dachs and Peters, 2014; Griffith et al., 2004) and a potential for significant spillovers on the innovation of local firms (Braconier et al., 2001; Castellani and Zanfei, 2006; Fu, 2008; Marin and Sasidharan, 2010; Todo, 2006; Belitz and Mölders 2016). Nevertheless, the impact of R&D FDIs on EI of regions and on their green specialisation may well depend on the characteristics of the industries in which FDIs occur and, in particular, on the technologies on which such industries rely. To illustrate, the regional specialisation in the fuel cell technology, one leading green-tech of this era, is expectedly helped by R&D FDIs in local automotive industries; given the increasing reliance of these industries on fuel cells, foreign R&D investments in in this technology could increase the knowledge-base of the region towards the acquisition of the relative specialisation (Tanner, 2016). The regional specialisation in a more mature green technology like early wind power, instead, is arguably more helped by engineering and production FDIs in local energy sectors, in which technologies are developed through a DUI (doing-using-interacting), rather than STI (science-technology-innovation) mode of innovating (Binz and Truffer, 2017).

---

[1] In particular, one would need to assign regional patents data to MNEs in each region. But identifying MNE, consolidating ownership structures of subsidiaries is only possible with a narrow geographical focus. As we will illustrate later, our analysis exploits data across all NUTS3 regions in the EU over the period 2003-2014. Though, distinguishing the direct and indirect effects that FDIs can have on the regional green-tech specialisation is key to understanding the role of FDI for regional eco-innovation and it is in our research agenda.

Based on the discussion above, we put forward the following research questions:

RQ1: *Do inward FDIs increase the regional capacity to specialize in environmental technologies?*

RQ2: *Does the green vs. non-green nature of the industries where inward FDIs occur affect the regional capacity to specialize in environmental technologies?*

RQ3: *Does the R&D vs. non-R&D nature of inward FDIs affect the region capacity to specialize in environmental technologies?*

2.2 The role of inward FDIs in the regional diversification into green technologies

A further aspect that has attracted significant research recently is the capacity of *regions to diversify their technological repertoire* over time. The role of MNEs in this process has been only limitedly investigated so far, but it could be extended to the green-tech domain too. In regions that have already acquired a green-tech specialisation, inward FDIs, especially green ones, can provide the focal industries with additional coherent knowledge and competencies to keep that specialisation over time, if not even to reinforce it. Indeed, a region's capacity to maintain a green-tech specialisation does not come for free and could diminish over time, especially in front of less costly and less complex non-green alternative technologies (Barbieri et al., 2020b). In specific circumstances, the absorption of external knowledge and experience that FDIs inject in the region could even reduce the risk of an "inverse transition", from the green to the non-green economy. From a specular perspective, one might argue that green FDIs can help more when regions are already familiar with the technology handled by foreign investors, as this will increase the local capacity to absorb and utilise the external green knowledge.

There may be reasons to expect that inward FDIs will also help regions gain a new green-tech advantage from scratch, should they not have it already, being specialised in other than green technologies. Indeed, previous studies have shown that the "fossil fuel paradigm" is marked by a highly persistent socio-technical system (Geels, 2002), and that path-dependence can combine with place-dependence in making regions even "replicate" their non-green technologies over time. Strong leverages are thus required to favour regional green-tech diversification, either by "transplanting" it from elsewhere or by favouring its internal "exaptation" (see Boschma et al., 2017 on this distinction). From this perspective, switching from non-green to green-tech specialisation can be a particular case of structural change. We are focussing here on a type of structural change that MNEs could help regions undertake, given their role in reshaping the set of production linkages of the hosting region and in affecting its degree of industrialization/tertiarization (Ascani and Iammarino, 2018).

Whether FDIs can actually help regions in acquiring a green-tech specialisation *ex-novo*, or if they rather confirm an already existing green-tech specialization, is an important issue to address. Accordingly, we also address the following research question:

RQ4*: To what extent do inward FDIs favour the shift from non-green to green-tech regional specialization?*

2.3 Technological relatedness and the effect of inward FDIs on green-technological specialisation

The literature on regional technological specialization/diversification has quite extensively emphasized the coherence of specialization patterns with the knowledge profile of regions. Previous studies have shown that, similarly to other technologies, also the development of (new) environmental ones occurs in a place-dependent way, through branching processes of pre-existing technologies, which are less costly and risky than saltation ones (Balland et al., 2018; Montresor and Quatraro, 2019; Santoalha and Boschma, 2021). In brief, regional green-tech specialisation exploits cognitive proximity, or relatedness, to pre-existing technologies in the knowledge space. This is achieved by recombining existing knowledge and gradually change the technological specialisation of a region transitioning into fields which are related to its previous specialisation. In this literature, some studies have shown that there are factors – such as regional Key Enabling Technologies (Montresor and Quatraro, 2019) and environmental policy attitudes (Boschma and Santhola, 2019) – that can favour the regional green-tech diversification depending on the cogent level of relatedness between new and pre-exiting green (and non-green) technologies. Whether FDIs can be among these factors represents an important issue to address. On the one hand, it can be argued that, by injecting the hosting region with outer and thus possibly more novel knowledge/competencies, FDIs help the development of relatively less constrained/related green technologies. In other words, technological relatedness would negatively moderate the green-tech effect of inward FDIs

(Elekes et al., 2019; Zhu et al., 2017). On the other hand, it can be claimed that FDIs are more effective in favouring the regional specialisation into green technologies that are more related to the existing ones, as the novelty of external knowledge needs to be compensated by a higher cognitive proximity: in brief, we could also expect that technological relatedness positively moderates the green-tech impact of FDIs.

As the previous outcomes could occur both in already green-tech specialised and non-specialised regions, the discussion above leads us to formulate the following two research questions.

RQ5: *Does technological relatedness moderate the role of FDIs in driving regions to specialize in environmental technologies?*

RQ6: *Does technological relatedness moderate the role of FDIs in driving the regional shift from non-green to green-tech regional specialization?*

3 Empirical analysis

3.1 Data

The previous research questions are addressed through an econometric investigation of 1,050 EU regions (NUTS3 level).[2] To do so, we combine information over the period 2003-2014 from the OECD-REGPAT, fDi Markets (fDi Intelligence, Financial Times), and from the Eurostat regional statistics databases.

From the OECD-REGPAT database we retrieve the number of patent applications made at the European Patent Office (EPO) by the inventors which reside in each NUTS3 region.[3] In order to measure EIs at the local level, we refer to regional "green patents" according to the taxonomy (based on CPC and IPC) recently put forward by the 'OECD-ENVTECH indicator' (Haščič and Migotto, 2015). It is well-known that patents are not free from limitations when used as measures of EIs (Popp, 2005) and their incidence in

---

[2] As in some case some different NUTS3 regions belong to the same economic system (metropolitan areas), these regions have been aggregated. For a NUTS3-based definition of metropolitan areas we considered the one adopted by Eurostat and available at https://ec.europa.eu/eurostat/web/metropolitan-regions/background.

[3] We allocate patents to the NUTS3 region of residence of the inventor, sorting them by priority date. Inventors have been chosen instead of assignees given that patents developed in a specific location could be assigned, for internal strategies, to the headquarter of the company or to the ultimate owner, making the address of the assignee a poor proxy of the location of the development of the invention.

capturing the advancements of green technologies somehow waned in the last decade (EEA, 2020). Still, patents remain the most reliable indicator for systematic empirical analysis of the regional production of technological knowledge (Acs et al., 2002) and will thus be used by taking their green nature into account. One issue that needs to be addressed in the specific case of our analysis is the risk of data-handling truncations, due to delayed publication of patent applications. In this paper we deal with this by cumulating green patents up to 2014. In order to attenuate patents lumpiness over time, we aggregate information across 3 temporal windows of 4-years each: 2003-2006, 2007-2010; 2011-2013.

From the fDi Markets database we retrieve the number of greenfield cross-border investment projects located in a certain European city in the period 2003-2013. [4] Unfortunately, our data do not allow to capture Mergers and Acquisitions (M&As) involving foreign investors and incumbent domestic companies. . While fDi Markets provides comprehensive information on the distribution of greenfield FDIs by industry (to identify green FDIs) and by functional activity (to identify the specific contribution of R&D FDIs), to the best of our knowledge no data source would allow to make the same distinctions for M&As. In addition, according to the World Investment Report 2018, over the period 2008-2014 the value (the number) of greenfield FDIs were twice (more than twice) as large as the value (the number) of net cross-border M&A deals (UNCTAD, 2018, pp. 7-8). Hence, the potential bias introduced by disregarding M&A should not be over-emphasized as focusing on greenfield investments allows to capture a large portion of FDI flows and reassures us about the reliability of our analysis.

Exploiting the information on longitude and latitude of the destination cities for each greenfield FDI project in fDi Markets, it is possible to attribute each investment to the correspondent NUTS3 European region. Furthermore, fDi Markets provides the information about the industry in which cross-border investments occur, referring to the NAICS classification, and the functional activity undertaken in each project. Based on these pieces of information we are able to identify FDI in green industries (as illustrated in Section 3.2.2) and those in R&D vs. non-R&D activities.

---

[4] fDi Markets is an event-based (or deal-based) database, wherein each entry is a cross-border greenfield investment project, for which the provider reports information from several publicly available information sources.

3.2 Variables and econometric strategy

3.2.1 *Dependent variable*

Our focal dependent variable is region *i*'s capacity to specialise in "green technology" at time *t*, $GreenSpec_{it}$. Following previous literature on regional green-tech specialisation/diversification (e.g. Montresor and Quatraro, 2019; Santoalha and Boschma, 2021), we use a dichotomous measure indicating whether a region is specialised or not in green technologies, irrespective of the degree of (de)specialisation.[5] We instead depart from these previous studies, which focus on the regional specialisation in one of the several specific green domains in which technologies can be developed, by referring here to a more encompassing indicator of the regional capacity to prioritise the development of its green technologies. Indeed, this indicator goes beyond the acquisition of technological advantage in one specific green technology and rather detects the advantage that a region exhibits in the development of technologies across the entire spectrum of possible green applications (a sort of meta green technology).

In analytical terms, $GreenSpec_{it}$ is obtained as binary transformation of a Revealed Technological Advantage (RTA) indicator that region *i* shows to have (or not) in green technology at time *t*, that is:

$$GreenSpec_{it} = \begin{cases} = 1 \text{ if } GreenRTA_{it} \geq 1 \\ = 0 \text{ otherwise} \end{cases} \tag{1}$$

where $GreenRTA_{it}$ is defined as follows:

$$GreenRTA_{it} = \frac{\frac{GreenPAT_{it}}{\sum_{i=1}^{n} GreenPAT_{it}}}{\frac{TotPAT_{it}}{\sum_{i=1}^{n} TotPAT_{it}}} \tag{2}$$

---

[5] In a robustness check of our results, reported in Appendix E, we also use as dependent variable the degree of specialisation in the green technology, as denoted by the variable $GreenRTA_{it}$ in Eq. (2).

