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Foreign Direct Investments and Regional Specialization in Environmental Technologies

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Abstract

The paper builds on (eco-)innovation geography and international business studies to investigate the effects of MNEs on regional specialisation in green 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 MNEs can positively impact on regions' specialisation in environmental technologies, when their Foreign Direct Investments (FDIs) occur in industries with a green technological footprint. The effect of green FDIs is further reinforced if they 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 patterns of specialisation. 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; MNEs; FDIs; environmental innovation.

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1 Introduction

Environmental sustainability is nowadays an inescapable priority, giving rise to a mounting concern for the development of "green technologies". While early studies paid little attention to spatial aspects of the generation and diffusion of such technologies (Truffer and Coenen, 2012), recent albeit exiguous research has emphasized the regional dimension of environmental innovations (EIs) (Cooke, 2011; 2012; Horbach 2014; Gibbs and o'Neill, 2017; Barbieri et al 2016; Montresor and Quatraro, 2019; Santoalha and Boschma, 2019; Consoli et al., 2019).

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. In spite of the emerging evidence of global patterns in the regional development of green technologies and of environmental upgrading into Global Value Chains (De Marchi and Gereffi, 2018; De Marchi et al., 2020), research about the impact of FDIs on regional green inventive activities appears rather scanty (Cainelli et al., 2012; Chiarvesio et al., 2014). In particular, five gaps can be identified in empirical research: i) the evidence about the impact of MNEs on local EIs is mainly based on case-studies and national surveys, whose results are hardly generalizable; ii) there is virtually no research on whether the 'greenness' of FDIs is actually able to increase regional EIs; iii) the channels through which MNEs can affect the region capacity to specialise in environmental technologies are also under-investigated; iv) more research is needed to ascertain whether MNEs can act as "agents of structural change" in the green domain, and eventually favour the regional transition towards the green economy; v) the extent to which FDIs interact with the other drivers of the geography of (eco-)innovation, and possibly affect its typical place-dependence, needs closer scrutiny.

This paper tackles the above-mentioned research gaps by combining the OECD-REGPAT and the fDi Markets datasets with reference to 1,050 European NUTS3 regions over the period 2003-2014. Our main results are as follows. First, we find that FDIs as a whole have a non-significant impact on regional specialisation. This may reflect a wide variety of underlying dynamics and motivations of foreign investors, whose effects on EIs might elide one another. Instead, as a second result, 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, providing 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 of 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., 2018; Colombelli and Quatraro, 2019; Corradini, 2019; Barbieri and Consoli, 2019; Montresor and Quatraro, 2019; Consoli et al., 2019; Santoalha and Boschma, 2019).

Against this background, some 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 wide cross-regional level. 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). Indeed, there is evidence that MNEs may either search for weaker environmental regulations and invest abroad by deteriorating the environmental performance of the host economy; or they can instead ameliorate it by transferring green-friendly technologies and environmental management practices/systems through their subsidiaries abroad.[1] While this literature usually refers to the effects of FDIs on recipient countries rather than regions, it highlights that the impact of FDIs on environmental performance of host locations cannot be taken for granted, and this might well apply also to the development of green technologies at the regional level. The combination between heterogeneous local MNEs strategies (De Marchi et al., 2020), on the one hand, and region-specific regulation stringency and green competencies/capabilities (Montresor and Quatraro, 2019), on the other hand, makes it quite difficult to draw straightforward predictions on whether inward FDIs increase or decrease the green knowledge base of regions, and hence affect their capacity to specialize in environmental technologies.

[1] As is well-know, in the extant literature the previous clash translates in that between the "Pollution Haven" and the "Pollution Halo" hypothesis, respectively.

The role of FDIs in helping regional EIs would apparently result less indeterminate when a focus is placed on what some recent literature has called *"green FDIs"*, by referring to the sustainability impact of the technologies and/or industries in which FDIs occur (see Greeninvest, 2017, for a survey).[2] In principle, non-green FDIs could be less directly functional than green ones to the regional development of environmental technologies. In fact, MNEs that invest in other than environmental industries/technologies of the region are arguably more effective in pushing it towards alternative (non-green) specialisations (Sawhney and Rastogi, 2015). Green FDIs could instead increase the regional eco-innovativeness more incisively both in a *direct* way, should foreign MNEs subsidiaries confirm their general superior innovativeness also in the green domain (Castellani and Zanfei, 2006, Guadalupe et al., 2012, Stiebale, 2016); and *indirectly*, should the spillovers that MNEs generally exert on the innovativeness of domestic (regional) firms (competitors, suppliers and customers) also work in the case of green technologies (Castellani et al., 2015; Crescenzi et al., 2015). However, the evidence about these two potential effects of green FDIs is scanty, sparse and mixed, as well as that of their overall regional impact, on which we focus in this paper. Firstly, the direct green effect of FDIs on greening local innovation has appeared ambiguous, as dependent on 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). Secondly, 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 set of circumstances (Rezza, 2013; Tang, 2015), which leave the research question still open[3].

An additional aspect that needs to be more deeply explored refers to *the functional activities* through which MNEs can affect the green-tech specialisation of regions. Looking at the regions' capacity of specializing in technologies (as for example revealed

[2] As we will say, the definition of green FDIs is heterogeneous across different sources, but their meaning is overall coherent. The OECD Policy Framework for Investment (2015), for example, defines as green those FDIs that refer to: (1) green infrastructures or greening of existing infrastructures; (2) sustainable management of natural resources and services they provide; (3) activities in EGSS and across green value chains.

[3] While it is important to assess whether FDIs affect EI directly or indirectly, disentangling these two effects would require the availability of a different dataset, and hence is beyond the scope of the empirical analysis conducted in this paper.

by their inventive activities), the international business mechanisms that most affect this capacity in the green domain are arguably those related to Research and Development (R&D) and innovation activities. 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, investing R&D in them from abroad 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, which rely on the same technologies and develop them through a DUI (doing-using-interacting), rather than STI (science-technology-innovation) mode of innovating (Binz and Truffer, 2017).

