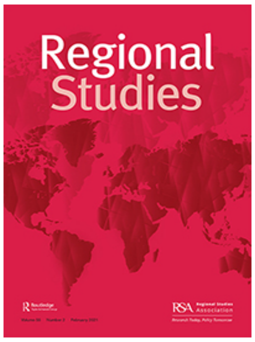

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Diversifying in green technologies in European regions: does political support matter?

Artur Santoalha[a] and Ron Boschma[b]

ABSTRACT
New green activities in regions tend to build on regional capabilities. This paper makes a first attempt to test the impact of political support for environmental policy at the national and regional scales, besides regional capabilities, on the ability of 95 regions in seven European countries to diversify into new green technologies during the period 2000–12. Evidence is found that related capabilities rather than political support in a region are associated with green diversification of regions. However, while political support at the national scale tends to moderate the role of regional capabilities, political support at the regional scale strengthens it.

KEYWORDS
green technologies; regional diversification; sustainability transition; political support; relatedness

JEL O18, O44, Q55, R11
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INTRODUCTION

It is well accepted that relatedness plays an important role in regional diversification (Boschma, 2017; Hidalgo et al., 2018). Diversification is characterized by past and place dependence, meaning that new activities emerge more easily in technological or industrial fields closely related to those that already exist in a place. In the regional diversification literature, there is a growing interest in a specific set of new activities, that is, green activities. This represents a relatively new topic of investigation within this strand of research, and this paper contributes to this growing stream of literature. Research in this field indicates that relatedness also appears to be a driving force behind green diversification of regions (Corradini, 2019; Montresor & Quatraro, 2019; Tanner, 2014, 2016; van den Berge & Weterings, 2014; van den Berge et al., 2019). This finding provides new and additional insights to the transition literature that has a tendency to underestimate processes of past dependence, and to overlook the role of regional capabilities.

However, this relatedness literature has drawn little attention to the role of politics and institutions (Boschma & Capone, 2015; MacKinnon et al., 2019). This is different from the transition literature that highlights the importance of policies and politics for sustainability transitions (Barbieri et al., 2016; Carrión-Flores & Innes, 2010; Dewald & Truffer, 2012; Karnøe & Garud, 2012; Lindberg et al., 2018; Requate, 2005). Studies have shown how urban and regional policies matter for sustainability transitions and have often run ahead of national and supranational policies (Hansen & Coenen, 2015). What has received little attention in the transition literature is, however, the effect of regional capabilities (and relatedness) on greening of economies. Moreover, the transition literature tends to focus primarily on idiosyncratic case studies in distinct places (Markard et al., 2012). As Hansen and Coenen (2015) put it, 'the consensus is still *that* place specificity matters while there is little generalizable knowledge and insight about *how* place specificity matters for transitions' (p. 105). Therefore, there is need for a systematic comparative approach to the ability of regions to diversify in green activities, in which the role of political support at various spatial scales is assessed.

The objective of this paper is to address this gap and increase our understanding of the importance of political support (and regional capabilities) for the ability of European regions to diversify in green technologies. This

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is a daunting task, as it is complex to operationalize political support at the regional scale. This paper makes a first attempt and focuses on a specific set of policies that are relevant for green technologies: environmental protection policies. More precisely, we use data from the manifestos of political parties to derive the extent to which political forces that lead national and regional governments attach importance in their political manifestos to environmental protection policies. Briefly, this reflects the intentions of political parties and their stance regarding this type of policies. This does not necessarily represent policy measures and their adoption by governments. However, we believe it may be considered an approximation that constitutes an important first step to address this gap in the literature.

We test the impact of regional capabilities and political support at both national and regional levels on the ability of 95 (NUTS-1 and NUTS-2) regions in seven European countries (Austria, Belgium, France, Germany, Italy, the Netherlands and Spain) to diversify into new green technologies during the period 2000–12. Overall, we find evidence that regional capabilities rather than political support is associated with green diversification of regions in Europe. Our results show that political support may indirectly influence green diversification through capabilities: political support at national/regional scale moderates/strengthens the importance of capabilities in processes of green diversification of regions in Europe.

The paper is organized as follows. The next section discusses the regional diversification, environmental policy and sustainability transition literatures and addresses the importance of politics for regional diversification into green technologies, proposing some hypotheses. The third section introduces the data and discusses the construction of the variables of interest. The fourth section presents and discusses the main findings. The fifth section concludes.

REGIONAL DIVERSIFICATION, GREENING AND POLITICS: THE MISSING LINK

Territories differ in their ability to diversify and adapt to change. This is true for their ability to develop new activities in general, and new green activities in particular. Regions present huge dissimilarities regarding their ability to create and develop new green activities. There is an uneven distribution of green specializations across regions in both Europe (Corradini, 2019; Tanner, 2014, 2016) and the United States (Barbieri & Consoli, 2019). Although climate change is a global phenomenon, local solutions may be crucial to respond to this global challenge (Murphy, 2015). This makes it important to understand what factors foster green diversification and drive interregional differences. This captures a key research challenge in the literature on the geography of sustainability transitions, which is to go beyond case studies, and to develop generalizable knowledge about place specificity in processes of sustainability transitions (Coenen & Truffer, 2012; Hansen & Coenen, 2015).

What has received little attention so far in the sustainability literature is the effect of regional capabilities on the greening of economies. There is strong evidence that regional capabilities play a key role in processes of regional diversification (Boschma, 2017). That is, new economic activities tend to develop more easily in industrial or technological fields closely related to those that already exist in a territory (Hidalgo et al., 2018). In other words, past and place dependence matter in regional diversification because they bear the seeds for the development of new industrial or technological specializations in regions (Kogler et al., 2013; Neffke et al., 2011; Rigby, 2015).

This tends to contrast with the transition literature that often refers to the need for transformative change to enable the greening of economies (Schot & Kanger, 2018) and tends to depict new green technologies as disruptive and radical (Dechezleprêtre et al., 2017). Therefore, while the regional diversification literature shows that related diversification is the rule and unrelated diversification the exception (Hidalgo et al., 2018; Pinheiro et al., 2018), the transition literature has a tendency to suggest that unrelated diversification would be more common in processes of sustainable transition.