$GreenPAT_{it}$ is the number of (EPO) patent applications made by region *i*'s inventors in any of the IPC and CPC codes that 'OECD-ENVTECH indicator' considers as environmental, and $TotPAT_{it}$ denotes the total number of patents by region *i*.[6]

Following a standard interpretation of RTAs, region *i* is identified as specialized (or not) in green technology, and $GreenSpec_{it}$ is equal to 1 (0), if $GreenRTA_{it}$ is larger than 1 (between 0 and 1), as the region is patenting relatively more (less) in the green domain compared to other regions.[7]

As a *prima facie* description of our dependent variable, Figure 1 reports the number of regions in our sample that, during each and every of the considered temporal windows (t; t-1) are: i) persistent in their green-tech specialisation (GreenSpec(t) = 1; GreenSpec(t-1) = 1), or ii) in their green-tech de-specialisation (GreenSpec(t) = 0; GreenSpec(t-1) = 0), rather than iii) switching towards (GreenSpec(t) = 1; GreenSpec(t-1) = 0) or iv) away from a green-tech specialisation (GreenSpec(t) = 0; GreenSpec(t-1) = 1). It appears evident that green technology specialisation is a quite persistent trait of EU regions. A large majority of the observed regions were (and remained) non-specialised in the green technology over the 3 considered periods, and the second largest group is represented by regions that were (and remained) specialised in it. The number of regions that moved across the specialisation threshold is intermediate between the previous groups, with an interesting variation over time. In the first observed period (2003-2006), the gain of a green-tech specialisation is more frequent than its loss, while the reverse holds true for the second (2007-2010), and more evidently, for the third (2011-2014) period. As these reductions in frequency of switching from non-green to green-tech specialisation in time roughly correspond to the explosion and aftermath of the global financial crisis, our finding is quite consistent with the idea that green transitions are a costly business and are thus less likely to occur in periods of deep recession. Overall, the transition towards the green-tech specialisation appears still a limited phenomenon, which deserves as much

---

[6] The OECD-ENVTECH indicator considers 8 broad categories of environment-related technologies: environmental management, water-related adaptation technologies, climate change mitigation (CCM) technologies related to energy generation, transmission or distribution, capture, storage, sequestration or disposal of greenhouse gases, CCM technologies related to transportation, CCM technologies related to buildings, CCM technologies related to wastewater treatment or waste management, CCM technologies in the production or processing of goods.

[7] As a robustness check, we also consider a more demanding threshold of 1.5 to define specialization. This means that a region is considered as 'specialized' if its share of environmental patents over its total patents is 50% larger than the world average.

attention as the regional capacity of keeping it once it has been attained. As we will see, following our RQ4, we will explicitly focus on these two different patterns of green-tech specialisation among the results.

Figure 1 – Number of regions by *GreenSpec* state (0; 1) in t and t-1

3.2.2 *Explanatory variables*

As far as the explanatory variables are concerned, the focal ones refer to the number of cross-border greenfield investment projects that MNEs announce in a certain region at time *t*. For the sake of simplicity, we will refer to measures derived from fDi Markets using the prefix FDI (keeping in mind that these are greenfield investments). When addressing RQ1, we simply count total number of FDI in the focal region and define the variable FDI_{it}, irrespectively from the industries or activities in which they are documented to occur. For the sake of RQ2, instead, we define the variable $FDI\text{-}Green_{it}$, which count the number of regional green FDIs. Previous analyses have estimated green FDIs mainly by looking at those occurring in industries and/or goods and services, which can be claimed to improve the environmental sustainability of an economy, either from a supply or a demand perspective, or both. While the rationale of this choice is comprehensible, the list of focal industries compiled on its basis is inevitably exposed to some degree of arbitrariness and has actually led to heterogeneous outcomes. As it has been extensively discussed by Greeninvest (2017) and summarised in Table 1 this has led to multiple (sometimes conflicting) definitions of Green-FDI.

Table 1 – Overview of estimates of Green FDIs

Source	**Concept**	**Included**	**Annual FDI Flow**
UNCTAD	Low-carbon FDI	Greenfield FDI in renewable energy, recycling activities and low-carbon technology manufacturing	US$ 90 billion (2009) US$ 82 billion (2016)
OECD	Green FDI	FDI in Environmental Goods and Services (EGS), proxied by FDI in electricity, gas and water sectors	US$ 41 billion (2005-2007 average)
		FDI into environmentally relevant sectors from home country with stricter environmental policies or higher energy efficiency than host country	Between US$ 268 and US$ 299 billion (2005-2007 average)
fDi Intelligence	FDI in Renewable Energy	Greenfield FDI in solar, wind, biomass, hydroelectric, geothermal, marine and other renewable power generation	US$ 76 billion (2015)
Bloomberg New Energy Finance	Global investment in clean energy, low carbon services and energy smart technologies	Greenfield and M&A activity in renewables (e.g., biofuels, small hydro, wind and solar), clean energy services (e.g., carbon markets), and energy smart technologies (e.g., digital energy, energy efficiency, and energy storage)	US$ 287 billion greenfield FDI (2016)

Source: Coinvest (2017)

We contend that a less arbitrary criterion, which is also more consistent one with our research questions, can be obtained through a systematic analysis of the technological basis of the industries in which FDIs occur. In particular, we suggest classifying as green FDIs those occurring in industries where green technologies are the most salient, that is, in industries whose knowledge-base relies significantly on the invention of new environmental technologies. To operationalize this notion, we associate green patents to industries and then define green industries as those that are specialised in green technologies. In practice, we first compute the total number of patent applications worldwide over the period 1978-2014 in any of the green technology classes as defined by the ‘OECD-ENVTECH indicator’ (Haščič and Migotto, 2015). Patents are then attributed to NAICS industries by means of their Cooperative Patent Classification (CPC) codes using the ‘Algorithmic Links with Probability’ (ALP) concordance developed by

Lybbert and Zolas (2014).[8] We then compute the green RTA for each industry (as from Eq.(2)) and identify as 'green' those industries for which the green RTA is larger than 1 (the list of 'green (specialized)' industries is reported in Table B1 in Appendix B, while Table B2 reports top 10 regions by total FDI projects, green FDI projects and green R&D FDI projects). Consistently with the previous argument, the variable $FDI\text{-}Green_{it}$ will be defined by the number of inward FDI projects in region i, which have occurred in any of the identified green industries. For the sake of comparison, this variable will be complemented by $FDI\text{-}NGreen_{it}$, measuring the number of regional FDIs in industries that do not show a world green-tech specialisation. Both $FDI\text{-}Green_{it}$ and $FDI\text{-}NGreen_{it}$ will be used as focal regressors to tackle RQ2 and to identify the green/non green nature of FDIs when dealing with subsequent RQs.

The last set of focal regressors of our analysis, used to address RQ3 (and to account for interactions with other variables when dealing with subsequent RQs), is represented by the number of FDI projects that, either in green or in non-green industries, is directed to region i. We distinguish FDI where the main functional activity is R&D ($FDI\text{-}Green\text{-}RD_{it}$ and $FDI\text{-}NGreen\text{-}RD_{it}$, respectively) rather than non-R&D business activities abroad ($FDI\text{-}Green\text{-}NRD_{it}$ and $FDI\text{-}NGreen\text{-}NRD_{it}$, respectively).[9]

Figure 2 shows the evolution of our focal regressors along the considered three periods of time. The total number of FDI projects directed to our NUTS3 regions has first increased, from period 1 to period 2, and then decreased from period 2 to period 3. Combined with the trend in the number of green FDIs, this has resulted in a share of them

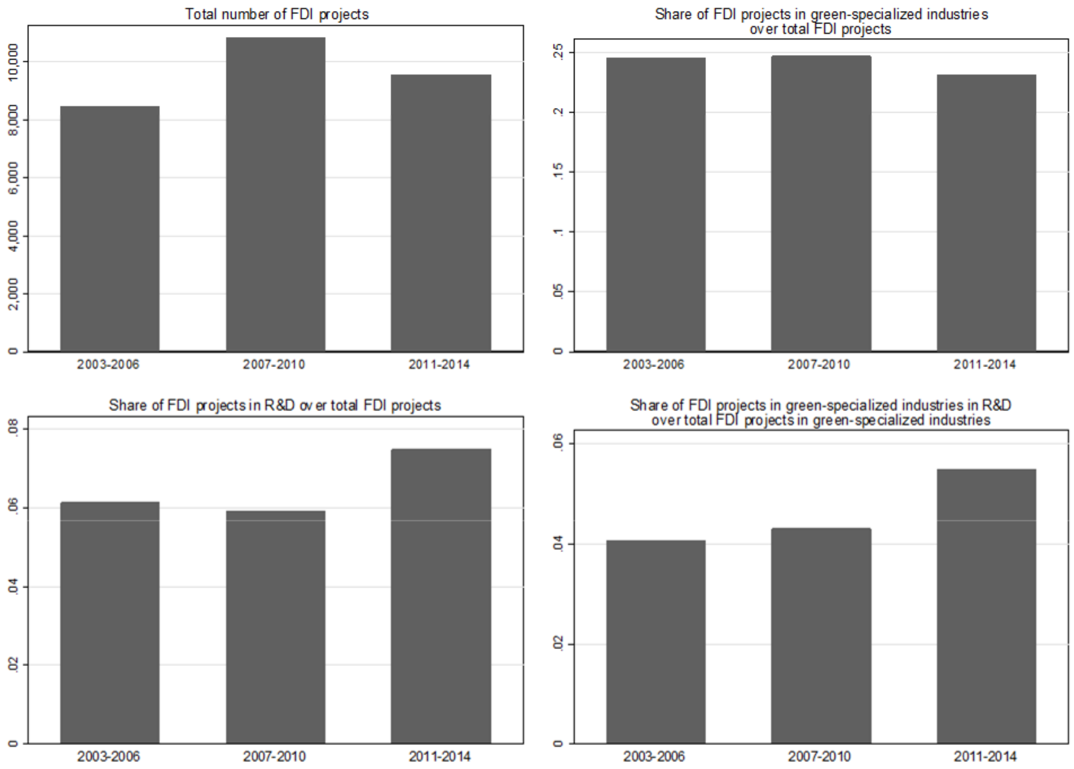
---

[8] The ALP concordance matches each 4-digit CPC class to one or more industries (with certain probability). The ALP concordance does not aim, a priori, to identify either the 'sector of use' (SOU) or the 'industry of manufacture' (IOM) of each technology class, as it was done by the Yale Technology Concordance (Kortum and Putnam, 1997). However, Lybbert and Zolas (2014) state that "*the weighted ALP approach appears to better fit IOM than SOU results*" (p. 538). For what concerns the industry classification, for each NAICS industry in the detailed sub-sector classification of fDI Markets we use the corresponding number of digits in the ALP concordance. For example, some industry in fDI Markets is defined at the 6-digit NAICS while other industries are defined at the 2-digit NAICS. As our definition of green technologies is based on a combination of CPC and IPC codes and the ALP concordance is either based on IPC or CPC, we identify at the level of each individual patent whether the patent is green or not, and then attribute the green patent to different industries based on its CPC codes, according to the ALP concordance. Regarding the timing of our measurement of industry specialization, we decided to consider the long-term specialisation pattern, while not focusing on year-to-year changes in specialisation, to avoid noisy changes. Green technology specialisation is, however, a very persistent phenomenon: the correlation between the time-invariant (1978-2014) industry-level green tech specialisation variable and the green tech specialisation variable computed within each time window used in our analysis is always greater than 0.9.