Based on the discussion above, we conclude that the effects of inward FDIs on regional technological specialization are quite likely to depend on the nature of such activities both across industries and across functional domains. This leads us to formulate 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., 2020). The absorption of external knowledge and experience that FDIs inject in the region could reduce the risk of an "inverse transition", from the green to the non-green economy. From a specular perspective, green FDIs can be thought to 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. 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. In particular, we are focussing here on a type of structural change that MNEs could help regions undertake, given their ascertained 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, with respect to which the literature does not provide a strong theoretical and/or empirical *a priori*. Accordingly, this leads us to formulate a further 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 degree of 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, 2019). In brief, regional green-tech specialisation is favoured by its cognitive proximity, or relatedness, to pre-existing technologies in the regional knowledge-base. 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, 20019) - which can attenuate or reinforce the effect of relatedness on green specialisation patterns. Whether FDIs can be among these factors represents an important issue to address. On the one hand, it can be argued that, also in the green domain, FDIs inject the hosting region with outer knowledge/competencies, which make the development of green-technologies less place-dependent (Elekes et al., 2019). By injecting such knowledge assets into host regions, FDIs could allow more exploration and higher degrees of cognitive freedom (Zhu et al., 2017). Accordingly, they could help regions in recombining existing capabilities for the sake of green specialisation and thus make them specialise in environmental technologies that are less related to the pre-existing ones. On the other hand, the technological content of inward FDIs could overlap with the extant regional knowledge base and reinforce prior specialisation patterns.

By injecting external knowledge assets, FDIs may either give rise to a sort of "weak" kind of structural change effect which attenuates the role of relatedness for the development of green technologies; or favour a “strong” kind of structural change inducing a shift from a non-green to a green-tech specialisation.

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).[4] 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 world region.[5] 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). The risk of data-handling truncations, due to delayed publication of patent applications, is dealt with by cumulating green patents up to 2014. In order to attenuate patents volatility over time, we consider 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. [6] Using

[4] 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.
[5] 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.
[6] fDi Markets is an event-based (or deal-based) database, wherein each entry is a FDI project, for which the provider reports information from several publicly available information sources.

longitude and latitude of the recipient cities, we then attribute them to the correspondent NUTS3 European region. We also draw information about the industry in which cross-border investments occur, referring to the NAICS classification, and the functional activity undertaken in each project (in particular, R&D vs. non-R&D activities).

3.2 Variables and econometric strategy

Our focal dependent variable is region *i*'s capacity to specialise in "green technology", $GreenSpec_{it}$. Unlike previous studies (e.g. Montresor and Quatraro, 2019; Santoalha and Boschma, 2019), which focus on the regional specialisation in one of the several specific green domains in which technologies can be developed, we hereby refer to a more encompassing indicator of the region capacity to prioritise the development of its green technologies. Indeed, this indicator goes beyond the acquisition of one single green-technological advantage and rather detects the advantage accruing to the region from its development of technologies across the entire spectrum of possible green applications. $GreenSpec_{it}$ is thus 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:

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

where $GreenPAT_{it}$ 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.

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

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 Figure 1 reveals, 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. Overall, the transition towards the green-tech specialisation appears still a

[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.

limited phenomenon, which deserves as much attention as the regional capacity of keeping it once it has been attained.

As far as the explanatory variables are concerned, the focal ones refer to the number of cross-border 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. When addressing RQ1, we simply count their total number 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 (see Table 1).

Table 1 – Overview of estimates of Green FDIs

Source	Concept	Included	Annual FDI Flow
UNCTAD[32]	Low-carbon FDI	Greenfield FDI in renewable energy, recycling activities and low-carbon technology manufacturing	US$90 billion (2009) US$82 billion (2016)
OECD[33]	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[34]	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[35]	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)

A less arbitrary criterion, and indeed a 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. Indeed, this criterion takes stock of the literature on how industry characteristics affect patterns of innovation, of which EIs are one typology. Following this literature, industries differ significantly in the way they can deal with technological constraints and opportunities, hence determining distinct directions along which innovation activities move (Nelson and Winter 1977; Dosi 1982). This way of theorising a paradigm-bounded and path-dependent nature of sectoral patterns of innovation (Malerba, 2005; Dosi et al., 2006; Kim and Shin, 2018) can be extended to suggest that the effects of FDIs in the domain of regional green technology might as well be shaped by the technological characteristics of industries in which FDIs occur. In particular, we suggest classifying as green the FDIs that occur in industries where green technologies are the most salient. In brief, industries can be deemed green when the knowledge-base that characterises such industries (through inventions) is relatively more oriented towards environmental technologies. To operationalize this, we associate green patents to industries and then define green industries as those that are specialised in green patents. 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 thus compute the green RTA for each industry 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). 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 green industries. For the sake of comparison, this variable will be complemented by $FDI\text{-}NGreen_{it}$, measuring the number of regional FDIs

[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.

in industries that do not show a world green-tech specialisation. Both *FDI-Green*$_{it}$ and *FDI-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, MNEs undertake in region *i* by carrying out R&D (*FDI-Green-RD*$_{it}$ and *FDI-NGreen-RD*$_{it}$, respectively) or non-R&D business activities abroad (*FDI-Green-NRD*$_{it}$ and *FDI-NGreen-NRD*$_{it}$, respectively). [9]