Studies applying a relatedness framework find that new green activities are more likely to be developed in a region with a local presence of activities related to green activities. Van den Berge and Weterings (2014) found that in European Union (EU) regions the probability of developing new eco-technologies depends on pre-existing technologies in related fields in the region during the period 1982–2005. Tanner (2016) found strong evidence for the impact of relatedness on the emergence of the new fuel cell industry in European NUTS-2 regions, besides the importance of local access to universities, research activities and user industries (Tanner, 2014). Montresor and Quatraro (2019) found a positive effect of technological relatedness to local green and non-green knowledge on the emergence of new green specializations in EU-15 regions.[1]

Based on the previous discussion, we develop the first hypothesis:

> *Hypothesis 1: New specializations in green technologies are more likely to occur in regions with related technologies*

The literature is rich providing examples on how new green technologies may emerge from recombinant innovations that involve non-green knowledge often embedded in a core or 'dirty' sector of the economy (Jaber et al., 2003; Makitie et al., 2018; Zeppini & van den Bergh, 2011). This might explain why green technologies tend to present higher levels of complexity and novelty compared with non-green technologies (Barbieri et al., 2020), as well as the fact that teams' recombinant capabilities increase the probability of generating green inventions (Orsatti et al., 2020). However, according to Zeppini and van den Bergh (2011) these recombinations are only possible if their effectiveness is large enough to prevent lock-in in dirty sectors. Otherwise, it might be more difficult to develop new green technologies in regions that are specialized in dirty technologies. Regional vested interests may oppose the development of green technologies that could challenge and form a threat to existing 'dirty' specializations in a region (Acemoglu et al., 2016; Wesseling, 2015). Accordingly, we have to account for the role of power among different political and economic interests (Shove & Walker, 2007), as transitions are often contested. The intensity of conflicts may vary across regions, resulting or not in environmental friendly policies and actions by firms and citizens (Murphy, 2015). Therefore, a potential barrier to the development of new green specializations is the existence of dirty specializations in a region.

Thus, we propose the following hypothesis

Hypothesis 2: New specializations in green technologies are less likely to occur in regions with existing specializations in 'dirty' technologies

However, this might not be the case if established dirty sectors foresee opportunities in terms of the development of green activities that derive from recombinant innovations (Zeppini & van den Bergh, 2011). This might be influenced by the cognitive proximity and complementarity between new green technologies that regions may potentially develop and the technological sectors that are already established in the region. If new green technologies can build on local knowledge that is cognitively close, this green technology is more likely to emerge there, despite the local presence of dirty technologies (van den Berge et al., 2019). Moreover, scholars have argued that in 'dirty' regions there is more awareness of the risks associated with the continuous use of non-ecofriendly activities and policies. Local actors, including political actors in 'dirty' regions, may regard the transition to greener technologies as an opportunity worth exploring. In this case, dirty regions may evolve towards a green path through the development of new green technologies that mitigate the negative effects of dirty ones (Grillitsch & Hansen, 2018). Ghisetti and Quatraro (2013) showed that local demand from polluting sectors may actually stimulate the development of new green knowledge. This either may be a voluntary decision of the established 'dirty' sectors or the outcome of a technology push supported by policy efforts.

Therefore, we propose the following two sub-hypotheses:

Hypothesis 2.1: The negative effect of 'dirty' technological specializations on new specializations in green technologies will be less relevant the stronger the relatedness between new green technologies and the knowledge base of the region.

Hypothesis 2.2: The negative effect of 'dirty' technological specializations on new specializations in green technologies will be less relevant the stronger the political support.

The transition literature claims that strong policy intervention is needed to meet sustainability objectives and to develop new green technologies in particular (Lindberg et al., 2018). The role of public policies in processes of transition has been widely explored (Markard et al., 2012; Rogge & Reichardt, 2016). There is a wide support for the idea that policies and environmental regulation enable transitions towards sustainability (Barbieri et al., 2016; Carrión-Flores & Innes, 2010; Dewald & Truffer, 2012; Matti et al., 2017; Requate, 2005): state intervention provides incentives to ease green transitions to overcome the initial lack of performance and cost competitiveness of new environmental technologies, and to mitigate barriers to their development and adoption (Karnøe & Garud, 2012). It has been argued that the specificity of green innovations requires the adoption of a varied set of policy measures (Kern et al., 2019; Kivimaa & Kern, 2016). This concerns especially the hybrid nature of green knowledge, the uncertainty underlying the development of eco-technologies (particularly at early stages of development), and the fact that processes involving the adoption of these technologies also depend on changes in social attitudes, production processes and market schemes (Kern et al., 2019).

One aspect that illustrates the importance of policies in environmental innovations is the issue of the 'double externality' that characterizes this specific sort of innovations (Rennings, 2000). Briefly, this means that these innovations do not exclusively produce positive externalities through knowledge spillovers, but they also create positive externalities via either the adaptation to or mitigation of climate change (Barbieri et al., 2016). Studies have used country-level data on the development of different types of eco-technologies and have concluded that policies foster this sort of innovations (Costantini et al., 2015, 2017). This confirms, in part, the Porter hypothesis, according to which environmental regulations (that might derive from environmental policies) foster the development of green technologies (Quatraro & Scandura, 2019).[2]

The analysis of policy initiatives to support sustainability transitions has neglected, to some extent, the spatial dimension of these policies and how environmental policies differ across regions. Studies on transitions often restrict their attention to environmental policy at the national level, such as the 'Energiewende' in Germany, or national environmental regulations (Lanjouw & Mody, 1996). The literature on the geography of sustainable transition (Coenen & Truffer, 2012; Hansen & Coenen, 2015) also looks at policy initiatives at the regional and local levels. The presence and nature of environmental policies differ widely across regions within and between countries (Cooke, 2010). This is likely to reflect the political attitude of regional actors towards environmental protection. Studies tend to focus on one particular case, or make a comparative analysis of several cases (Markard et al., 2012), but what has received little attention is a systematic approach that assesses the impact of political support at the regional scale (Ghisetti & Quatraro, 2017). Cainelli et al. (2015) investigated how firms in regions with stricter waste policies are more likely to adopt environmental innovations. Giudici et al. (2019) tested systematically across 110 Italian provinces whether local environmental awareness (defined as the sensitivity to environmental issues by local governments, firms and residents) has a positive effect on clean-tech entrepreneurship. However, we have little understanding of whether regional political support for green policy affects the ability of regions to develop new green activities, also when controlling for regional capabilities, as tested in Hypothesis 1.