[9] We included in the R&D FDI category those investment project registered by fDi Markets classified as dealing with either or both R&D and Design, Development and testing.

that has remained nearly stable from period 1 to period 2, for then slightly decreasing from period 2 to period 3, but always around negligible amounts (between 0.2 and 0.25 %). Quite interestingly, the share of regional FDI projects in R&D activities has increased both in all and in green industries, when the first and the second periods are compared, but the increase has been continuous only in the latter case.

Figure 2 – FDI-All and FDI-Green Projects



3.2.3 *Control variables*

In investigating the role of the previous focal regressors, we first of all control for a variable that, according to eco-innovation studies, represents the main driver of the development and adoption of new green technologies, that is, the stringency of environmental policies (see Popp et al., 2010 for a review). Even though the focus of our research is not to assess the effectiveness of such policies in driving green technology specialization, our econometric specification needs to account for environmental policies as they are expectedly correlated both with our dependent variable and our focal regressor.[10] In order to do that, we first include in our regressions country-by-year dummies, which could account for country-level time-varying changes in environmental policy in a flexible way.

However, even in presence of homogeneous country-level rules and standards, regions might differ in their exposure to policies: such as in the case of a policy imposing standards on industrial plants to reduce SOx air emissions. The demand for innovative pollution abatement equipment could be either high or low, depending on the number of local plants with substantial SOx emissions and on the total amount of local SOx emissions. In order to control for this issue, we use regional information on polluting plants and corresponding emissions from the European Pollution Release and Transfer Registry (E-PRTR). We run a Principal Component Analysis, from which we obtain two indicators (the first two components, PC#1 and PC#2) of the regional exposition to environmental policy: “Exposure to env policy (PC#1)” and “Exposure to env policy (PC#2)” (see Appendix C for further details). With the same aim, we also consider the interaction between these two proxies of regional exposure and a country-level proxy of environmental regulatory stringency, that is the EPS (Environmental Policy Stringency index) indicator developed by the OECD (Botta and Kozluk, 2014).[11]

A second fundamental control that we use in our estimates is a variable that, following recent developments in the geography of innovation (Balland, 2016), is expected to drive the regions’ capacity to specialise and diversify into a certain technological domain: that is, its *relatedness* to the technologies that regions already master. This variable is meant as a synthetic measure of the cognitive proximity of the focal technological domain with the set of technological specialisations Boschma, 2005). As we mentioned in Section 2,

---

[10] For example, Marin and Zanfei (2019) and Noailly and Ryfisch (2015) show that MNEs tend to offshore patents in environmental technologies in countries with more stringent environmental regulations.

[11] “The OECD Environmental Policy Stringency Index (EPS) is a country-specific and internationally-comparable measure of the stringency of environmental policy. Stringency is defined as the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behaviour. The index ranges from 0 (not stringent) to 6 (highest degree of stringency). … The index is based on the degree of stringency of 14 environmental policy instruments, primarily related to climate and air pollution“ (https://stats.oecd.org/Index.aspx?DataSetCode=EPS). As the indicator is not available for few newly accessing eastern European countries (Bulgaria, Estonia, Croatia, Lithuania, Latvia and Romania), we attribute the average EPS of other newly accessing eastern European countries for which data is available (Czech Republic, Hungary, Poland, Slovenia and Slovakia). The rationale is that the evolution of national environmental policy stringency for all these newly accessing countries is likely to be rather similar as all these countries had to adopt the EU acquis on environmental policy (Carr and Massey, 2006).

recent studies have shown that, similarly to other technologies, also the development of (new) environmental ones is easier when it occurs in a place-dependent way, through branching processes of pre-existing technologies (Montresor and Quatraro, 2019; Santoalha and Boschma, 2021). By extending this idea to our analytical approach, which focuses on region *i*'s capacity to specialise in the meta green technology (as we have defined it in Section 3.2.1), our $Relatedness_{it,t\text{-}1}$ variable informs about the cognitive proximities between the green technology at *t* and all of technologies in which the region was already specialised in *t*-1. As it is usually the case in the extant literature, dyadic proximities between technologies are identified by measuring the co-occurrence of regional RTA of the meta-code that keeps together all the green IPC and CPC of the OECD classification, and all the codes on a worldwide basis (see Appendix A for more analytical details about the construction of the variable). Besides using $Relatedness_{it,t\text{-}1}$ as a control variable, it will also be used as a moderator to address our RQ5 and RQ6.

The remaining set of controls is intended to capture the structural features of the sample regions that can be considered salient for our analysis. First of all, in order to account for the local availability of (eco-) innovation inputs, we use Eurostat data (https://ec.europa.eu/eurostat/web/regions/data/database) on regional human capital (share of working age population with a tertiary degree) and R&D expenditure (total R&D expenditure per capita, in log). Due to extensive missing values at the NUTS3 level, these variables have been collected at a more aggregated geographical level of analysis (i.e. NUTS2). Furthermore, given the role that General Purpose Technologies have been found to have in the development of green ones (Montresor and Quatraro, 2019), we also retain the regional availability of knowledge in Key Enabling Technologies (KETs, refer to European Commission, 2012 for the list of KETs-related IPC classes), by counting the number of KETs in which regions turn out specialised (according to the RTA of Eq. (2)).

We finally control for the size of the focal region in terms of GDP_{it} (from Eurostat) and share of its country's total patents,[12] and for its population density (in log, based on data from Cambridge Econometrics) to account for the role of agglomeration economies. Given that our reference period includes the Great Recession, we also control for the regional performance during the crisis that hit the world economy in the first decade of

---

[12] As we include country-by-year dummies, it would be indifferent to include the share of region's patent or total region's patent in our specification.

the XXI century, by interacting the GDP growth in 2007-2009, from Eurostat, with time dummies.

Basic descriptive statistics for our variables of interest are reported in Table 2.

Table 2 – Descriptive statistics

1,050 EU regions (NUTS3), for three periods: 2003-2006; 2007-2010; 2011-2014.

Variable	Mean	SD	Min	Max
GreenSpec	0.40	0.49	0	1
log(GDP)	8.57	1.18	2.25	13.37
GDP growth 2007-2009	-0.04	0.10	-0.39	0.27
log(pop density)	-2.07	1.10	-6.30	1.60
log(R&D per capita), NUTS2	5.38	1.25	0.92	6.91
Share of working age pop with tertiary degree, NUTS2	0.25	0.09	0.07	0.51
KETs	0.43	0.50	0	1
Region's share of country patents	0.01	0.02	0	0.38
FDI	8.78	32.85	0	665
FDI-RD	0.57	2.38	0	53
FDI-Green	2.11	6.67	0	138
FDI-Green-RD	0.10	0.43	0	6
Relatedness	0.11	0.04	0	0.35
Exposure to env policy (PC#1)	0	1.63	-1.18	55.16
Exposure to env policy (PC#2)	0	1.10	-1.16	11.18
EPS	0.45	0.08	0.24	0.65

3.2.4 Econometric strategy

Our baseline specification is the following:

$$GreenSpec_{it} = \phi(\alpha + FDI'_{it}\gamma + X'_{it}\theta + \lambda_{ct} + \varepsilon_{it}) \qquad (3)$$

where FDI'_{it} is the vector of FDI-related variables, X'_{it} is the vector of our controls for unobserved heterogeneity, λ_{ct} is a series of year-specific country dummies to account for country-level time-varying unobserved features, and ε_{it} an error term with standard properties.

In order to account for time-invariant unobserved heterogeneity in a flexible way, we plug among the regressors of Eq. (2) the pre-sample mean of our dependent variable, *GreenSpec*, measured in the period 1991-1994 (see Blundell et al., 2002, for an illustration of this methodology). In econometric terms, the idea is that the pre-sample mean is a good proxy of time-invariant individual (i.e. region) fixed effects. Its inclusion also enables us to control for the temporal persistence of the regional green-tech specialisation, which we expect to hold given the path-dependence that technological development usually reveals over time.

In spite of the rich set of controls we have considered, especially with respect to the stringency of environmental policies, endogeneity remains a concern in our framework. A first source of endogeneity relates to the fact that green FDIs are likely to locate where the pre-conditions for green specialization were already well developed. Accounting for the ‘historical’ green specialization (pre-sample mean) and for the region’s relatedness partly addresses this issue. Secondly, it could be the case that the (unobserved) local demand for environmental technologies at the same time contributes to green technological specialisation and attracts green FDIs. We cannot explicitly account for this unobservable component as our only proxy for local demand is GDP. However, as long as local specificities in the demand for green technologies are time-invariant or strongly persistent, the inclusion of the pre-sample mean could suffice to account for this source of endogeneity.

As we said in Section 3.2.1, in line with the literature, our preferred dependent variable is a dichotomic measure of specialisation ($GreenSpec_{it}$). As a consequence, our baseline regressions are estimated using a Probit model. However, given the superior methodological tractability of an econometric model using continuous dependent variable, as a robustness check, in Appendix E we also report results based on $GreenRTA_{it}$, using both pooled OLS and panel fixed effects estimators. In order to test whether results differ with respect to different levels of regional specialisation in the green-tech we also run quantile regression estimations.