Figure 2 – FDI-All and FDI-Green Projects

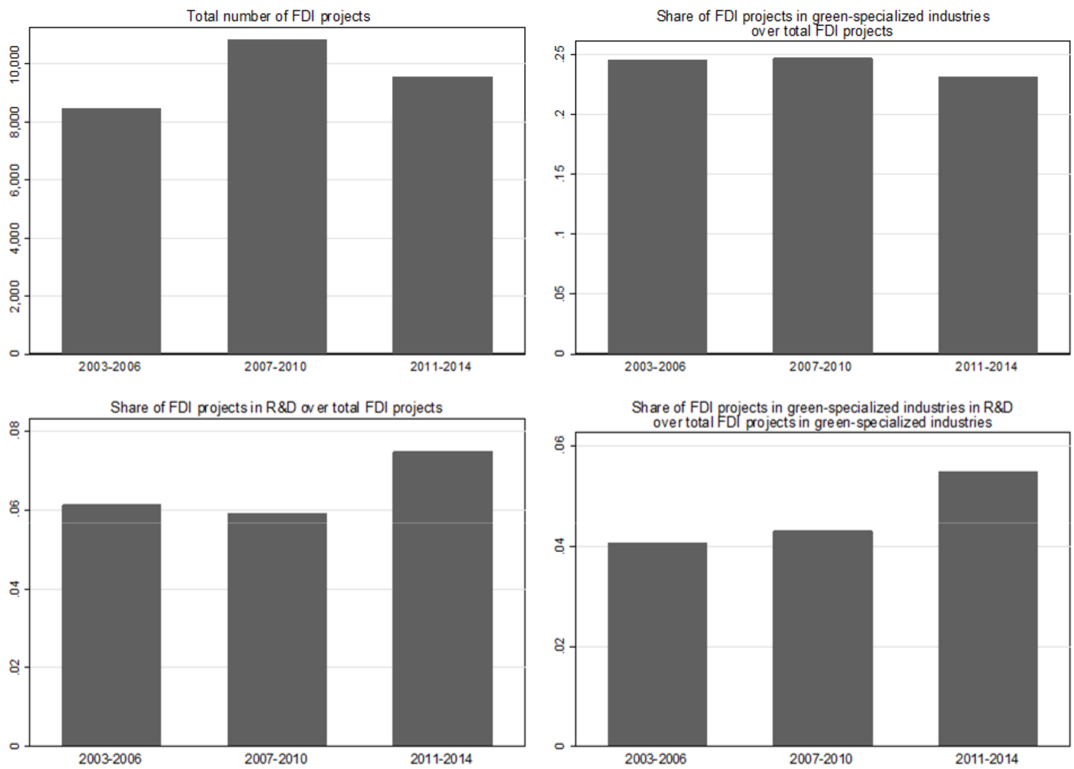


Figure 2 shows the evolution of our focal regressors along the considered three periods of time. The total number of FDI projects directed to our NUTS3 regions has first increased, from period 1 to period 2, and then decreased from period 2 to period 3. Combined with the trend in the number of green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

[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.

In investigating the role of the previous focal regressors, we first of all control for a variable that, according to 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 former to the latter (Boschma, 2005). As mentioned in Section 2, 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, 2019). By extending this idea to our analytical approach, which focuses on region *i*'s capacity to specialise in "the (meta) green technology", 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 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.

In addition to relatedness, we also control for the economic size of the region in terms of GDP_{it} (average over time and in log, from Eurostat), and for its relative technological importance within its country, by retaining its share of the country's patents. Finally, we retain the regional availability of knowledge in Key Enabling Technologies (KETs, refer to European Commission, 2012 for the list of KETs-related IPC classes), which have been found crucial in driving green technological specialisation (Montresor and Quatraro, 2019).

Using the previous set of variables, our baseline specification is a probit estimation of the following model:

$$GreenSpec_{it}^{0,1} = \phi(\alpha + FDI'_{it}\gamma + X'_{it}\theta + \lambda_{ct} + \varepsilon_{it}) \quad (2)$$

where FDI'_{it} is the vector of FDI-related variables, X'_{it} is the vector of our controls for unobserved heterogeneity, λ_{ct} 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.

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. Another source of endogeneity is the failure to consider region-specific environmental policies which are likely correlated both with green specialization and with green FDIs. However, most environmental policies are at the country level and we account for them in the most flexible way by means of country-year dummies. Finally, 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.

Basic descriptive statistics for our variables of interest are reported in Tables C1 and C2 in Appendix C.

4 Results

Table 2 reports the results of the estimates to address our first three RQs. To start with, let us notice that the ambiguity in the possible impact of overall FDIs which we discussed in Section 2.1 gets reflected in a non-significant coefficient for the correlation between *FDIs* and *GreenSpec*: this is found both in specification 1, when the RTA threshold is set at 1, and in specification 4, when it is increased to 1.5. Regional inward FDIs are possibly 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.

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 green specialization in 1991-1994 are about 17.5% more likely to be green specialized in 2003-2014 compared to other regions (13.7% for specialization defined as RTA>1.5). In all of the specifications, as expected, the specialisation in the green technology is also significantly and positively associated with our indicator of relatedness (which captures the technological proximity of pre-existing specialisations to the green technology). In specification (1) the propensity to specialise in the green technology appears higher for larger regions (in terms of GDP), whose advantage however disappears with respect to more substantial specialisation advantages (specification (4)). 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.

It is worth mentioning that the explicative power that KETs have revealed in previous studies with respect to individual green-techs disappears here (Montresor and Quatraro, 2019). This may be due to the fact that in this study all the green technologies of a region are collapsed into one meta-technology. It could be that by aggregating green technologies we miss some heterogeneity, making it difficult to draw a general conclusion at this level of analysis.

When it comes to RQ2, specification (2) of Table 4 suggests that the distinction between green and non-green FDIs does actually matter. Although (slightly) under the conventional threshold for their statistical significance, *FDI-Green* and *FDI-NGreen* show a positive and a negative correlation, respectively, with *GreenSpec* defined using a standard RTA threshold (equal to 1). These coefficients (and the corresponding average marginal effects) increase in magnitude and become quite significantly different from zero when *GreenSpec* is defined through a more demanding threshold (equal to 1.5), in specification (5). Consistently with extant literature about the FDI effects on the technological performance of host economies in general (see Section 2), we find that FDIs would help regions to develop environmental technologies when occurring in green (specialised) industries. Instead, non-green FDIs would lead regions to reduce their capacity to specialise in green technologies, and possibly spur them to specialise in non-green ones. 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 (0.8); while such a capacity reduces of only 0.3% for an additional non-green FDI project.