Moreover, we have little understanding at which level (national or regional) political support is relevant for regional diversification into green technologies (Markard et al., 2012). It might be that national environmental policy affects the development of new green specializations in some regions but not in other regions in a country. This may have to do with local capabilities that enable some regions to turn national support into new green activities, or it may be attributed to stronger political support in these regions. Dewald and Truffer (2012) observed varying tendencies of German regions to develop a photovoltaic market, in spite of a national policy framework. This regional heterogeneity may be attributed to differences in regional capabilities, but an alternative explanation is differences in political support to environmental policy across regions. We test the effect of political support at the national and regional scale in the following hypothesis:

Hypothesis 3: New specializations in green technologies are more likely to occur in regions with political support.

The transition literature has a tendency to claim that new environmental technologies are disruptive, because subject to fundamental uncertainty (and high risks of failure), as they have to confront many obstacles both at the supply and demand sides. In that context, it is unlikely that incremental changes will contribute to transformations towards sustainability (Frenken, 2016; Markard et al., 2012). Such a view on transitions would expect that relatedness would not matter (contrary to Hypothesis 1), while the political and institutional dimension would instead be considered as crucial to develop new green technologies, because of a lack of (related) capabilities in the region. However, local (related) capabilities and political support may also both matter. For instance, Fornahl et al. (2012) stated that related capabilities and active policy intervention (at both the national and regional scales) contributed to the development of the offshore wind energy industry in northern Germany. The question remains whether political support relaxes or strengthens the importance of related capabilities in the region. We have no a priori predictions whether stronger political support will strengthen or weaken the role of relatedness in the emergence of new green technological specializations in regions. To our knowledge, these possibilities of substitution or complementarity between local related capabilities and political support have not yet been explored. Accordingly, we test the following hypothesis:

Hypothesis 4: The effect of relatedness on new specializations in green technologies is affected by political support at the national and regional scales.

DATA AND VARIABLES

This paper aims to explain the ability of regions to develop new green specializations in Europe. The analysis includes 95 regions, all of which are NUTS-2 regions, except in Belgium and Germany where the unit of analysis is NUTS-1. We calculate the entry of new green technological specializations in a region for nine overlapping periods of five years each (2000–12), following other studies on regional diversification (e.g., Boschma & Capone, 2015; Rigby, 2015). The paper only considers regions in which the average number of patents over the period 2000–08 is at least equal to five.

Most explanatory variables are lagged with at least one year to the beginning of each five-year period. This means they cover the period 1999–2007. To measure the effect of political support, it is assumed that a given election is only relevant for a given five-year period if the year of the election is lagged with at least three years to the start of a five-year period. For instance, if the analysis concerns the development of new green technological specializations between 2000 and 2004, only regional elections in 1997 or before are considered. Moreover, it is minimized the time difference between the year of the election and the year corresponding to the beginning of the five-year period.

Our main variables of interest are: regional capabilities, political support at the national and regional scales, and dirty specializations in regions. The following subsections explain all the variables.

Dependent variable: entry of new green technological specializations in regions

Following previous research on technological diversification in regions (Kogler et al., 2013; Rigby, 2015), this paper focuses on the emergence of new green technological specializations in European regions, making use the Organisation for Economic Co-operation and Development's (OECD) REGPAT patent database.[3] Our spatial unit of analysis is mainly NUTS-2 regions for which regional data are available over the period 2000–12. NUTS-2 regions are often regions in which regional governments have direct responsibility for issues related to environmental protection, such as in Italy (Giudici et al., 2019).[4]

Studies have identified green technologies and linked them to technology classes of patents. We follow the classification of *environment-related technologies* proposed by the OECD ENV-TECH, in which the International Patent Classification (IPC)/Cooperative Patent Classification (CPC) codes of patent applications have been recoded according to the search strategies for the identification of selected environment-related technologies (OECD, 2016). It is considered the most detailed classification with 107 different three-digit categories of environment-related technologies. Most existing research assumes that if the first digits of a given IPC code are considered environment related, all patents that start by these digits are environment related (Montresor & Quatraro, 2019; van den Berge & Weterings, 2014). We avoid the risk of overestimating the number of green patent applications, as the recodification is based on full IPC/CPC codes (and not only on first digits).

Although it is possible to identify 107 OECD ENV-TECH three-digit technological categories, the OECD REGPAT database only has patents in 52 of these categories. This is mainly due to the absence of group 9 (*Climate change mitigation technologies in the production or processing of goods*) patent applications in the database. Appendix A in the supplemental data online shows the full list of three-digit environment-related technological categories identified by the OECD (2016), and those for which there are data on patent applications in the data set used in this paper.

We regionalized the patent data based on assignees' addresses.[5] To determine whether a region is specialized in a green technology, we compute, for each year and each region in the sample, the revealed comparative advantage (RCA) for each technology (both green and non-green):

$$\mathrm{RCA}_{izt} = \frac{\mathrm{PAT}_{izt} / \sum_{z=1}^{n} \mathrm{PAT}_{izt}}{\sum_{i=1}^{m} \mathrm{PAT}_{izt} / \sum_{i=1}^{m} \sum_{z=1}^{n} \mathrm{PAT}_{izt}} \qquad (1)$$

where RCA_{izt} represents the revealed comparative advantage of region *i*, in technology *z*, at year *t*; while PAT_{izt} is the number of patent applications attributed to technological field *z* in region *i* and year *t*. This indicator assesses the relative strength of a given region, at a given time, in technology *z*, in comparison with all other regions. If RCA > 1, that means region *i* is specialized in technology *z*, in year *t*.