4 Results

4.1 Baseline results

Table 3 reports the results of the estimates to address our first three RQs discussed in Section 2 (RQ1-RQ3). Before moving to our focal regressors, it is interesting to notice that the regional specialisation in the green technology appears quite a persistent phenomenon: the pre-sample mean of *GreenSpec* is always significantly positive, suggesting that the history of green-tech specialisations actually matters. More specifically, regions with a green specialization in 1991-1994 are about 18% more likely to be green specialized in 2003-2014 compared to other regions (14% for specialization defined as RTA>1.5, see Table D3 in Appendix D for marginal effects). Somehow surprisingly, the proxies we used to account for the (eco-)innovation inputs of the regions (i.e. human capital and KETs) are not significant, with the partial exception of R&D expenditure, which mainly in the more RTA demanding specifications (columns 4, 5 and 6) appears to disfavour the green-tech specialisation. Let us however retain that such an effect refers to the direction of the technological efforts undertaken by regions, and not to their outcome in terms of innovation performance, which is apparently greater in other non-green technological domains.[13]

In the baseline specifications, where technological specialisation is defined by GreenRTA>1 (columns 1, 2 and 3), the propensity to specialise in the green technology appears higher for larger regions (in terms of GDP). This advantage however disappears when we use a more demanding definition of technological specialisation (GreenRTA>1.5) (columns 4, 5 and 6). Only slightly more robust across the two RTA thresholds is the significantly negative coefficient for the region's share of country patents. Quite interestingly, the most technologically endowed regions of a country have a lower propensity to specialise in the green domain than the least endowed ones, suggesting that the acquisition of a revealed green-tech advantage is easier in regions that contribute the less to the inventive capacity of a country, and which possibly have more degrees of freedom in orienting its direction. Our proxy of agglomeration economies (population density) turns out not significant, possibly because of its rough nature in capturing a complex phenomenon. Finally, the region's performance during the years of the Great Recession (2007-2009) does not correlate with the region's propensity to specialize in green technologies.

---

[13] Although an in-depth discussion of these aspects is beyond the scope of this paper, one might venture saying that these results might also reveal that, on average, regions have historically directed most of their R&D efforts and of their human capital accumulation in areas other than environmental technologies. This argument is consistent with the fact that the attention to environmental issues and to green technology is a relatively recent phenomenon.

Table 3 – Inward FDIs and green-tech regional specialisation (RQ1, RQ2, RQ3)

Dependent variable: RTA in selected technologies (dummy)	GreenSpec if RTA>1			GreenSpec if RTA>1.5		
	(1)	(2)	(3)	(4)	(5)	(6)
GreeSpec pre-sample mean (1991-1994)	0.522***	0.520***	0.522***	0.542***	0.540***	0.541***
	(0.0681)	(0.0681)	(0.0681)	(0.0858)	(0.0859)	(0.0861)
Relatedness	5.552***	5.499***	5.564***	5.522***	5.467***	5.545***
	(0.883)	(0.881)	(0.882)	(0.920)	(0.918)	(0.918)
Region's share of country patents	-5.440***	-5.390***	-4.615**	-4.785*	-4.159*	-3.786
	(1.950)	(1.930)	(1.895)	(2.500)	(2.471)	(2.356)
KETs (lag)	0.00958	0.00555	0.00844	-0.0478	-0.0538	-0.0499
	(0.0561)	(0.0562)	(0.0562)	(0.0621)	(0.0623)	(0.0624)
log(GDP)	0.178***	0.169***	0.169***	-0.0419	-0.0542	-0.0594
	(0.0459)	(0.0457)	(0.0455)	(0.0557)	(0.0564)	(0.0563)
Growth 2007-2009 GDP pc	0.0626	0.0719	0.119	-0.636	-0.633	-0.594
	(0.904)	(0.905)	(0.906)	(1.063)	(1.061)	(1.060)
Growth 2007-2009 GDP pc x D2007-2010	1.342	1.295	1.336	0.927	0.860	0.933
	(1.080)	(1.083)	(1.086)	(1.222)	(1.226)	(1.226)
Growth 2007-2009 GDP pc x D2011-2014	-0.604	-0.576	-0.576	0.0247	0.0249	0.0585
	(1.128)	(1.131)	(1.134)	(1.325)	(1.329)	(1.333)
log(pop density)	-0.0148	-0.0154	-0.0162	-0.0210	-0.0212	-0.0213
	(0.0429)	(0.0430)	(0.0430)	(0.0505)	(0.0505)	(0.0506)
log(R&D per capita), NUTS2	-0.108*	-0.110*	-0.108*	-0.155**	-0.159**	-0.159**
	(0.0620)	(0.0620)	(0.0620)	(0.0677)	(0.0677)	(0.0678)
Share of working age pop with tertiary degree, NUTS2	-0.627	-0.569	-0.531	-0.566	-0.447	-0.459
	(1.005)	(1.003)	(1.003)	(1.336)	(1.343)	(1.343)
Exposure to env policy (PC#1)	-0.208	-0.212	-0.206	-0.310*	-0.321*	-0.318*
	(0.153)	(0.154)	(0.153)	(0.179)	(0.181)	(0.180)
Exposure to env policy (PC#2)	0.122	0.126	0.114	0.202	0.206	0.197
	(0.218)	(0.218)	(0.218)	(0.226)	(0.227)	(0.227)
EPS x Exposure to env policy (PC#1)	0.491	0.500	0.485	0.769*	0.796*	0.788*
	(0.368)	(0.370)	(0.369)	(0.430)	(0.435)	(0.433)
EPS x Exposure to env policy (PC#2)	-0.213	-0.224	-0.196	-0.430	-0.445	-0.424
	(0.494)	(0.494)	(0.494)	(0.508)	(0.510)	(0.510)
FDI	0.00000906			-0.00143		
	(0.00110)			(0.00154)		
FDI-Green		0.0173			0.0335**	
		(0.0113)			(0.0132)	
FDI-NGreeen		-0.00407			-0.0117***	
		(0.00285)			(0.00442)	
FDI-Green-RD			0.152**			0.188**
			(0.0718)			(0.0793)
FDI-Green-NRD			0.00738			0.0230*
			(0.0120)			(0.0135)
FDI-NGreen-RD			-0.0660***			-0.0558
			(0.0232)			(0.0370)
FDI-NGreen-NRD			0.000822			-0.00738
			(0.00338)			(0.00497)
Pseudo R sq	0.0943	0.0952	0.0974	0.0919	0.0944	0.0963
N	3054	3054	3054	3015	3015	3015

Probit model. Observations: NUTS3 regions for three periods (2003-2006; 2007-2010; 2011-2014). Additional variables: country-by-year dummies. Standard errors clustered by region in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Coming to the most relevant controls, in all of the specifications, as expected, the specialisation in the green technology is significantly and positively associated with our indicator of relatedness (which captures the technological proximity of pre-existing specialisations to the green technology). For what concerns the two proxies of exposure to environmental regulation, instead, they are not jointly different from zero. Even though this result could seem at odds with the wide literature about the relevance of environmental regulation for environmental technology, it should be reminded that the bulk of cross-region variation in policy stringency comes from country-level regulations and standards, which are already captured by country-year dummies. Quite interestingly, it is the combination of national level environmental policy stringency with regional exposure to environmental issues (of the first type PC#1), that appears to have a positive and significant impact on green specialisation, when using the most restrictive threshold (GreenRTA>1.5).

As far as our focal regressors and RQs are concerned, let us notice that the ambiguity in the possible impact of overall FDIs that we discussed in Section 2.1 gets reflected in a non-significant coefficient for the correlation between *FDIs* in general and *GreenSpec*: this is found both in specification (1), when the GreenRTA threshold is set at 1, and in specification (4), when it is increased to 1.5. In response to RQ1, this set of results suggest that regional inward FDIs are likely to be heterogeneous and consist of foreign activities that can have both positive and negative environmental effects also at the technological level, thus possibly eliding in the aggregate.

When it comes to RQ2, specifications (2) and (5) of Table 3 highlight that the distinction between green and non-green FDIs does actually matter. This effect is more precisely estimated when GreenRTA > 1.5. The marginal effects suggest that, on average, one additional inward green FDI project would increase the regional capacity to specialize in the green-tech with a 1.5 threshold of less than 1 percentage points (0.9%); while such a capacity reduces of 0.3% for an additional non-green FDI project.

In response to our RQ3, the functional activity in which FDIs occur also matter. Irrespectively from their being green or non-green, only FDIs in R&D significantly correlate with regional green-tech specialisation, showing the importance of their effect on the stock of knowledge of which regions can benefit from. On the contrary, business operations that MNEs carry out in the region out of the R&D domain, irrespectively from the green nature of the recipient industries, do not affect the region’s capacity to specialize in environmental technology. The knowledge embodied in other functional activities carried out by foreign affiliates (e.g. engineering, production, marketing) does not appear enough to feed inventive activities in the green domain that are higher than average. When FDIs in R&D are considered, results provide an interesting qualification to those obtained with respect to green and non-green FDIs in the aggregate. When green FDIs occur in R&D, there appear to be a greater array of effects, enabling regions to get a green-tech specialisation of any level, i.e., for both RTA>1 (specification 3) and RTA>1.5 (specification 6). On the other hand, the fact of occurring in R&D makes the de-specialisation effect of non-green FDIs in general more “restrictive”, leading regions to reduce their green-tech specialisation even at the lower threshold level (RTA>1, specification 3). Finally, average marginal effects suggest that both the effects are indeed sizable. An additional green FDI project in R&D increases the *GreenSpec* probability by about 5 percentage points (5.3% for RTA>1 and 4.9% for RTA>1.5). Conversely, one more non-green FDI project in R&D activities reduces the *GreenSpec* probability by 1-2 percentage points (2.3% for RTA>1 and 1.4% for RTA>1.5, though not significant).

Overall, the spectrum of foreign operations through which FDIs can affect the regional capacity to specialise in green-tech appears quite circumscribed, not only in terms of industries in which FDIs occur, but also in terms of their functional activities. What is more, the regional specialisation in the green technology is very sensitive to nature of FDI: not only do green FDI in R&D favour its occurrence, but non-green FDIs in R&D disfavour it. In other words, it is likely that R&D FDIs in non-green industries favour innovation in domains that are not environmentally friendly, which translates into a lower probability that the region achieves a green technological specialisation.

In addressing RQ4, Table 4 reports the results of the effects exerted by FDI variables in the estimates of Eq. (3) by distinguishing between regions that were and were not specialised in green technologies at t-1 (Table D4 in Appendix D reports average marginal effects).[14]

Significant effects of FDIs on regional specialisation in environmental technologies emerge almost exclusively with respect to *regions that are already specialised in green*

---

[14] Additional variables and dummies are not reported but the relative estimates are consistent and available from the authors upon request.

technologies (in t–1). It thus appears that FDIs do not help non-green-tech specialised regions to make the switch to a green-tech specialisation, providing a negative answer to RQ4. All of the effects we had detected in Table 3 without distinguishing the green-tech starting point of regions vanish with respect to non-specialised ones. Although very weakly significant, the only exception is represented by non-green FDIs in R&D, which make non-specialised regions less likely to switch to green technologies (*FDI-NGreen-RD* is negative for the regions at stake, though for the lower threshold only).