In response to our RQ3, the functional activity in which FDIs occur also matter. In particular, only FDIs in R&D significantly correlate with regional green-tech specialisation, by affecting 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 do not affect the region's capacity to specialize in the green technology; this suggests that the knowledge embodied in other functional activities carried out by foreign affiliates (e.g. engineering, production, marketing) is not enough to lead to an inventive capacity in the green domain that is higher than average. The role of FDIs in R&D gets an interesting qualification when we distinguish between green and non-green FDIs. While green FDIs in R&D significantly increase the region capacity to specialise in the green technology, non-green FDI have a negative association with our dependent variable (specifications (3) and (6) in Table 4). 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 4-5 percentage points. Conversely, one more non-green FDI project in R&D activities reduces the *GreenSpec* probability by 1-2 percentage points.

Table 2 – Inward FDIs and green regional technological specialisation (RQ1, RQ2, RQ3)

Dependent variable: RTA in the green technology (dummy)	GreenSpec if RTA>1			GreenSpec if RTA>1.5		
	(1)	(2)	(3)	(4)	(5)	(6)
GreeSpec pre-sample mean (1991-1994)	0.496***	0.494***	0.496***	0.519***	0.516***	0.518***
	(0.0666)	(0.0666)	(0.0666)	(0.0831)	(0.0831)	(0.0833)
Relatedness	5.517***	5.472***	5.529***	5.572***	5.528***	5.595***
	(0.842)	(0.840)	(0.841)	(0.879)	(0.877)	(0.877)
Region's share of country patents	-5.340***	-5.301***	-4.524**	-4.661*	-4.109	-3.740
	(1.893)	(1.873)	(1.782)	(2.662)	(2.619)	(2.448)
KETs (lag)	0.0111	0.00675	0.00945	-0.0600	-0.0662	-0.0628
	(0.0551)	(0.0551)	(0.0551)	(0.0608)	(0.0610)	(0.0610)
log(GDP)	0.138***	0.131***	0.130***	-0.0431	-0.0521	-0.0560
	(0.0364)	(0.0362)	(0.0360)	(0.0393)	(0.0397)	(0.0397)
FDI	-0.000040			-0.00241		
	(0.00110)			(0.00170)		
FDI-Green		0.0176			0.0312**	
		(0.0111)			(0.0130)	
FDI-NGreeen		-0.00422			-0.012***	
		(0.00282)			(0.00443)	
FDI-Green-RD			0.150**			0.163**
			(0.0711)			(0.0799)
FDI-Green-NRD			0.00810			0.0219*
			(0.0118)			(0.0132)
FDI-NGreen-RD			-0.069***			-0.0633*
			(0.0228)			(0.0378)
FDI-NGreen-NRD			0.000777			-0.00763
			(0.00331)			(0.00486)
Pseudo R sq	0.0910	0.0919	0.0942	0.0829	0.0852	0.0869
N	3141	3141	3141	3102	3102	3102

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

Overall, the spectrum of foreign operations through which MNEs 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 the choice MNEs make with respect to the same spectrum: not only do green FDI in R&D favours 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.

When it comes to RQ4, Table 3 shows that the effects of FDIs on regional specialisation in environmental technologies emerge almost exclusively with respect to *regions that are already specialised in green technologies (in t–1)*. Green FDIs in R&D are associated with a larger probability to specialise in environmental technologies when the specialisation was already present, and such a probability increases on average of more than 10% for one more project of the kind. Quite interestingly, unlike in the specifications of Table 2, a positive correlation emerges this time also for green FDIs in non-R&D activities and for green FDIs in general. This suggests that, if the region has already a specialisation in green-technologies, and has thus possibly acquired the entailed 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. This appears to occur for both R&D and non-R&D activities of MNEs investing in the region. 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 the pre-existing green-tech specialisation of the region is explicitly considered, also the results about the effect of non-green FDIs take on some interesting nuances. As we could have expected, non-green FDIs associate with a significant reduction in a region's capacity to keep the green-tech specialisation that it had previously acquired (*FDI-NGreen* turns out significantly negative for green-tech specialised regions, though for the higher RTA threshold only). A possible explanation of this result is that foreign non-green operations make the region target alternative non-green technologies. This effect is confirmed when we look at non-green FDIs in non-R&D activities, which also reduce the region's capacity to persist in the green-tech.

When considering *regions that are not specialised in environmental technologies at t-1*, it appears that green FDIs in R&D do not help in acquiring a green-tech specialisation. When non-green FDIs occur in R&D, non-specialised regions are even less likely to switch to green technologies (*FDI-NGreen-RD* is significantly negative for non-specialised regions in the green-tech, though for the higher threshold only). What is more, when compared to the marginal effect of *FDI-NGreen-NRD* for specialised regions (less than 1%), that of *FDI-NGreen-RD* for non-specialised ones is remarkably higher (more than 3%).

Table 3 – Persistence vs switch in the regional green-tech specialization (RQ4)