As this paper focuses on the development of new green technological specializations, the analysis includes all pairs of regions and green technologies *z* in which a given region is not specialized at time *t*. The dependent variable represents the entry of a new green technological specialization in a region, and it is defined as follows:

$$S_{izt+4} = 1 \text{ if } \mathrm{RCA}_{izt} \leq 1 \wedge \mathrm{RCA}_{izt+4} > 1 \wedge \Delta\mathrm{PAT}_{izt,t+4} > 0 \wedge \Delta\mathrm{RCA}_{izt,t+4} \geq 0.5 \wedge \mathrm{RCA}_{izt+5} > 1 \wedge \mathrm{Green}_z = 1 \qquad (2)$$

$$S_{izt+4} = 1 \text{ if } ((\mathrm{RCA}_{izt} \leq 1 \wedge \mathrm{RCA}_{izt+4} > 1) \vee (\Delta\mathrm{PAT}_{izt,t+4} \leq 0) \vee (\Delta\mathrm{RCA}_{izt,t+4} \geq 0.5) \vee (\mathrm{RCA}_{izt+5} > 1)) \wedge \mathrm{Green}_z = 1$$

where S_{izt+4} is a dummy variable that takes the value 1 if region *i*, which did not have a specialization in green technology *z* at time *t*, acquires that specialization at time *t* + 4. Otherwise, S_{izt+4} takes the value 0, which means region *i* has not succeeded in acquiring a new specialization in technology *z* between *t* and *t* + 4. In order to avoid that slight variations either in the RCA or in the regional patenting activity lead a region to become specialized in a given green technology *z*, three additional conditions are imposed. The first is that a region only acquires a new green technological specialization when there is a substantial increase in the RCA of that technology in that region (i.e., $\Delta\mathrm{RCA}_{izt,t+4} \geq 0.5$). The second condition is that a given region should present an absolute growth in the number of patents in technology *z* between the beginning and the end of each period (i.e., $\Delta\mathrm{PAT}_{izt,t+4} > 0$). The third one is that the given region remains specialized in the newly acquired technological specialization at least for 1 year after the end of each period (i.e., $\mathrm{RCA}_{izt+5} > 1$).

Relatedness

A key objective is to assess whether the entry of a new green specialization in a region depends on the degree of relatedness with existing technologies in the regions. We calculate a relatedness measure similar to other studies on regional diversification (e.g., Balland et al., 2019; Rigby, 2015). This requires computing the degree of relatedness between pairs of technologies. To do so, the paper establishes all combinations of two technological domains for which a given region, in a given year, has at least a share in a patent application. Next, we compute the relatedness between technologies composing a pair, where a and b represent two technological fields, and RCA is defined as in (1), following the formula:

$$\Omega_{ab} = \min\{P(\mathrm{RCA}_a > 1 | \mathrm{RCA}_b > 1), P(\mathrm{RCA}_b > 1 | \mathrm{RCA}_a > 1)\}, \qquad (3)$$

where:

$$P(\mathrm{RCA}_a > 1 | \mathrm{RCA}_b > 1) = \frac{P(\mathrm{RCA}_a > 1 \cap \mathrm{RCA}_b > 1)}{P(\mathrm{RCA}_b > 1)} \qquad (4)$$

In (3), Ω_{ab} indicates the relatedness between technologies a and b, while the expression $P(\mathrm{RCA}_a > 1 \mid \mathrm{RCA}_b > 1)$ represents the conditional probability of there being, in the sample, cases where technology a has an RCA > 1 given that for technology b RCA > 1. To compute Ω_{ab} and its underlying probabilities, in the sample one observation is a pair consisting of a region and a year. In total, the sample contains more than 3000 pairs of years (2000–13) and regions.[6] The relatedness between two technological fields is computed based on the frequency of finding the spatial co-occurrence of a specialization (RCA > 1) in these fields.

Now it is possible to compute relatedness between each green technology *z* in which region *i* is not specialized at time *t* and the technological specializations s of region *i* at time *t*. To do so, we compute a variant of the density index as proposed by Hausmann and Klinger (2007):[7]

$$\mathrm{AvgProximity}_{izt} = \frac{\sum_{s=1}^{n} \Omega zs \mathrm{Sist}}{\sum_{s=1}^{n} \mathrm{Sist}} \qquad (5)$$

such that:

$$S_{ist} = 1 \text{ if } \mathrm{RCA}_{ist} > 1 \qquad (6)$$

$$S_{ist} = 0 \text{ if } \mathrm{RCA}_{ist} \leq 1$$

where $\mathrm{AvgProximity}_{izt}$ represents the average proximity (or relatedness) of a given green technology *z* in which the region *i* is not specialized at time *t* to the set of technologies *s* in which region *i*, at time *t*, is already specialized. Briefly, this indicator divides the sum of the proximities between *z* and the technological specializations existing in region *i* at time *t* by the total number of technological fields *s* in which region *i* has a specialization at time *t*.

Political support to environmental protection

The biggest challenge is to come up with a good comparative indicator that measures political support to environmental protection at the scale of European regions. We propose two indicators: political support to environmental protection policy at the regional and at the national scales.

A lot of research exists on the link between individuals' and political parties' political ideology and their policy stances regarding environmental protection. At least until recently, studies have found evidence that left-wing individuals/parties are more concerned about environmental issues than right-wing individuals/parties (Facchini et al., 2017). A novelty of our paper is that it proposes to measure the extent to which there is political support in a region, as proxied by the political stance of regional governments regarding environmental protection policies. To our knowledge, Le Maux et al. (2011) is the only paper to focus on regional-level data (i.e., French *Départments*) to investigate the role of political ideology on policy decisions (in this case, social public expenditures per capita). We follow the literature that explores the link between political ideology and environmental concerns and use the Manifesto Project Database. We construct a continuous variable Env(Reg) that measures to what extent political parties assume, in their manifestos, environmental issues as a political priority.

The first step to do so is to ascertain whether each EU country has a regional government. In cases where regional governments exist, we verify if they are operationalized at NUTS-1, NUTS-2 or NUTS-3 level. This information is collected from The Council of European Municipalities and Regions (CEMR) (2016). This paper considers exclusively countries where regional governments exist in all regions at NUTS-1 or NUTS-2 level. To allow data comparability over time, the analysis is also restricted to countries whose regional governments operate consistently at the same regional structures since the 1990s up to the present. This leaves seven countries: Austria, Belgium, France, Germany, Italy, the Netherlands and Spain.