Overall, results about non-green specialised regions suggest that a pre-existing experience in the green technology is a necessary condition for the knowledge and competencies brought by inward FDIs to have an effect, namely in keeping and/or reinforcing the relative specialisation.

Findings illustrated in Table 4 hence suggest that, if the region has already a specialisation in green-technologies and has thus possibly acquired a greater capacity to absorb green-tech knowledge from outside, it is in a better position to take advantage from green FDIs in keeping a specialisation in environmental technologies. In other words, the strict spectrum of foreign operations that affect the regional green-tech specialisation in general, becomes wider when regions are already specialised in environmental technologies, and are thus well placed to absorb relevant knowledge through FDIs as to maintain and even reinforce their specialisation.

When already specialised regions are considered, also results about the effect of non-green FDIs take on some interesting nuances. *FDI-NGreen* do not only reduce the region’s capacity to keep the green-tech specialisation that it had previously acquired (though for the higher RTA threshold only), as expected and consistently with Table 3. But the same emerges true also for non-green FDIs in activities other than R&D (*FDI-NGreen-NRD* is significantly negative, though for the higher RTA threshold only). A possible explanation of this result is that foreign non-green operations induces the region to target alternative non-green technologies and that this occurs also (and especially) when these are non-innovative operations. Quite symmetrically, in the case of Green FDIs it is not only R&D FDIs that reinforce the green-tech specialisation of regions that are already specialised in environmental technologies. Also Green FDIs in activities other than R&D appear to have an effect in the same direction, although with a lower impact than in the case of Green FDIs in R&D.

Table 4 – Persistence vs switch in the regional green-tech specialization (RQ4)

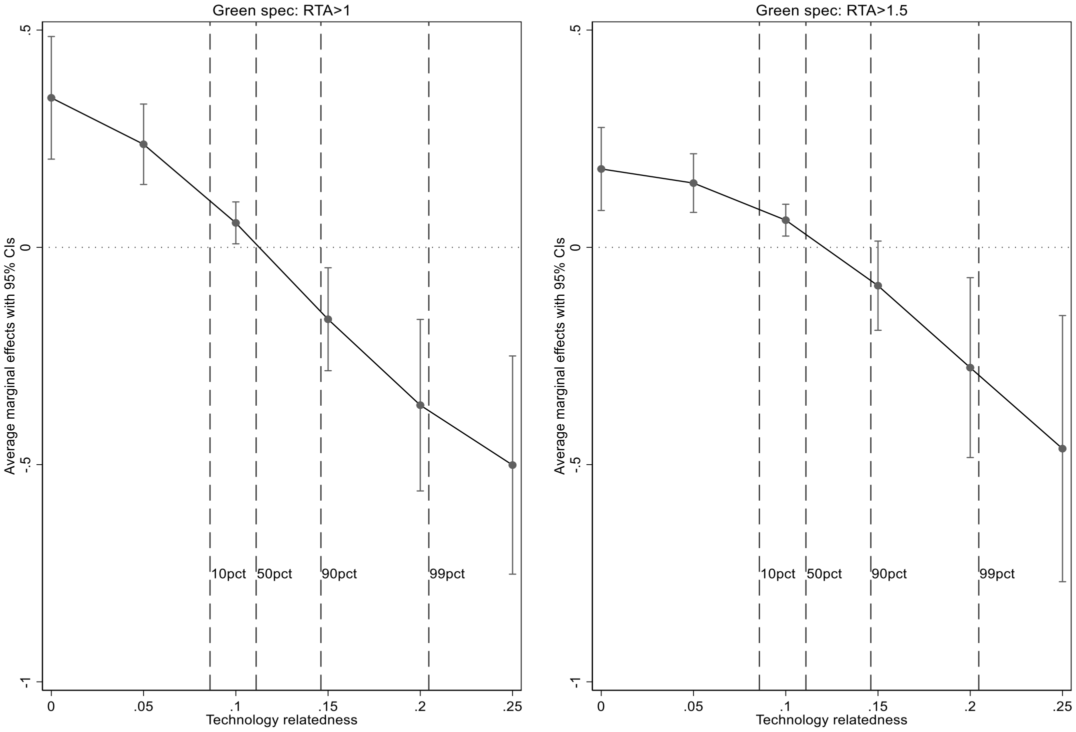
Dependent variable: RTA in selected technologies (dummy)	GreenSpec if RTA>1		GreenSpec if RTA>1.5	
	(1)	(2)	(3)	(4)
FDI-Green	-0.00948		0.00757	
(*Non-green specialised regions*)	(0.0146)		(0.0144)	
FDI-Green	0.0477***		0.137***	
(*Green specialised regions*)	(0.0182)		(0.0307)	
FDI-NGreen	-0.00679		-0.00802	
(*Non-green specialised regions*)	(0.00450)		(0.00596)	
FDI-NGreen	-0.00587		-0.0327***	
(*Green specialised regions*)	(0.00459)		(0.00889)	
FDI-Green-RD		-0.102		0.116
(*Non-green specialised regions*)		(0.124)		(0.0967)
FDI-Green-RD		0.311***		0.487**
(*Green specialised regions*)		(0.119)		(0.191)
FDI-Green-NRD		-0.00877		-0.00176
(*Non-green specialised regions*)		(0.0165)		(0.0142)
FDI-Green-NRD		0.0331*		0.114***
(*Green specialised regions*)		(0.0190)		(0.0338)
FDI-NGreen-RD		-0.0731*		-0.0625
(*Non-green specialised regions*)		(0.0426)		(0.0460)
FDI-NGreen-RD		0.00194		0.0393
(*Green specialised regions*)		(0.0458)		(0.0878)
FDI-NGreen-NRD		-0.00166		-0.00243
(Non-green specialised regions)		(0.00649)		(0.00566)
FDI-NGreen-NRD		-0.00479		-0.0322***
(Green specialised regions)		(0.00561)		(0.0123)
Pseudo R sq	0.108	0.111	0.104	0.107
N	3054	3054	3015	3015

Probit model. Observations: NUTS3 regions for three periods (2003-2006; 2007-2010; 2011-2014). Additional variables: country-by-year dummies, GreeSpec pre-sample mean (1991-1994), Relatedness, Region's share of country patents, KETs (lag), log(GDP), GDP growth in 2007-2009 interacted with time dummies, log(pop density), log(R&D per capita) of NUTS2, Share of working age population with tertiary degree of NUTS2, Exposure to env policy (PC#1), Exposure to env policy (PC#2), EPS x Exposure to env policy (PC#1), EPS x Exposure to env policy (PC#2). Standard errors clustered by region in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

In interpreting previous results about the effect of FDIs on the green-technological specialisation of regions, it is important to consider that these hold true *ceteris paribus*, that is, for an average level of other regional characteristics, including the degree of technological relatedness. However, as we have argued in Section 2.3, technological relatedness can be expected to moderate the effect of FDIs on the regional green-tech specialisation (RQ5) and also in determining their impact on the regional capacity to switch from a non-green to a green-technology specialisation (RQ6). To explore the possible moderating role of technology relatedness, we extend the specifications of Eq.

(3) which we used to test RQ3 and RQ4, by interacting FDIs variables with the technology relatedness variable.

Figure 3 – Average marginal effects of FDI-Green-RD for different levels of relatedness (RQ5)



Given the driving role that we have recognised for green R&D FDIs, Figure 3 shows the moderating effect that relatedness exerts on their impact on *GreenSpec*, irrespectively from the initial green-tech specialisation of regions (RQ5).[15] Quite interestingly, the marginal effect of *FDI-Green-RD* is positive for regions that at t-1 were specialised in technologies with relatedness to the green-technology below the median, reaching a maximum for very low relatedness values, that is when green-technologies are less bounded by the cognitive proximity to pre-existing specialisations of the recipient region. Against this background, green-FDIs in R&D bring external knowledge that allows the region a larger leap from technologies relatively more unrelated to the green-tech. A different way to read this finding is that, in the absence of R&D green-FDI, the

---

[15] Estimation tables are reported in Appendix C: Table C3 for RQ5 and Table C4 for RQ6. Marginal effects of FDI-NGreen-RD conditional on different values of relatedness are available upon request from the authors. It is worth noting that these are generally negative for regions with relatedness below the median and positive but quite imprecisely estimated for high relatedness values: the marginal effect is positive and significant only for some outliers regions (above 90th percentile of relatedness).

specialisation in green technology occurs mainly when the latter is highly related to pre-existing knowledge base of the region, confirming previous evidence about its place dependence; and it is extremely unlikely for regions that are specialised in technologies which are most unrelated to the green-technology. The marginal effect of *FDI-Green-RD* attenuates when relatedness increases and becomes even negative in regions where prior specialisation was highly related to the green technology (although this negative effect is significant only around the 90th and 99th percentile when RTA threshold is set at 1 and 1.5 respectively). Hence, when relatedness is very high, the spanning role of external knowledge brought in by MNEs through their Green R&D FDIs - which might eventually favour green-tech specialisation - clashes with the binding role of the relatedness to pre-existing knowledge.