Dependent variable: RTA in the green technology (dummy)	GreenSpec if RTA>1		GreenSpec if RTA>1.5	
	(1)	(2)	(3)	(4)
GreenSpec pre-sample mean (1991-1994)	0.457***	0.449***	0.496***	0.490***
	(0.0655)	(0.0657)	(0.0824)	(0.0826)
Relatedness	5.291***	5.326***	5.350***	5.441***
	(0.834)	(0.833)	(0.872)	(0.871)
Region's share of country patents	-4.359**	-3.985**	-4.056	-3.713
	(1.888)	(1.853)	(2.876)	(2.653)
KETs (lag)	-0.00472	0.00211	-0.0726	-0.0708
	(0.0549)	(0.0548)	(0.0604)	(0.0604)
log(GDP)	0.134***	0.130***	-0.0529	-0.0600
	(0.0359)	(0.0360)	(0.0399)	(0.0397)
FDI-Green	-0.0114		0.00636	
(*Non-green specialised regions*)	(0.0145)		(0.0147)	
FDI-Green	0.0499***		0.124***	
(*Green specialised regions*)	(0.0176)		(0.0304)	
FDI-NGreen	-0.00626		-0.00961	
(*Non-green specialised regions*)	(0.00438)		(0.00626)	
FDI-NGreen	-0.00665		-0.0295***	
(*Green specialised regions*)	(0.00433)		(0.00891)	
FDI-Green-RD		-0.0808		0.0891
(*Non-green specialised regions*)		(0.120)		(0.0985)
FDI-Green-RD		0.302***		0.460**
(*Green specialised regions*)		(0.117)		(0.187)
FDI-Green-NRD		-0.0122		-0.00142
(*Non-green specialised regions*)		(0.0163)		(0.0143)
FDI-Green-NRD		0.0357*		0.101***
(*Green specialised regions*)		(0.0184)		(0.0333)
FDI-NGreen-RD		-0.0875**		-0.0737
(*Non-green specialised regions*)		(0.0421)		(0.0486)
FDI-NGreen-RD		0.00273		0.0342
(*Green specialised regions*)		(0.0457)		(0.0844)
FDI-NGreen-NRD		0.0000429		-0.00334
(Non-green specialised regions)		(0.00626)		(0.00567)
FDI-NGreen-NRD		-0.00565		-0.0288**
(Green specialised regions)		(0.00530)		(0.0121)
Pseudo R sq	0.105	0.107	0.0941	0.0970
N	3141	3141	3102	3102

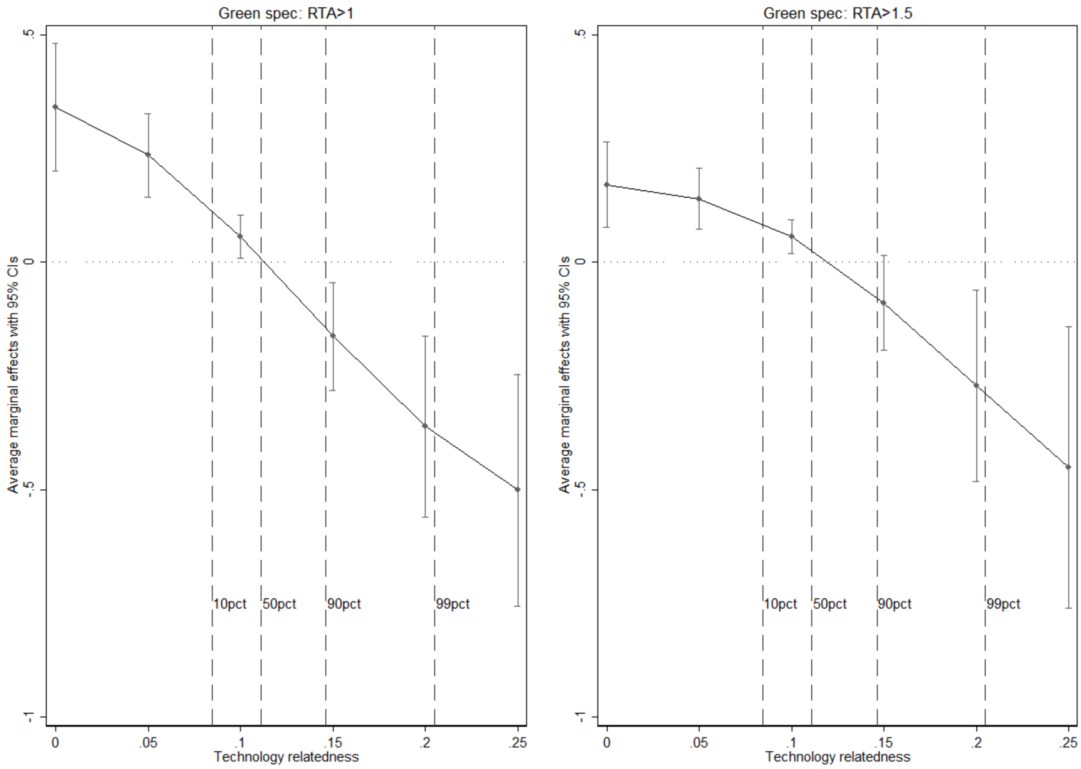
Probit model. Observations: NUTS3 regions for three periods (2003-2006; 2007-2010; 2011-2014). Additional variables: year dummies. standard errors clustered by region in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Previous results about the effect FDIs have on the green-technological specialisation of regions hold *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, 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 our specifications for RQ3 and RQ4, respectively, by interacting FDIs-related variables with the technology relatedness variable.

Figure 3 shows the moderating effect that relatedness exerts on the impact of green R&D FDIs on *GreenSpec* (RQ5).[10] 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. In these cases, green-technologies are limitedly bounded by the cognitive proximity to pre-existing specialisations of the recipient region (i.e. they are highly unrelated). Against this background, green-FDI in R&D bring external knowledge that allows the region a larger leap into 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 regional green-tech specialisation occurs mainly when the latter are 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 were 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.

[10] 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).