The government support to environmental policies is determined based on political parties' stance on this issue. This opens the question which political parties should be taken into account to determine the political stance of regional governments regarding green policies. We adopt the view that a given regional government is strongly influenced by the party of the government leader. For instance, Leinaweaver and Thomson (2016) consider the prime minister's party's stance regarding environmental policy as the most relevant in a given government, and use this approach to measure to what extent national governments support environmental protection. They argue that in multiparty coalitions, the policy influence of the prime minister's party is preponderant.

The Dandoy and Schakel (2013) and Schakel (2013) database[8] on regional elections is used to identify, among other things, the year in which regional elections have been taking place in European regions. The political affiliation of the leader of a given regional government after a given regional election was collected manually, for each region and electoral year. Different sources were used: in most cases, it was necessary to search on the web the designation of the head of regional governments in each country, either in English or in the respective national language.[9] It is assumed that the political mandate of a given regional government expires in the year in which the next election will take place.

To collect data on each party's political support to environmental protection, we use the Manifesto Project Dataset. These data include a variable that reflects the share of quasi-sentences in topics related to environmental protection policies, calculated as a fraction of the total number of codes available in the political manifesto of a political party, in a given national election. The quasi-sentences whose code falls into the environmental protection category include 'general policies in favor of protecting the environment, fighting climate change, and other "green" policies' (Manifesto Project Dataset, 2016, p. 17). This represents a great diversity of policies with the common objective of fostering environmental protection. This variable has been used in the expanding literature on the determinants of political parties' concerns regarding environmental protection and climate change (Facchini et al., 2017; Farstad, 2018). To our knowledge, there are no studies using these data and this variable to investigate green diversification, and to operationalize this variable at the regional level.

As the Manifesto Project Database has no available data on parties' political manifestos for regional elections, this paper assumes that political parties have similar positions regarding environmental protection policies at national and regional elections. In most countries, regional and national elections do not occur simultaneously. It is therefore essential to determine criteria to match a given regional election to the relevant national election. The paper assumes that a given national election is relevant to determine the political support to environmental protection policies in a given region, if the national election happens at most two years before or at most two years after the regional election. Within this time window, we prioritize national elections that take place: (1) in the same year of the regional election; (2) the year immediately before and the year immediately after the regional election; and (3) two years before and two years after the regional election. Applying these rules, we attribute to every regional government their policy stance regarding environmental protection, called Env(Reg).

We also constructed a variable that not only measures the effect of political support at the regional but also at the national scale: Env(Nat). Since the Manifesto Project Database has data on national elections, it is only necessary to match the party that leads the executive after a given national election with the political position of that party regarding environmental policy, as expressed in its political manifesto prepared for the national election. The information on the party that leads the executive is available at the World Bank Database of Political Institutions.

It can be the case that, in the past, more arguments and details were needed in the political parties' manifestos to convince voters about the importance of environmental protection and climate change. If so, this does not mean that political parties attribute less importance to environmental protection in more recent times. However, the data would reflect so. Thus, in order to mitigate this, we standardize Env(Reg) and Env(Nat) to have a zero mean and unit standard deviation by period.

Dirty technological specializations

To test Hypothesis 2, we construct a dummy variable to identify the existence of dirty technological specializations in regions. We follow Dechezleprêtre et al. (2017) and identify two types of dirty technologies based on two groups of IPC codes: transport and electricity production. We compute a dummy taking the value of 1 when a region has a specialization, at the beginning of each period, in at least one of the dirty technologies.

Control variables

It is important to control for several regional features that may affect the development of new green technological specializations and that simultaneously might be correlated with the political support to environmental protection policies. First, we include gross domestic product per capita (GDPpc) because it has been argued that populations in richer countries are more concerned about environmental conditions. Second, we account for the technological capacity of regions (research and development (R&D) percentage of GDP). Third, we control for the regional stock of human capital (share of population with higher education). Fourth, we include a variable share of elderly population, as ageing population is considered to attribute less importance to environmental issues. Fifth, we control for population density in a region, as this is likely to increase the demand for environmental improvements, as more densely populated areas are, in principle, more affected by environmental degradation than sparsely populated areas. Sixth, we account for regional unemployment, as high unemployment rates might decrease the population support for government spending on environmental issues. Seventh, we include the OECD Environmental Policy Stringency Index at the country level, which reflects the degree of stringency of environmental policies and regulations in each country (Martínez-Zarzosoa et al., 2019; Montresor & Quatraro, 2019; Sterlacchini, 2019). Finally, we control for the relative strength of each region in terms of previous green specializations by considering the share of green specializations to the overall number of technological specializations of the regions at time t.

RESULTS

Table B1 in Appendix B in the supplemental data online shows the summary statistics of the variables. Our data include 39,318 observations. Each observation represents a triplet constituted by a region, a five-year period, and a green technology, in which the region is not specialized at the beginning of each five-year period. The acquisition of a green technological specialization by a given region, during a given five-year period, is a rare event, as it only happens in around 3% of the observations. The distribution of the success rate in the acquisition of new green technological specializations is very uneven across European regions. Regarding the variable on regional political support Env(Reg), the highest scores are observed in some Dutch, German and Spanish regions. Regions with the highest average entry rates on green technologies are not necessarily those with the highest scores in terms of political support to environmental protection policies. The correlation matrix in Table B2 in Appendix B online confirms this: the correlation between green entry and political support is weak.

To investigate the hypotheses, we estimate the following model specification:

$$\begin{aligned} S_{izt,t+4} = \alpha &+ \beta_1 \text{AvgProximity}_{izt} + \beta_2 \text{Dirty}_{it} \\ &+ \beta_3 \text{Env(Reg)}_{it} + \beta_4 \text{Env(Nat)}_{it,t+4} \\ &+ \gamma^k \text{Controls}^k_{it-1} + \eta_i + \theta_t + \varepsilon_{it} \end{aligned} \tag{7}$$

where i indicates the region; z is the green technology; t is the year; S represents a dummy that is 1 if a technological specialization z enters a region i between t and $t+4$, and 0 otherwise.[10] AvgProximity denotes relatedness as described in the previous section. The variables Env(Reg) and Env(Nat) represent the two measures of political support to environmental protection policies. Dirty represents a dummy variable that takes value 1 if region i has at least one technological specialization in a dirty technology at time t, and 0 otherwise. Controls is the set of k control variables; η_i is region fixed effects; and θ_t is time fixed effects (a dummy for each of the nine five-year periods).