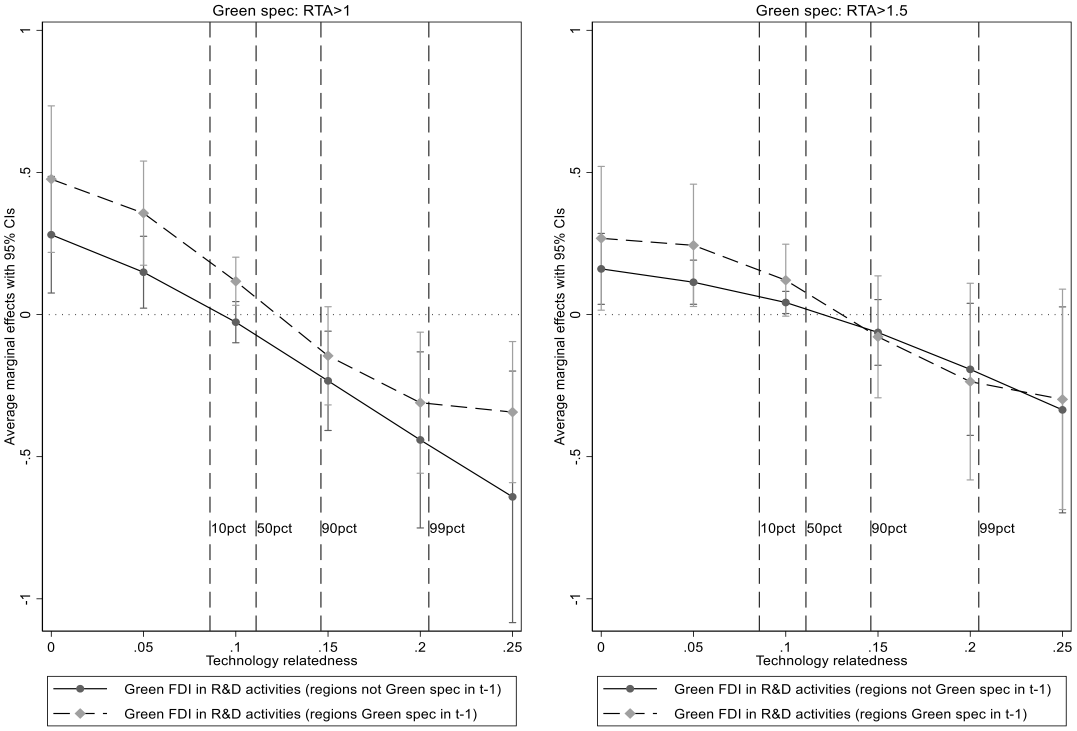
As a final step in our analysis, Figure 4 reports the average marginal effects of *FDI-Green-RD* with respect to RQ6, where we consider whether the moderating role played by technological relatedness differs between regions that were or were not already specialized in green technologies.[16] Somehow confirming previous results in Table 4, the largest marginal effect of green R&D FDIs is observed in regions that were already specialised in green-technologies (dotted lines), providing the regional portfolio of pre-existing technological specialisations was relatively unrelated to the green-tech. A new important result however emerges with respect to what we found in Table 4, where the effect of *FDI-Green-RD* on the green-tech specialisation of non-specialised regions was not significant. Provided that relatedness is very low (approximately below the 10th percentile), green FDIs in R&D now positively correlate also with the regional capacity to switch from non-green to the green-tech specialisation. Quite interestingly, under these circumstances, FDIs thus appear to play also a "strong" structural change effect on the hosting regions, favouring their "green (tech) transition". Indeed, this effect exclusively materialises with respect to green-technologies that are less bounded by the place-dependent effect of relatedness. While, in general, we have identified a weak structural change effect of FDI-Green-RD, in attenuating the role of relatedness, we here highlight that Green FDIs in R&D are also conducive to a "strong" structural change effect, leading

---

[16] Marginal effects of FDI-NGreen-RD conditional on different values of relatedness are still available upon request from the authors.

to a switch from non-green to green-tech specialisation when environmental technologies are highly unrelated to prior specialisation of regions.

Figure 4 – Average marginal effects of FDI-Green-RD for different levels of relatedness: green vs non-green specialized (in t-1) regions (RQ6)



A quick note is due about the fact that, in spite of its limited conceptual fitting with the innovation geography perspective we are following, the estimates of our econometric model with respect to the continuous variable RTA, as defined in Eq.(2), confirms the role that green FDIs in R&D has revealed with respect to GreenSpec (see Appendix E). Many of the results obtained with respect to variables that are expected to favour the “entry” of the green-technology in the regional knowledge-base vanish or get substantially changed. However, it is interesting to notice that, overall, FDI-Green-RD could have a role also in increasing the regional specialisation in the green tech along the intensive margin. In addition, it is worth highlighting that once we turn to linear regression models in Appendix E, we can provide further evidence on robustness of our baseline results. In particular, when using GreenSpec as a dependent variable, we can compare results from a Pooled OLS with pre-sample mean and a within-group (regional fixed effects) model. Our findings reveal that the two specifications yield very similar estimates, thus reassuring us on the ability of the pre-sample mean to account for regional unobserved heterogeneity. Furthemore, using *GreenSpec* as a dependent variable, Figure E1 (in Appendix E) shows the results of the quantile estimation of the model we have used to address RQ3 (see Table 3). Focusing on our main variables of interest, we do not observe substantial heterogeneity in the relationship between FDI and regional green-tech specialisation at different quantiles.

4.2 Heterogeneous effects

Further insights about the relationship between inward FDIs and regional green-tech specialisation can be obtained by distinguishing different kinds of environmental technologies and different types of specialising regions.

As regards the characteristics of green technologies, the literature has increasingly emphasised the differences in their stage of development, detectable by looking at the regional spread (i.e. number of areas specialized in the technology, as a proxy of diffusion) and at the patenting intensity in each green technology field. To account for the these characteristics of green technologies, we followed Perruchas et al. (2020) and Barbieri et al. (2020a) and considered the four stages of the technology lifecycle (TLC)– i.e. 'emergence' (TLC1), 'development' (TLC2), diffusion' (TLC3), and 'maturity' (TLC4) - and re-allocated each 2-digit class of our OECD-ENVTECH taxonomy to one of the four TLC phases.[17] Given the very low number of patents assigned to some stages and regions, in order to preserve the efficiency of our estimates we have grouped together the 'emergence' (TLC1) and 'development' (TLC2) classes, sharing a high geographical concentration, into the group "early stage" green-technologies; similarly, we have assembled the 'diffusion' (TLC3) and 'maturity' (TLC4) classes, characterized by a growing geographical diffusion and standardization, into the group "later stage" green-technologies. We have then used this bipartition to re-estimate, for each of the two groups of green technologies, the parsimonious version of our model that addresses RQ3, without distinguishing between already green-tech specialized and not specialized regions (see Table 3).

Table 5 shows that our main results are invariant with respect to the maturity of the considered environmental technologies. Inward FDIs in R&D favour the regional

---

[17] We consider the 2000 rather than the 2010 definition. Results based on the 2010 definition are qualitatively very similar and remain available upon request.

specialisation only when they are green, and they do so for green technologies at both at an early (Column 1) and late (Column 2) stage of the lifecycle. However, important differences emerge by looking at marginal effects in Table D5 (in the Appendix D). In particular, the impact of green FDIs in R&D on regional specialization is almost twice as large for more mature environmental technologies compared to less mature ones. This suggests that the entry of foreign knowledge in the region can more effectively recombine with local competencies when the properties and the characteristics of the target green technologies are already established and possibly standardised.

Table 5 – RQ3 for green technologies at different stages of the technology life-cycle

Dependent variable: RTA in selected technologies (dummy) broken down by technology lifecycle stage	(1) Early stage green-tech (TLC1-2; 2000 definition)	(2) Later stage green-tech (TLC3-4; 2000 definition)
FDI-Green-RD	0.149**	0.213**
	(0.0688)	(0.0930)
FDI-Green-NRD	-0.00475	-0.00814
	(0.0126)	(0.0123)
FDI-NGreen-RD	-0.0590**	-0.0394*
	(0.0293)	(0.0212)
FDI-NGreen-NRD	0.00289	0.00187
	(0.00257)	(0.00293)
Pseudo R sq	0.0872	0.107
N	3006	3041

Probit model. Observations: NUTS3 regions for three periods (2003-2006; 2007-2010; 2011-2014). Additional variables: country-by-year dummies, GreeSpec pre-sample mean (1991-1994), Relatedness, Region's share of country patents, KETs (lag), log(GDP), GDP growth in 2007-2009 interacted with time dummies, log(pop density), log(R&D per capita) of NUTS2, Share of working age population with tertiary degree of NUTS2, Exposure to env policy (PC#1), Exposure to env policy (PC#2), EPS x Exposure to env policy (PC#1), EPS x Exposure to env policy (PC#2). Standard errors clustered by region in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

As for the heterogeneity across types of regions, we have focused on four differentiating characteristics that are particularly salient in dealing with regional green technologies: i) the level of economic outcome during the Great Recession, as the regions' capacity to benefit from FDIs in reaching a green-tech specialisation could vary with their resilience to this big shock; ii) population density, as the effect of FDIs on green-tech specialisation could be stronger in areas that benefit from larger infrastructures and agglomeration economies (such are metropolitan areas); iii) country-level environmental regulatory stringency (captured by the EPS indicator), as in regions within more stringent countries our focal relationship could find a higher regulatory push; iv) R&D per capita, as the green-tech impact of FDIs could be favoured, if not even conditioned, by a higher level of local inventive activities and absorptive capacity.

Table 6 – RQ3 for regions with different characteristics

Dependent variable: RTA in selected technologies (dummy)	(1)	(2)	(3)	(4)
FDI-Green-RD	0.309**	0.0151	0.0937	0.0276
	(0.124)	(0.124)	(0.116)	(0.141)
FDI-Green-NRD	0.00810	0.0100	0.00878	0.00664
	(0.0175)	(0.0209)	(0.0164)	(0.0180)
FDI-NGreen-RD	-0.0159	-0.0779*	-0.0495	-0.0143
	(0.0399)	(0.0462)	(0.0310)	(0.0410)
FDI-NGreen-NRD	-0.00205	0.0145	0.000185	0.00254
	(0.00478)	(0.00932)	(0.00465)	(0.00655)
FDI-Green-RD	-0.240			
x GDP growth 07-09 < median (dummy)	(0.154)			
FDI-Green-NRD	-0.00109			
x GDP growth 07-09 < median (dummy)	(0.0245)			
FDI-NGreen-RD	-0.0795			
x GDP growth 07-09 < median (dummy)	(0.0507)			
FDI-NGreen-NRD	0.00232			
x GDP growth 07-09 < median (dummy)	(0.00688)			
FDI-Green-RD		0.205		
x Pop density > median (dummy)		(0.157)		
FDI-Green-NRD		-0.0143		
x Pop density > median (dummy)		(0.0248)		
FDI-NGreen-RD		-0.0133		
x Pop density > median (dummy)		(0.0543)		
FDI-NGreen-NRD		-0.0107		
x Pop density > median (dummy)		(0.0102)		
FDI-Green-RD			0.0654	
x EPS > median (dummy)			(0.138)	
FDI-Green-NRD			-0.00285	
x EPS > median (dummy)			(0.0214)	
FDI-NGreen-RD			-0.0600	
x EPS > median (dummy)			(0.0484)	
FDI-NGreen-NRD			0.00278	
x EPS > median (dummy)			(0.00525)	
FDI-Green-RD				0.170
x R&D pc > median (dummy)				(0.161)
FDI-Green-NRD				-0.0101
x R&D pc > median (dummy)				(0.0229)
FDI-NGreen-RD				-0.117**
x R&D pc > median (dummy)				(0.0509)
FDI-NGreen-NRD				0.00331
x R&D pc > median (dummy)				(0.00760)
Pseudo R-sq	0.0899	0.0920	0.0880	0.0898
N	3054	3054	3054	3054

Probit model. Observations: NUTS3 regions for three periods (2003-2006; 2007-2010; 2011-2014). Additional variables: country-by-year dummies, GreeSpec pre-sample mean (1991-1994), Relatedness, Region's share of country patents, KETs (lag), log(GDP), GDP growth in 2007-2009 interacted with time dummies, log(pop density), log(R&D per capita) of NUTS2, Share of working age population with tertiary degree of NUTS2, Exposure to env policy (PC#1), Exposure to env policy (PC#2), EPS x Exposure to env policy (PC#1), EPS x Exposure to env policy (PC#2). Standard errors clustered by region in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

We have then re-estimated the model for RQ3 (see Table 3) by building a dummy that captures the regions' position with respect to the median of each of the four variables and by interacting it with our focal FDI regressors. Table 6 reports the results of these estimates and Table D6 (in the Appendix D) the relative marginal effects.