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

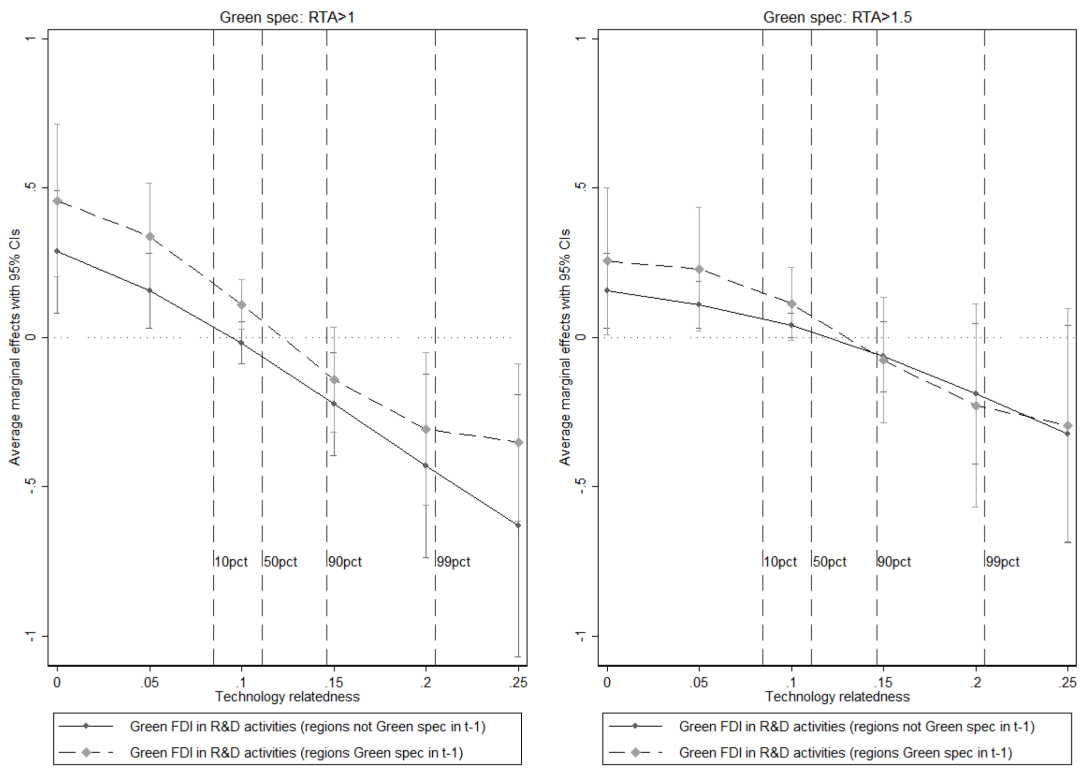


As a final step in our analysis, Figure 4 reports the average marginal effects of *FDI-Green-RD* with respect to RQ6, where we consider whether the moderating role played by technological relatedness differs between regions that were or were not already specialized in green technologies.[11] Somehow confirming previous results in Table 3, the largest marginal effect of green R&D FDI 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 3, where the effect of *FDI-Green-RD* was not significant. Provided relatedness is very low (approximately below the 10^{th} 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, MNEs thus appear to play also a "strong" structural change effect on

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

the hosting regions, favouring their “green (tech) transition”. However, not only does such an effect pass exclusively through their foreign R&D operations in green industries, but it exclusively materialises with respect to green-technologies that are limitedly 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 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)



5 Conclusions

This paper investigates the extent to which MNEs 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 MNEs in helping regions to develop eco-innovations is extremely important and in need of more in-depth investigation.

Our results show that inward FDIs do have effects on green specialisation. These effects, however, are mostly driven by FDIs involving R&D activities in green-related industries. Instead FDIs in non-green industries may reduce a region's probability of obtaining a green specialisation. These effects appear stronger for regions that were already green specialised in the past. Furthermore, our results suggest that green inward FDIs in R&D contribute to region's green specialisation for low levels of relatedness, and that for these low levels they could even favour the regional green-tech transition.

These results have important implications, in terms of both research and policy. As for the former, we suggest that MNEs can contribute to the greening of a region's knowledge base, and thus possibly to a more sustainable local development, but only through specific foreign operations. Future research is thus encouraged to investigate these operations more deeply, in particular, by distinguishing the direct contribution of MNEs to the production of green technologies in a region, through their R&D activities, from the indirect effect these foreign operations can have on the green innovation of local firms in the form of spillovers. 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 also stimulates future research in deepening the scanty knowledge that has been obtained so far about the role of foreign firms and FDIs in attenuating the role of relatedness in driving regional technological diversification.

In terms of policy, the results that we have obtained 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.

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Appendix A – Definition of green technologies, green specialisation, and relatedness

We follow the recent literature (e.g. Montresor and Quatraro, 2019) in the construction of our indicator of technology relatedness. For each technology class *k* and time window *t* we first compute the RTA for each NUTS3 region (all world countries) *i* as follows:

$$RTA_{it}^{k} = \frac{Pat_{it}^{k} \big/ \sum_k Pat_{it}^{k}}{\sum_i Pat_{it}^{k} \big/ \sum_i \sum_k Pat_{it}^{k}}$$

where Pat_{it}^{k} represents the count of EPO patents in region *i*, time window *t* and technology class *k*. Technologies are defined in terms of 4-digit CPC classes. As our interest here is on green technologies as a whole, we consider them all as constituting a single technology meta-class: this means that out of a total number of *K* technology classes, there are *K-1* that are non-green 4-digit CPC classes, and there is *one* green technology meta-class (that comprises more than one green CPC 4-digit classes). The dependent variable used in the text, $GreenSpec_{it}$ is set to be equal to 1 (0), if RTA_{it}^{k} calculated for the meta-class of green technologies is larger than 1 (between 0 and 1)., For each time period, we then identify $GreenProximity_{t}^{k}$ as an average measure of co-occurrence across all regions of $GreenSpec_{it}^{k}$, and of specialisations in each of the other technology classes ($Spec_{it}^{k}$). .

Finally, we define our measure of relatedness for region *i* in time window *t* as the combination of technology specializations in time window *t-1* ($Spec_{it-1}^{k}$) and the proximity between technology *k* and green technologies in time windows *t* ($GreenProximity_{t-1}^{k}$):

$$Relatedness_{it} = \frac{1}{K} \sum_{k} GreenProximity_{t}^{k} \times Spec_{it-1}^{k}$$