Following previous research on technological diversification in regions (Balland et al., 2019), our baseline results are estimated by ordinary least squares (OLS) using a linear probability model (LPM).[11] Tables 1 and 3 present the regression results. As shown in Table 1, our first hypothesis is confirmed. As expected, relatedness shows a positive and significant coefficient in all specifications, meaning that new specializations in green technologies are indeed more likely to occur in regions with related technologies. This replicates findings in earlier studies (e.g., van den Berge & Weterings, 2014; van den Berge et al., 2019).

Moreover, we find strong support for Hypothesis 2: the pre-existence in the region of a specialization in dirty technologies hampers the development of new green technological specializations. Interestingly, we find that relatedness moderates this negative association between regions with dirty technological specializations and the development of new green technological specializations (Dirty*Relatedness), implying that relatedness relaxes the negative effect of the local presence of dirty technologies. As shown in Table 2, this negative effect is even taken

Table 1. Regression results I.

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
Dirty		−0.00451**	−0.00447**	−0.01551***	−0.00446**	−0.00388*	−0.01473***
		(0.00210)	(0.00207)	(0.00358)	(0.00208)	(0.00211)	(0.00360)
Relatedness	0.49074***		0.49073***	0.44062***	0.49072***	0.49062***	0.44072***
	(0.02312)		(0.02311)	(0.02770)	(0.02312)	(0.02311)	(0.02771)
Env(Reg)					−0.00008		−0.00032
					(0.00168)		(0.00179)
Env(Nat)						−0.00039	−0.00013
						(0.00222)	(0.00236)
Dirty*Relatedness				0.10109***			0.10065***
				(0.03714)			(0.03713)
Dirty*Env(Reg)					0.00024		0.00209
					(0.00203)		(0.00224)
Dirty*Env(Nat)						−0.00435*	−0.00536*
						(0.00249)	(0.00276)
GDP per Capita	−0.00000	−0.00000	−0.00000	−0.00000	−0.00000	−0.00000	−0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
R&D	−0.00115	−0.00153	−0.00142	−0.00143	−0.00140	−0.00162	−0.00157
	(0.00120)	(0.00120)	(0.00120)	(0.00119)	(0.00123)	(0.00123)	(0.00123)
Human Capital	−0.00054	−0.00075	−0.00063	−0.00062	−0.00063	−0.00073	−0.00079
	(0.00072)	(0.00074)	(0.00073)	(0.00073)	(0.00073)	(0.00073)	(0.00073)
Share Elderly Population	−0.09132	−0.14517	−0.10477	−0.10360	−0.10403	−0.14297	−0.13503
	(0.20687)	(0.21225)	(0.20744)	(0.20747)	(0.20780)	(0.20591)	(0.20645)
Unemployment Rate	0.00029	0.00027	0.00017	0.00016	0.00017	−0.00005	−0.00001
	(0.00052)	(0.00053)	(0.00052)	(0.00052)	(0.00052)	(0.00053)	(0.00053)
Population Density	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)
EPS	0.00196	0.00123	0.00142	0.00135	0.00148	0.00054	0.00145
	(0.00501)	(0.00513)	(0.00504)	(0.00504)	(0.00535)	(0.00504)	(0.00535)
Share Green Spec.	−0.04777***	−0.05797***	−0.04236***	−0.04226***	−0.04243***	−0.04270***	−0.04323***
	(0.01322)	(0.01376)	(0.01350)	(0.01349)	(0.01357)	(0.01347)	(0.01357)
Constant	−0.01375	0.05490	−0.00994	−0.00460	−0.01024	0.00732	0.00929
	(0.05260)	(0.05329)	(0.05274)	(0.05277)	(0.05358)	(0.05260)	(0.05329)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Overall R^2	0.062	0.061	0.023	0.062	0.062	0.062	0.062
N	39,318	39,318	39,318	39,318	39,318	39,318	39,318

Notes: Linear probability model (LPM) was estimated by ordinary least squares (OLS). Dependent variable: Entry of new green technological specializations. Standard errors clustered at the region and technology level are shown in parentheses.
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$.

Table 2. Marginal effects of the presence of dirty technological specializations in regions, for different levels of relatedness and political support.

		Interaction variables
Dirty	−0.015***	Relatedness = minimum
	−0.011***	Relatedness = Q1
	−0.006***	Relatedness = Q2
	0.001	Relatedness = Q3
	0.028**	Relatedness = maximum
Dirty	−0.005	Env(Reg) = minimum
	−0.005**	Env(Reg) = Q1
	−0.005**	Env(Reg) = Q2
	−0.004*	Env(Reg) = Q3
	−0.003	Env(Reg) = maximum
Dirty	0.004	Env(Nat) = minimum
	−0.002	Env(Nat) = Q1
	−0.005**	Env(Nat) = Q2
	−0.006***	Env(Nat) = Q3
	−0.013**	Env(Nat) = maximum

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

away when relatedness is very high. Therefore, dirty technologies thwart the development of new green technological specializations in regions, but not once green technologies are strongly related to the technological structure of the region. In this case, dirty may even foster the development of green technologies. This might be even more true when dirty technologies are related to green technologies: dirty technologies provide relevant local capabilities on which new green technologies can actually build in a region.[12] Therefore, we confirm Hypothesis 2.1. However, we reject Hypothesis 2.2, as we find no evidence that political support fulfils such moderating role.

Table 3 tests Hypotheses 3 and 4. We find little support for Hypothesis 3 on the effect of political support to environmental protection policies on the development of new green technological specializations. The coefficient of political support at the regional scale is positive and non-significant, while the coefficient of political support at the national scale tends to be negative. It is significant in specification (iii), but only at the 0.1 level. We also interacted relatedness with each one of the two variables of political support to test Hypothesis 4. We find the coefficient of political support at national scale is positive and statistically significant, while the interaction term is negative and statistically significant. However, the coefficient of regional political support and its interaction term are non-significant (iv). Therefore, although in specifications (v) and (vi), we find positive and significant coefficients for the national political support variable, its signs and statistical significance depend on the degree of relatedness. Thus, we remain with little support for Hypothesis 3.