The first column of Table 6 shows that green FDIs in R&D exert a significantly positive effect on green technology specialization only for regions that were not badly hit by the 2008-2009 recession[18]. Furthermore, Table D6 in Appendix D reveals that non-green FDIs in R&D have a negative effect on the same specialisation in the regions that have experienced a large collapse in the aftermath of the same recession. This is quite interesting and might suggest that the local resilience to large economic shocks represents a necessary context condition for green FDIs in R&D to favour the regional specialisation in environmental technologies. Indeed, a large resilience (i.e. a low impact of the recession) seems even capable to neutralize the negative effect that non-green FDIs in R&D otherwise (high impact) exert on the same capacity.

Coming to population density, while the negative effect of non-green FDIs in R&D is somehow ubiquitous (Table 6, column 2), Table D6 in Appendix D shows that the positive effect green FDIs is fully driven by the more populated regions. This is an important result, hinting that foreign green investments in R&D may foster the local development of Greentech specialisation exclusively in the presence of those urbanisation and agglomeration advantages that are present in the more densely populated areas (such as metropolitan areas). The average positive effect we have detected for green FDIs in R&D in Table 3 does also appear mainly driven by regions within relatively more environmentally stringent countries (Table D6, Appendix D), pointing to a wider spectrum of applications of the regulatory-push approach to EIs. Lastly, our focal relationship between green FDIs in R&D and green-tech specialisation appears to be moderated by a high level of R&D intensity in the specialising regions, suggesting that an appreciable local endowment of innovative knowledge and absorptive capacity is crucial to leverage R&D FDI into fostering regional specialisation in environmental technologies.

---

[18] This finding is quite consistent with the descriptive evidence offered in section 3.2.1 on changes in green-tech specialisation of regions in times of crisis

5 Conclusions

This paper investigates the extent to which FDIs can contribute to the regional specialization in green technologies. Given the increasing openness that regions are experimenting in the era of the global value chains (De Marchi et al., 2018), we have argued that the role of FDIs in helping regions to develop eco-innovations and master new green technologies is extremely important and in need of more in-depth investigation. In fact, the intersections between research on the geography of eco-innovation and green technologies, and on international business studies have been limited so far and have at most enabled us to identify research questions that we have contributed to address. Does the direction of technological change entailed by eco-innovations require a certain "greenness" of inward FDIs for regions to move along it? Which kinds of FDIs and MNEs strategies fit with a green regional technological specialisation? Could FDIs enable regions to shift from non-green to green-tech specialisations? Do FDIs interfere with the recombinatory processes of related knowledge through which also eco-innovations have been shown to emerge at the regional level?

Through an original combination of different datasets, we have addressed these research questions on a systematic basis, with respect to a large sample of European regions at a quite disaggregated level of analysis (i.e. NUTS3) over the period 2003-2014. In so doing, we have also contributed to test and generalise a set of insights about eco-innovations and FDIs that previous studies had obtained mainly through case-studies and/or with respect to specific country-based surveys.

Our results show that inward greenfield FDIs can have significant effects on the regional green-tech specialisation. These effects, however, are mostly driven by FDIs involving R&D activities in industries wherein green technologies play a salient role. Instead FDIs in non-green industries may reduce a region's probability of obtaining a green specialisation. These effects appear to be largely limited to regions that were already green-tech specialised suggesting the importance of pre-existing experience in environmental technologies. The same effects emerge conditional to the level of relatedness of the green-technology to the knowledge-base of the region, and are higher for lower levels of it. In particular, in the presence of very low relatedness, that is, in the absence of a cognitively binding knowledge base, green inward FDIs in R&D can even favour a strong structural change towards environmental technologies in regions with a non-green tech starting point. Quite interestingly, the relationships that we have identified between green and non-green FDIs in R&D and regional specialisation in environmental technologies appear robust across different vintages of them along their technological lifecycle. In addition, we found that the impact of green FDIs significantly differs according to specific characteristics of regions. In particular, the positive and significant effect of green FDIs in R&D on green-tech specialisation that we have observed aand discussed is mainly at work in regions that: are densely populated, are marked by high R&D intensity, exhibit a relatively high resilience to deep crises (as the Great Recession) and belong to countries with highly stringent environmental regulations.

These results have important implications, in terms of both research and policy. As for the former, we suggest that FDIs can contribute to the greening of a region's knowledge base, and thus possibly to a more sustainable local development, but only through a restricted set of specific foreign operations. In so doing, we suggest that the progress in the combination between innovation geography and international business studies should proceed by adopting a highly granular approach, not only to the kinds of technologies that regions develop but also of the FDIs that they receive. Moreover, we also observe a sort of substitutability between the 'external' contribution to green knowledge related to green R&D FDIs and the 'internal' contribution to green knowledge in terms of related knowledge bases of the region. This suggest that, when it comes to the green transition, the ascertained role of MNEs as agents of structural change face some cognitive trade-offs on which we need further research.

In terms of policy, our results suggest that favouring inward FDIs and supporting the insertion of local firms into global value chains could help the green transition, but still under certain conditions, which policy makers should carefully retain in supporting the green transition of regions. In particular, in favouring environmental sustainability through technological development, regional policy makers need to be capable to target specific types of FDIs and to deal with the possible crowding out effect that local green-related knowledge exerts on 'foreign' green knowledge. Combining relatedness and (external) connectivity thus appears to be a fundamental policy challenge to deal with to favour regional smart and sustainable specialisation. The heterogenous effects that we have detected across regions of different kinds, also suggest that, as usual, the policy support to the relationship at stake should be evidence-based and context-specific.

As usual, our work is not free from limitations, mainly due to aspects that we have not explicitly considered in the analysis, and on which future research could focus. Firstly, more conceptual and refined empirical work is required to disentangle the extent to which the results we got reflect the inventive activities of MNEs' subsidiaries located in the regions – direct effects – rather than the spillovers they have on the local firms with which they interact along the value chain – indirect effects. Secondly, a more granular spatial analysis would be needed to investigate the extent to which the indirect effects of FDIs concentrate in the hosting regions and distribute across the neighbouring ones. Thirdly, the integration of additional datasets could help in disentangling if the results we obtained with respect to greenfield FDIs extend to the consideration of Mergers and Acquisitions (M&As). Fourthly, the proposed research questions could be refined in different respects, for example, by better identifying the role of MNEs' strategies in determining their effects on regional specialisation; and by distinguishing the degree of economic development and the technological profile of the FDI home countries and by considering their matching with those of the hosting regions. This is just a limited set of open issues, for whose analysis the results we have obtained could hopefully provide a useful starting point.

References

Acs, Z. J., Anselin, L., and Varga, A. (2002). Patents and innovation counts as measures of regional production of new knowledge. Research Policy 31 (7): 1069–85. doi:10.1016/S0048-7333(01)00184-6.

Aguilera-Caracuel J, Aragón-Correa JA, Hurtado-Torres NE, Rugman AM (2012) The effects of institutional distance and headquarters' financial performance on the generation of environmental standards in multinational companies. Journal of Business Ethics, 105(4):461–474.

Albornoz F, Cole MA, Elliott RJR, Ercolani MG (2009) In search of environmental spillovers. World Economy, 32(1):136–163.

Antonioli D, Borghesi S, Mazzanti M (2016) Are regional systems greening the economy? Local spillovers, green innovations and firms' economic performance. Economics of Innovation and New Technology, 25(7):692-713.

Arranz NF, Arroyabe C, Fernandez de Arroyabe JC (2019) The effect of regional factors in the development of eco-innovations in the firm. Business Strategy and the Environment, online first.

Ascani A, Iammarino S (2018) Multinational enterprises, service outsourcing and regional structural change. Cambridge Journal of Economics, 42(6):1585–1611.

Balland PA, Boschma R, Crespo J, Rigby DL (2018) Smart Specialization policy in the European Union: Relatedness, knowledge complexity and regional diversification. Regional Studies, 53:1252–1268.

Balland PA (2016) Relatedness and the geography of innovation. in Shearmu R, Carrincazeaux C, Doloreux D (eds) Handbook on the Geographies of Innovation. London, Edward Elgar.

Barbieri N, Consoli D (2019) Regional diversification and green employment in US metropolitan areas. Research Policy, 48:693-705.

Barbieri N, Ghisetti C, Gilli M, Marin G, Nicolli F (2016) A survey of the literature on environmental innovation based on main path analysis. Journal of Economic Surveys, 30(3):596–623.

Barbieri N, Perruchas F. Consoli D (2020a) Specialization, diversification and environmental technology-life cycle. Economic Geography, 96(2), 161-186, DOI: 10.1080/00130095.2020.1721279.

Barbieri N, Marzucchi A, Rizzo U (2020b) Knowledge sources and impacts on subsequent inventions: Do green technologies differ from non-green ones? Research Policy, 49(2):103901.

Beise M, Rennings K (2005) Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations. Ecological Economics, 52(1):5-17.

Belitz H, Mölders F (2016) International knowledge spillovers through high-tech imports and R&D of foreign-owned firms. The Journal of International Trade & Economic Development, 25(4):590-613.

Binz C, Truffer B (2017) Global Innovation Systems—A conceptual framework for innovation dynamics in transnational contexts. Research Policy, 46(7):1284-1298.

Blundell R, Griffith R, Windmeijer F (2002) Individual effects and dynamics in count data models. Journal of Econometrics, 108(1):113–131.

Boschma R. (2017) Relatedness as driver of regional diversification: a research agenda Regional Studies, 51:3, 351-364, DOI: 10.1080/00343404.2016.1254767

Boschma R (2015) Proximity and Innovation: A Critical Assessment. Regional Studies, 39(1):61-74.