Appendix B – Definition of green specialized industries

Table B1 – Subsectors with Green RTA>1

Subsectors (NAICS-based fDI Markets classification)	Green RTA
Iron ore mining	8.03
Other (Consumer Electronics)	7.58
Copper, nickel, lead, & zinc mining	7.35
Batteries	7.07
Computer facilities management services	6.67
Water, sewage & other systems	6.67
Waste management & remediation services	6.53
Scenic & sightseeing transport	6.26
Motor vehicle electrical & electronic equipment	6.17
Natural, liquefied and compressed gas	6.11
Semiconductor machinery	5.94
Other metal ore mining	5.53
Gold ore & silver ore mining	5.53
Communications equipment	4.74
Motor vehicle gasoline engines & engine parts	4.68
All other electrical equipment & components	4.18
Coal mining	3.77
All other electrical equipment & components	3.51
Light trucks & utility vehicles	3.43
Heavy duty trucks	3.43
Motor vehicle stamping	3.38
Household appliances	3.14
Wind electric power	2.88
Other electric power generation (Alternative/Renewable Energy)	2.88
Biomass power	2.88
Geothermal electric power	2.88
Hydroelectric power	2.88
Marine electric power	2.88
Solar electric power	2.88
Power transmission equipment	2.84
Other (Engines & Turbines)	2.84
Engines & Turbines	2.84
Petroleum refineries	2.79
Aircraft engines, other parts & auxiliary equipment	2.69
Electrical equipment	2.62
Lime & gypsum products	2.45
Pipeline transportation of natural gas	2.41
Other (Space & Defence)	2.41
Other non-metallic mineral products	2.34
Nonmetallic mineral mining & quarrying	2.34
Heavy & civil engineering	2.28
Air transportation	2.25
Other (Aerospace)	2.20
Boiler, tank, & shipping container	2.14
Other pipeline transportation	2.11
Oil & gas extraction	2.06
Clay product & refractory	1.99
Pipeline transportation of crude oil	1.98
Motor vehicle transmission & power train parts	1.95
Railroad rolling stock	1.95
Aircraft	1.93
Ships & boats	1.77
Forging & stamping	1.76

Subsectors (NAICS-based fDI Markets classification)	Green RTA
Iron & steel mills & ferroalloy	1.73
Measuring & control instruments	1.67
Navigational instruments	1.67
Animal production	1.63
Other (Minerals)	1.58
Other (Building & Construction Materials)	1.58
Other (Ceramics & Glass)	1.58
General purpose machinery	1.57
Crop production	1.54
Ventilation, heating, air conditioning, and commercial refrigeration equipment manufacturing	1.51
Advertising, PR, & related	1.48
Automobiles	1.43
Bakeries & tortillas	1.42
Guided missile & space vehicles	1.42
Basic chemicals	1.41
Residential building construction	1.34
Support activities for transportation	1.33
Other (Transportation)	1.33
Freight/Distribution Services	1.33
Plastic bottles	1.29
Glass & glass products	1.28
Support activities for mining & energy	1.20
Support Activities for Mining	1.20
Spring & wire products	1.17
Transit & ground passenger transportation	1.15
Fishing, hunting & trapping	1.13
Agriculture, construction, & mining machinery	1.12
Cement & concrete products	1.11
Electric lighting equipment	1.08
Other (Metals)	1.07
Other fabricated metal products	1.07
Animal food	1.06
Soft drinks & ice	1.03

Appendix C – Descriptive evidence, additional estimation tables and average marginal effects

Table C1 – Basic descriptive statistics

Variable	Mean	SD	Min	Max
GreenSpec	0.40	0.49	0	1
log(GDP)	8.57	1.18	2.25	13.37
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

Table C2 – Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) GreenSpec	-							
(2) log(GDP)	0.147	-						
(3) KETs	0.056	0.089	-					
(4) Region's share of country patents	-0.018	0.274	-0.041	-				
(5) FDI	0.025	0.394	-0.043	0.438	-			
(6) FDI-RD	0.006	0.368	-0.041	0.409	0.830	-		
(7) FDI-Green	0.039	0.385	-0.036	0.416	0.937	0.718	-	
(8) FDI-Green-RD	0.055	0.310	-0.013	0.224	0.542	0.609	0.587	-
(9) Relatedness	0.128	-0.023	0.066	-0.008	-0.059	-0.052	-0.049	-0.060

Table C3 – Technological relatedness as a moderating factor

Dependent variable: RTA in the green technology (dummy)	(1) GreenSpec if RTA>1	(2) GreenSpec if RTA>1.5
GreenSpec pre-sample mean (1991-1994)	0.492***	0.504***
	(0.0669)	(0.0843)
Relatedness	5.979***	5.567***
	(0.893)	(0.936)
Region's share of country patents	-4.537**	-3.938
	(1.948)	(2.631)
KETs (lag)	0.00180	-0.0740
	(0.0554)	(0.0613)
log(GDP)	0.133***	-0.0513
	(0.0361)	(0.0401)
FDI-Green-RD	1.394***	1.258***
	(0.300)	(0.331)
FDI-Green-NRD	-0.00351	0.0178
	(0.0407)	(0.0444)
FDI-NGreen-RD	-0.529***	-0.792***
	(0.132)	(0.214)
FDI-NGreen-NRD	0.0201	-0.00313
	(0.0161)	(0.0231)
FDI-Green-RD	-12.32***	-10.30***
x Relatedness	(2.982)	(3.166)
FDI-Green-NRD	0.0687	-0.00684
x Relatedness	(0.384)	(0.406)
FDI-NGreen-RD	4.363***	6.186***
x Relatedness	(1.223)	(1.769)
FDI-NGreen-NRD	-0.175	-0.0116
x Relatedness	(0.168)	(0.216)
Pseudo R sq	0.100	0.0934
N	3141	3102

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

Table C4 – Technological relatedness as a moderating factor: persistence vs switch