To quantify the importance of the interaction effects, Table 4 presents the marginal effects of relatedness for different levels of political support. It shows marginal effects of relatedness when political support is equivalent to: minimum, first quartile, second quartile, third quartile and maximum. Marginal effects are computed using specifications (iv) and (v) of Table 3. Table 4 suggests that the effect of relatedness is stronger in regions with strong political support at the regional scale. For instance, an increase in relatedness by 0.1 may increase by 4.7 (Env(Reg) = min) to 5.3 (Env(Reg) = max) percentage points the probability a given region acquires a new green technological specialization. However, the opposite happens in the presence of high levels of political support at national scale. For instance, an increase in relatedness by 0.1 may increase by 6.4 (Env(Nat) = min) to 3.4 (Env(Nat) = max) percentage points the probability a region acquires a new green technological specialization. This differentiated role of political support on relatedness at the regional and national scales may indicate that the regional dimension strengthens relatedness, while the national one weakens it. Thus, we find support for Hypothesis 4 that the effect of relatedness may depend on the level of political support. An interesting finding is the opposite sign of the interaction terms for regional and national political support. One possible explanation is that political support at the national scale might trigger, eventually, policies that are less place based, while political support at the regional scale might lead to policies favouring the use of local resources for the development of new green technologies.

With respect to the control variables, only the share of green specializations shows a negative and significant coefficient. The other control variables are not statistically significant.[13] The fact that the environmental policy stringency index (EPS) is not statistically significant is in line with our results for the political support variables. As an additional robustness check, Table B3 in Appendix B in the supplemental data online shows the marginal effects of dirty and relatedness for different levels of the EPS. The marginal effects present some similarities to Tables 3 and 4 when dirty and relatedness are interacted with Env(Nat) – we find no statistical evidence that EPS can take away the negative effect of dirty (although EPS moderates it), and EPS moderates relatedness. This means political support at the national scale (Env(Nat)) seems to play a role in the development of new green technological specializations to some extent, similar to the role of actual policy measures at national scale, as embodied in EPS.

CONCLUSIONS

Diversification into green activities is a key topic that combines the strengths of two strands of literatures that have, so far, hardly been combined (Boschma et al., 2017). Broadly speaking, the regional diversification literature has been strong in assessing the role of regional capabilities in quantitative studies, while the geography of sustainability transition literature is strong in pointing out the importance of policies and politics in processes of transformation in case studies. This paper has made an attempt to combine both literatures by investigating the roles of both regional capabilities and political support for the ability of European regions to develop new green technologies. We have made

Table 3. Regression results II.

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Dirty	−0.00447**	−0.00438**	−0.00446**	−0.00447**	−0.00437**	−0.00444**
	(0.00208)	(0.00207)	(0.00208)	(0.00208)	(0.00207)	(0.00208)
Relatedness	0.49073***	0.49064***	0.49065***	0.49066***	0.50041***	0.50341***
	(0.02312)	(0.02311)	(0.02311)	(0.02312)	(0.02370)	(0.02385)
Env(Reg)	0.00004		0.00073	−0.00080		−0.00423*
	(0.00136)		(0.00140)	(0.00193)		(0.00219)
Env(Nat)		−0.00277	−0.00308*		0.00530**	0.00778***
		(0.00181)	(0.00186)		(0.00249)	(0.00282)
Relatedness*Env(Reg)				0.00769		0.04562**
				(0.01913)		(0.02179)
Relatedness*Env(Nat)					−0.07462***	−0.10028***
					(0.02490)	(0.02856)
GDP per Capita	−0.00000	−0.00000	−0.00000	−0.00000	−0.00000	−0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
R&D	−0.00142	−0.00122	−0.00126	−0.00142	−0.00127	−0.00130
	(0.00121)	(0.00121)	(0.00121)	(0.00121)	(0.00120)	(0.00120)
Human Capital	−0.00063	−0.00062	−0.00068	−0.00063	−0.00061	−0.00066
	(0.00073)	(0.00073)	(0.00073)	(0.00073)	(0.00073)	(0.00073)
Share Elderly Population	−0.10433	−0.13906	−0.13422	−0.10428	−0.13729	−0.13158
	(0.20790)	(0.20608)	(0.20660)	(0.20790)	(0.20595)	(0.20645)
Unemployment Rate	0.00017	−0.00008	−0.00004	0.00017	−0.00008	−0.00004
	(0.00052)	(0.00053)	(0.00053)	(0.00052)	(0.00053)	(0.00053)
Population Density	0.00002	0.00003	0.00002	0.00002	0.00003	0.00002
	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)
EPS	0.00147	0.00058	0.00147	0.00147	0.00049	0.00138
	(0.00535)	(0.00503)	(0.00535)	(0.00535)	(0.00503)	(0.00535)
Share Green Spec.	−0.04234***	−0.04151***	−0.04110***	−0.04239***	−0.04131***	−0.04116***
	(0.01353)	(0.01347)	(0.01349)	(0.01353)	(0.01347)	(0.01351)
Constant	−0.01018	0.00664	0.00381	−0.01019	0.00543	0.00213
	(0.05361)	(0.05262)	(0.05330)	(0.05361)	(0.05262)	(0.05330)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Overall R^2	0.062	0.062	0.062	0.062	0.062	0.062
N	39,318	39,318	39,318	39,318	39,318	39,318

Notes: Linear probability model (LPM) was estimated by ordinary least squares (OLS). Dependent variable: Entry of new green technological specializations. Standard errors clustered at the region and technology level are shown in parentheses.
$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

use of a unique data set (Manifesto Project Database) that, jointly with other data, allowed one to regionalize the political support for environmental policy in several European countries.

A key finding is that regional capabilities matter for green diversification in regions. While the transition literature often tends to underline the radical or disruptive nature of green technologies, we find strong evidence that new green activities are more likely to develop in regions where related capabilities are available. This outcome replicates findings in other studies (Corradini, 2019; van den Berge & Weterings, 2014; Tanner, 2014, 2016).