Boschma R, Coenen L, Frenken K, Truffer B (2017) Towards a theory of regional diversification: combining insights from Evolutionary Economic Geography and Transition Studies. Regional Studies, 51(1):31-45.

Botta, E. and T. Koźluk (2014), “Measuring Environmental Policy Stringency in OECD Countries – A Composite Index Approach”, OECD Economics Department Working Papers, No 1177, OECD Publishing.

Braconier H, Ekholm K, Midelfart Knarvik KH (2001) In search of FDI-transmitted R&D spillovers: A study based on Swedish data. Review of World Economics, 137(4):644–665.

Cainelli G, Mazzanti M, Montresor S (2012) Environmental innovations, local networks and internationalization, Industry and Innovation, 19(8):697-734.

Cantwell J (1989) Technological Innovation and Multinational Corporations. Basil Blackwell, London.

Carr F, Massey A (2006) Public policies and the new European agendas. Edward Elgar, Cheltenham, UK.

Carraro C, Topa G (1994) Should environmental innovation policy be internationally coordinated? in Carraro C (Ed.) Trade, innovation, environment. Dordrecht, The Netherlands: Springer.

Castellani D, Mancusi ML, Santagelo MD, Zanfei A (2015). Exploring the links between offshoring and innovation. Economia e Politica Industriale, 42(1):1–8.

Castellani D, Zanfei A (2006) Multinational Firms, Innovation and Productivity. Edward Elgar, Cheltenham.

Chiarvesio M, De Marchi V, Di Maria E (2015) Environmental innovations and internationalization: Theory and practices. Business Strategy and the Environment, 24 (8):790-80.

Cole MA, Elliott RJR, Zhang L (2017) Foreign Direct Investment and the Environment, Annual Review of Environment and Resources. 42:465–87.

Cole MA, Elliott RJR, Strobl E (2008) The environmental performance of firms: the role of foreign ownership, training, and experience. Ecological Economics, 65(3):538–546.

Colombelli A, Quatraro F (2019) Green start-ups and local knowledge spillovers from clean and dirty technologies. Small Business Economics, 52(4):773-792.

Consoli D, Castellacci F, Santoalha A (2019) Do digital skills foster green diversification? A study of European regions. Working Papers on Innovation Studies 20191029, Centre for Technology, Innovation and Culture, University of Oslo.

Cooke P (2011) Transition regions: Regional-national eco-innovation systems and strategies. Progress in Planning, 76:105-146.

Cooke P (2012) Transversality and transition: green innovation and new regional path creation. European Planning Studies, 20(5):817-834.

Corradini C (2019) Location determinants of green technological entry: evidence from European regions. Small Business Economics, 52:845-858.

Costantini V, Crespi F, Palma A (2017) Characterizing the policy mix and its impact on eco - innovation: A patent analysis of energy - efficient technologies. Research Policy, 47:799–819.

Crescenzi R, Gagliardi L, Iammarino S (2015) Foreign multinationals and domestic innovation: Intra-industry effects and firm heterogeneity. Research Policy, 44:596–609.

Dachs B, Peters B (2014) Innovation, employment growth, and foreign ownership of firms: A European perspective. Research Policy, 43(1):214-232.

De Marchi V, Di Maria E, Khrishnan A, Ponte S (2020) Environmental Upgrading in Global Value Chains. In Gereffi G, Raj-Reichert G, Ponte S (Eds.) Research Handbook of Global Value Chains. Edward Elgar.

De Marchi V, Gereffi G (2018) Local clusters in global value chains: linking actors and territories through manufacturing and innovation. Abingdon, UK, Routledge.

Dechezleprêtre A, Glachant M (2014) Does Foreign Environmental Policy Influence Domestic Innovation? Evidence from the Wind Industry. Environmental and Resource Economics, 58(3):391-413.

Dosi G (1982) Technological paradigms and technological trajectories. Research Policy, 11:147-162.

European Commission (2012) Connecting smart and sustainable growth through smart specialisation. S3 Smart Specialisation platform.

EEA (2020). The sustainability transition in Europe in an age of demographic and technological change. An exploration of implications for fiscal and financial strategies. European Environment Agency. Luxembourg: Publications Office of the European Union, 2020ISBN 978-92-9480-238-5ISSN 1977-8449doi:10.2800/571570

Elekes Z, Boschma R, Lengyel B (2019) Foreign-owned firms as agents of structural change in regions. Regional Studies, 1-11.

Fu X (2008) Foreign direct investment, absorptive capacity and regional innovation capabilities: evidence from China. Oxford Development Studies, 36(1):89-110.

Geels FW (2002) Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Research Policy, 31:1257–1274.

Gibbs D (2006) Prospects for an environmental economic geography: linking ecological modernization and regulationist approaches. Economic Geography, 82:193–215.

Gibbs D, O’Neill K (2017) Future green economies and regional development: a research agenda. Regional Studies, 51(1):161-173.

Giudici G, Guerini M, Rossi-Lamastra C (2019) The creation of cleantech startups at the local level: the role of knowledge availability and environmental awareness. Small Business Economics, 52:815–830.

Greeninvest (2017) Green foreign direct investment in developing countries. United Nations Environment Programme.

Griffith R, Harrison R, Van Reenen J (2006) How special is the special relationship? Using the impact of US R&D spillovers on UK firms as a test of technology sourcing. American Economic Review, 96(5):1859–1875.

Guadalupe M, Kuzmina O, Thomas C (2012) Innovation and Foreign Ownership. American Economic Review, 102(7):3594–3627.

Haščič I, Migotto M (2015) Measuring environmental innovation using patent data. OECD Environment Working Papers 89, OECD Publishing, Paris.

Horbach J (2014) Do eco-innovations need specific regional characteristics? An econometric analysis for Germany. Review of Regional Research, 34(1):23-38.

Kawai N, Strange R, Zucchella A (2018) Stakeholder pressures, EMS implementation, and green innovation in MNC overseas subsidiaries. International Business Review, 27(5):933-946.

Kim J, Shin J (2018) Mapping extended technological trajectories: integration of main path, derivative paths, and technology junctures- Scientometrics, 116(3):1439–1459.

Kokko A, Tansini R, Zejan M (1996) Local Technological Capability and Productivity Spillovers from FDI in the Uruguayan Manufacturing Sector. Journal of Development Studies, 32(4):602-611.

Kortum S, Putnam J (1997) Assigning Patents to Industries: Tests of the Yale Technology Concordance. Economic Systems Research, 9(2):161-176.

He, C., Yan, Y. & Rigby, D. (2018). Regional industrial evolution in China, Papers in Regional Science, 97(2), 173-199

Leoncini R, Montresor S, Rentocchini F (2016) CO2-reducing innovations and outsourcing: evidence from photovoltaics and green construction in North-East Italy. Research Policy, 45(8):1649-1659.

Lybbert TJ, Zolas NJ (2014) Getting patents and economic data to speak to each other: An ‘Algorithmic Links with Probabilities’ approach for joint analyses of patenting and economic activity. Research Policy, 43:530– 542.

Marin A, Sasidharan S (2010) Heterogeneous MNC subsidiaries and technological spillovers: Explaining positive and negative effects in India. Research Policy, 39(9):1227-1241.

Marin G, Zanfei A (2019) Does host market regulation induce cross-border environmental innovation? The World Economy, 42(7):2089-2119.

Montresor S, Quatraro F (2019) Green technologies and smart specialisation strategies: a European patent-based analysis of the intertwining of technological relatedness and Key-Enabling-Technologies. Regional Studies (online first).

Nelson R, Winter S (1977) In search of a useful theory of innovation. Research Policy, 6:36-76.

Ning, L., Wang, F. (2018). Does FDI Bring Environmental Knowledge Spillovers to Developing Countries? The Role of the Local Industrial Structure. Environ Resource Econ 71, 381–405. https://doi.org/10.1007/s10640-017-0159-y

Noailly J, Ryfisch D (2015) Multinational firms and the internationalization of green R&D: A review of the evidence and policy implications. Energy Policy, 83:218–228.

Papanastassiou M, Pearce R, Zanfei A (2020) Changing perspectives on the internationalization of R&D and innovation by multinational enterprises. A review of the literature. Journal of International Business Studies, 51:623–664.

Perruchas F, Consoli D, Barbieri N (2020) Specialisation, diversification and the ladder of green technology development. Research Policy, 49(3):103922.

Popp, D. (2005), Lessons from patents: using patents to measure technological change in environmental models, Ecological Economics 54(2-3), pp. 209-226.

Popp D, Newell RG, Jaffe AB (2010) Energy, the Environment, and Technological Change. In Hall BH, Rosenberg N (eds.) Handbook of the Economics of Innovation Volume 2, Chap 21, Pages 873–937.

Rezza A (2013) FDI and pollution havens: Evidence from the Norwegian manufacturing sector. Ecological Economics, 90:140–149.

Santoalha, A. and Boschma, R. (2021) Diversifying in green technologies in European regions: does political support matter?, Regional Studies, 55:2, 182-195, DOI: 10.1080/00343404.2020.1744122

Sawhney A, Rastogi R (2015) Is India specialising in polluting industries? Evidence from US-India bilateral trade. The World Economy, 38(2):360-378.

Stiebale J (2016) Cross-border M&As and innovative activity of acquiring and target firms. Journal of International Economics, 99:1-15.

Tang J (2015) Testing the Pollution Haven Effect: Does the Type of FDI Matter? Environmental and Resource Economics, 60:549-578.

Tanner AN (2016) The emergence of new technology-based industries: the case of fuel cells and its technological relatedness to regional knowledge bases. Journal of Economic Geography, 16:611–635.

Tatoglu E, Demirbag M, Bayraktar E, Sunil S, Glaister K (2014) Determinants of voluntary environmental management practices by MNE subsidiaries. Journal of World Business, 49(4):536–548.

Todo Y (2006) Knowledge spillovers from foreign direct investment in R&D: Evidence from Japanese firm-level data. Journal of Asian Economics, 17(6):996-1013.

Truffer B, Coenen L (2012) Environmental innovation and sustainability transitions in regional studies. Regional Studies, 46(1):1-21.

UNCTAD (2018) World Investment Report 2018. Investment and new industrial policy. eISBN 978-92-1-045178-9.

Van den Berge M, Weterings A (2014) Relatedness in eco-technological development in European regions. Papers in Evolutionary Economic Geography #14.13.

Zugravu-Soilita N (2017) How does Foreign Direct Investment Affect Pollution? Toward a Better Understanding of the Direct and Conditional Effects. Environmental Resource Economics, 66:293-338.

Zhu, S., Hey, C. & Zhou, Y. (2017). How to jump further and catch up? Path-breaking in an uneven industry space, Journal of Economic Geography, 17, 521–545