Dependent variable: RTA in the green technology (dummy)	(1) GreenSpec if RTA>1	(2) GreenSpec if RTA>1.5
GreenSpec pre-sample mean (1991-1994)	0.355***	0.365***
	(0.0590)	(0.0725)
Region's share of country patents	-3.996**	-4.834*
	(1.785)	(2.750)
KETs (lag)	0.0178	-0.0514
	(0.0529)	(0.0593)
log(GDP)	0.127***	-0.0333
	(0.0323)	(0.0366)
Relatedness	2.920***	2.333**
(*Non-green specialised regions*)	(0.900)	(0.948)
Relatedness	5.714***	7.186***
(*Green specialised regions*)	(0.504)	(0.623)
FDI-Green-RD	1.150***	1.074**
(*Non-green specialised regions*)	(0.439)	(0.435)
FDI-Green-RD	1.718***	1.403**
(*Green specialised regions*)	(0.513)	(0.702)
FDI-Green-NRD	-0.0365	0.0487
(*Non-green specialised regions*)	(0.0507)	(0.0544)
FDI-Green-NRD	0.0682	-0.0643
(*Green specialised regions*)	(0.0894)	(0.136)
FDI-NGreen-RD	-0.576***	-0.505*
(*Non-green specialised regions*)	(0.217)	(0.269)
FDI-NGreen-RD	-0.151	-1.758***
(*Green specialised regions*)	(0.248)	(0.625)
FDI-NGreen-NRD	0.0177	-0.0646**
(Non-green specialised regions)	(0.0248)	(0.0309)
FDI-NGreen-NRD	0.000539	0.170***
(Green specialised regions)	(0.0257)	(0.0622)
FDI-Green-RD	-12.09***	-8.864**
(Non-green spec regions) x Relatedness	(4.445)	(4.290)
FDI-Green-RD	-14.19***	-10.78*
(Green spec regions) x Relatedness	(4.900)	(6.197)
FDI-Green-NRD	0.347	-0.424
(Non-green spec regions) x Relatedness	(0.505)	(0.506)
FDI-Green-NRD	-0.451	1.016
(Green spec regions) x Relatedness	(0.721)	(1.089)
FDI-NGreen-RD	4.913**	3.708
(Non-green spec regions) x Relatedness	(2.027)	(2.257)
FDI-NGreen-RD	1.428	14.98***
(Green spec regions) x Relatedness	(2.047)	(5.257)
FDI-NGreen-NRD	-0.152	0.601**
(Non-green spec regions) x Relatedness	(0.247)	(0.292)
FDI-NGreen-NRD	-0.0652	-1.700***
(Green spec regions) x Relatedness	(0.249)	(0.554)
Pseudo R sq	0.150	0.161
N	3141	3102

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

Table C5 – Average marginal effects for RQ1, RQ2 and RQ3

Dependent variable: RTA in selected technologies (dummy)	GreenSpec if RTA>1			GreenSpec if RTA>1.5		
	(1)	(2)	(3)	(4)	(5)	(6)
Pre-sample mean (1991-1994)	0.175***	0.174***	0.174***	0.137***	0.136***	0.136***
	(0.0225)	(0.0225)	(0.0224)	(0.0216)	(0.0216)	(0.0215)
Technology relatedness	1.942***	1.924***	1.939***	1.469***	1.454***	1.468***
	(0.291)	(0.290)	(0.290)	(0.229)	(0.228)	(0.228)
Region's share of country patents	-1.880***	-1.864***	-1.587**	-1.228*	-1.081	-0.981
	(0.665)	(0.657)	(0.623)	(0.702)	(0.689)	(0.643)
RTA (dummy) in KETs (lag)	0.00392	0.00237	0.00331	-0.0158	-0.0174	-0.0165
	(0.0194)	(0.0194)	(0.0193)	(0.0160)	(0.0160)	(0.0160)
log(GDP)	0.0487***	0.0461***	0.0455***	-0.0114	-0.0137	-0.0147
	(0.0127)	(0.0127)	(0.0125)	(0.0103)	(0.0104)	(0.0104)
N of inward FDI (total)	-0.000014			-0.000635		
	(0.00039)			(0.000450)		
N of inward FDI (green spec industries)		0.00621			0.00821**	
		(0.00391)			(0.00342)	
N of inward FDI (non-green spec industries)		-0.00148			-0.003***	
		(0.000991)			(0.00117)	
N of inward FDI (green spec industries; R&D activities)			0.0527**			0.0427**
			(0.0249)			(0.0209)
N of inward FDI (green spec industries; other activities)			0.00284			0.00576*
			(0.00413)			(0.00346)
N of inward FDI (non-green spec industries; R&D activities)			-0.024***			-0.0166*
			(0.00797)			(0.00991)
N of inward FDI (non-green spec industries; other activities)			0.000272			-0.00200
			(0.00116)			(0.00128)

Average marginal effects from probit model (see Table 5). Standard errors clustered by region in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table C6 – Average margin for RQ4

Dependent variable: RTA in selected technologies (dummy)	GreenSpec if RTA>1		GreenSpec if RTA>1.5	
	(1)	(2)	(3)	(4)
N of inward FDI (green spec industries)	-0.00397		0.00163	
non-green spec regions	(0.00501)		(0.00376)	
N of inward FDI (green spec industries)	0.0175***		0.0336***	
green spec regions	(0.00611)		(0.00816)	
N of inward FDI (non-green spec industries)	-0.00217		-0.00247	
non-green spec regions	(0.00152)		(0.00160)	
N of inward FDI (non-green spec industries)	-0.00233		-0.0080***	
green spec regions	(0.00151)		(0.00238)	
N of inward FDI (green spec industries; R&D activities)		-0.0280		0.0228
non-green spec regions		(0.0417)		(0.0252)
N of inward FDI (green spec industries; R&D activities)		0.106***		0.125**
green spec regions		(0.0406)		(0.0507)
N of inward FDI (green spec industries; other activities)		-0.00423		-0.000365
non-green spec regions		(0.00564)		(0.00366)
N of inward FDI (green spec industries; other activities)		0.0125*		0.0275***
green spec regions		(0.00642)		(0.00897)
N of inward FDI (non-green spec industries; R&D activities)		-0.0303**		-0.0189
non-green spec regions		(0.0146)		(0.0124)
N of inward FDI (non-green spec industries; R&D activities)		0.000955		0.00930
green spec regions		(0.0160)		(0.0230)
N of inward FDI (non-green spec industries; other activities)		0.0000149		-0.000857
non-green spec regions		(0.00217)		(0.00145)
N of inward FDI (non-green spec industries; other activities)		-0.00198		-0.00785**
green spec regions		(0.00185)		(0.00328)

Average marginal effects from probit model (see Table 4). Standard errors clustered by region in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.