Second, we found that the regional presence of dirty technologies hampered the development of new green technological specializations in a region. However, relatedness tends to relax this negative effect of the local presence of dirty technologies, and it may even take it away when local related capabilities are strong. Moreover, we found that dirty technologies can even provide relevant local capabilities on which new green technologies can actually build in a region (see also van den Berge et al., 2019). Third, we found little evidence of a direct effect of political support on the likelihood of regions to develop new green technologies. However, we found an interaction effect between relatedness and political support: relatedness, which is a key driving force behind green diversification in regions, tends to be weakened by national political support but strengthened by regional political support.

Table 4. Marginal effects of relatedness for different levels of political support.

		Interaction variables
Relatedness	0.47***	Env(Reg) = minimum
	0.49***	Env(Reg) = Q1
	0.49***	Env(Reg) = Q2
	0.49***	Env(Reg) = Q3
	0.53***	Env(Reg) = maximum
Relatedness	0.64***	Env(Nat) = minimum
	0.53***	Env(Nat) = Q1
	0.49***	Env(Nat) = Q2
	0.46***	Env(Nat) = Q3
	0.34***	Env(Nat) = maximum

Note: $*p < 0.1$, $**p < 0.05$, $***p < 0.01$.

This paper also comes with several limitations. First, we used as dependent variable regional diversification in green technologies, not green activities in general. As not all green activities are taken up by patent data, and green activities also concern applications of environmental technologies that contribute to the greening of economies, future research should investigate diversification in green economic activities, and assess more fully the role of political support. Second, we made use of a unique data set (Manifesto Project Database) that allowed one to regionalize the political support for environmental policy, and to make a distinction between national and regional support. This has been operationalized by the extent to which political parties that lead national and regional governments defend, in their political manifestos, policies related to environmental protection and climate change. This indicator does not take up the direct impact of environmental policy: we had no information on whether the political support resulted in the implementation of environmentally friendly policies and practices in the region. In other words, we cannot draw conclusions whether environmental policy made a difference or not. Needless to say, this is a crucial issue that needs to be explored systematically in future research (Giudici et al., 2019).

Third, we looked at the impact of political support in the period 2000–12. Political programmes still differed a lot in terms of environmental policy during that period. We might expect this is less the case in more recent years, as environmental policy is rapidly gaining momentum in European countries, and therefore have entered by now in almost all programmes of political parties. This might imply that this indicator does not take up anymore large differences between European regions with respect to their political support to environmental policy, as compared to the period that we investigated. We leave that point for further research.

Fourth, we found strong evidence of a negative effect of dirty technologies on the probability of a region to develop new green technologies. This may be attributed to the local presence of regional vested interests in dirty technologies, but exactly through which mechanisms this negative effect of dirty technologies works is still unclear.

Finally, we assessed the role of geography in terms of regional capabilities and at the regional and national levels in terms of political support. We did not account for network linkages across regions at various spatial scales, though these are increasingly recognized as potentially relevant for (green) diversification (Binz et al., 2014). These and other questions are crucial to increase our understanding of the role of politics and political support in developing new green activities in regions.

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NOTES

1. Empirical evidence on relatedness and greening is expanding. Corradini (2019) found an inverted 'U'-shaped relationship between entry of regions in green technologies and relatedness to green knowledge in the region. As new environmental technologies are often at an early stage of development (OECD, 2015), they are complex technologies that need inputs from a variety of sources (Barbieri & Consoli, 2019; Cooke, 2012). Compared with non-green technologies, they recombine pieces of knowledge that may be less cognitively proximate (Barbieri et al., 2020; Fusillo, 2019; Orsatti et al., 2020; Quatraro & Scandura, 2019). Barbieri and Consoli (2019) found that both related and unrelated variety had a positive impact on green employment growth in US metropolitan statistical areas. Colombelli and Quatraro (2019) found that a local knowledge base of related technological fields had a positive effect on the creation of green start-ups in Italian regions, but did not find support for unrelated variety. Barbieri, Perruchas, and Consoli (2018) showed that unrelated variety is more prominent in the early stage of the green technology life cycle, while related variety becomes more important as a green technology matures.
2. The Porter hypothesis also states that the development of green innovations will improve both the environmental

and economic performance of firms. However, this is beyond the scope of this paper.
3. OECD REGPAT database, February 2016.
4. Regional governments in Belgium and Germany are operationalized at the NUTS-1 level. This is the reason why for these two countries the unit of analysis is NUTS-1 rather than NUTS-2.
5. Patent data regionalized based on inventors' addresses were used as a robustness check.
6. This means that proximity between technological domains is computed based on patent data from all EU regions with available data.
7. The use of the density indicator, as proposed by Hausmann and Klinger (2007), would attribute, by construction, higher relatedness to regions with more specializations at time *t*. To avoid such shortcoming, we have adapted it as in equation (5).
8. See https://www.arjanschakel.nl/regelec_dat.html/.
9. For instance, 'Minister-President' for Austria, Belgium and Germany, 'Queen's Commissioner' for the Netherlands, 'Présidents des Conseils Régionaux' in France, etc.
10. The entry of new technological specializations between t and $t+5$ was used as a robustness check.
11. We also estimated probit and logit models to assess the robustness of the OLS regression results and, explicitly, to consider the binary nature of our dependent variables. Findings are more or less similar. Although the dependent variable has a large number of zeros (the acquisition of new green specializations is a rare event), the fact we are using a large sample lowers the risk of obtaining biased estimates.
12. Following Montresor and Quatraro (2019), we also unpacked relatedness. We distinguished relatedness between green technologies and three types of technological specializations in regions at time *t*: (1) green technological specializations; (2) non-green and non-dirty technological specializations; and (3) non-green and dirty technological specializations. All three types of relatedness show a positive and statistically significant coefficient. This corroborates the recombinant nature of green technologies that rely on both green and non-green capabilities. Unfortunately, we cannot test the interaction Dirty*Non-green and non-dirty relatedness because this is only possible in regions for which dirty = 1.
13. Although we cannot confirm all expectations regarding control variables, one should also bear in mind that this literature on regional green technological diversification is quite recent and still lacks a comprehensive frame of reference. Having said that, some of the few existing empirical studies on green diversification of regions tend to confirm that most of the control variables we consider are either weakly or non-statistically significant (e.g., Corradini, 2019; Montresor & Quatraro, 2019; van den Berge & Weterings, 2014).

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