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Abstract

This paper analyzes the role of relatedness in the development of new green specializations for the Argentinean provinces between 2008-2019. The development of products with environmental benefits (called green products) is considered one step towards a sustainable transition. These products present a growing demand that may provide an opportunity in terms of green development. The empirical strategy draws on the evolutionary economic geography through indices that capture knowledge bases in the region. The aim is to analyze the role of green and non-green relatedness in the development of new green specializations and to identify potential diversification opportunities. Empirical results show that the green economy has an uneven spatial distribution across the country, that remains stable over time. Furthermore, the development of a new green specialization is positively related to the productive knowledge bases present in the region (proxied by relatedness density). Both, green and non-green relatedness are relevant to develop new specializations in green products. Potential diversification opportunities are also in favor of wealthier regions. Finally, the results reveal a path dependence process on the development of new specialization in green products.

Key words: Green products - Diversification – Relatedness density

JEL Classification: R11, R12, O54

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▪ Introduction

The growing environmental problems associated with climate change and pollution call for a more explicit and attentive consideration of the sustainable character of local economic development processes. Even though many governments in emerging countries consider environmental protection as a luxury concern, the academic debate suggests that the green transition should not be subordinated to other objectives (Altenburg & Rodrick, 2017). In fact, there are at least two reasons why emerging countries should foster the green economy. First, since they are often specialized in activities connected to natural resources, environmental degradation can directly affect large portions of their economy (Altenburg & Rodrick, 2017). Second, shifting towards green activities may provide an opportunity to narrow development gap with more advanced economies that are already focusing on the green transition (Padilla 2017; Altenburg & Rodrick, 2017).

In this framework, products with environmental benefits (called green products[1]) represent an opportunity for niche producers targeting more environmentally conscious consumers (Cooke, 2010; Kautish & Sharma, 2019). Besides, many green products are characterized by a high level of complexity (Mealy & Teyyelboym, 2020), meaning that they can both contribute to economic growth (Hidalgo & Hausmann, 2009) and to the environmental performance (Boleti et al., 2021; Mealy & Teyyelboym, 2020; Romero & Gramkow, 2020). This raises the question of whether green products could be a realistic diversification option in the context of emerging economies.

The diversification of local economies strongly depends on the typology and nature of pre-existing local activities and thus reflects the underlying spatially-embedded capabilities of a region (Balland et al., 2019). Several studies consistently find that regional economies endowed with activities that are related with each other in terms of competences and knowledge bases generate more local economic development opportunities than regions characterized by unrelated sets of activities (Boschma et al., 2012; Essletzbichler, 2015; Rigby, 2012). Green products also emerge following a path dependence process of technological development (Mealy & Teyyelboym, 2020, Trippl et al., 2020), but it remains unclear what role relatedness (green & non-green) plays in the development of green specialization. In this context, a second

[1] The concept involves a wide range of inputs/products associated with alternative energies, cleaner technologies, recycled materials, water, and waste management, among others (OECD, 1999).

question is whether these elements contribute to explaining the process of green diversification at the regional level in emerging countries. In this paper, these questions are investigated for the Argentinean case drawing on the Evolutionary Economic Geography tradition (Balland et al., 2019; Boschma & Frenken, 2011; Boschma, 2017; Neffke et al., 2011).

In Argentina, the green economy appears to be a relevant topic for policymakers[2]. The green economy is also a potential source of employment in various sectors. Estimates for 2015 indicate that 7% of registered employment in Argentina is green. Green employment is mainly concentrated in manufacturing (38%) (Ernst et al., 2019). However, recent research shows a decline in green exports and consequently a decrease in competitiveness (Palazzo et al., 2021). Despite this, considering the heterogeneity that characterizes Argentina's provinces, it is still necessary to understand the regional dynamics to provide a territorial overview of green products in Argentina. To address this gap, this research analyzes the relationship between the development of new regional specializations in green products and regional relatedness (green & non-green), by focusing on Argentinean provinces over 2008-2019[3].

This paper provides two mains' contributions. Firstly, this research explicitly analyzes the subnational geography of an emerging economy, where there is a considerable research gap related to the green economy (Pérez- Hernández et al., 2021). Second, the results provide concrete indications of future diversification opportunities, which can serve as a basis for regional policies that foster the green economy in Argentinean regions.

This paper is structured as follows. The next section summarizes the related literature. Then, the methodology and the data are described. The subsequent section includes the main results. The paper ends with the conclusion and discussion about the main findings and further analysis.

[2] Argentina has implemented policies in renewable energies (wind, solar, geothermal, hydrogen), sustainable transport, climate change, bio-economy, and circular economy. However, the stop-go pattern is one of its main characteristics (see Bril Mascarenhas et al. (2021) and OIT (2021) for a complete description of the main green public policies).

[3] The unit of analysis is the province. Argentina is divided into 23 federated states and Ciudad Autónoma de Buenos Aires. In this paper, region and province are used interchangeably.

▪ Literature review

In recent years, several studies within Evolutionary Economic Geography (EEG) have contributed to explain regional development dynamics based on territorial characteristics. Specific interest is devoted to the concept of relatedness (Balland et al., 2019; Boschma & Frenken, 2011; Boschma, 2017; Neffke et al., 2011) and to the path dependent nature of the processes shaping local economic structures (Martin & Sunley, 2006).

Only a few studies have integrated the green economy into the relatedness framework (Colombelli & Quatraro, 2019; Bergamini & Zachmann, 2021; Parruchas et. al., 2020; Montresor & Quatraro, 2019; Santoalha & Boschma, 2021). Nonetheless, the green economy deserves special attention for at least the following reasons. Firstly, the production and diffusion of goods within the green economy is considered a step towards a sustainable transition because they are environmentally preferable products (OECD, 1999). Secondly, it is a growing market that can represent an opportunity for the development of regional economies (Cooke, 2010; Kautish & Sharma, 2019). Therefore, analyzing whether the arguments of the EEG literature on green products can be of interest in the design of regional and industrial policies. As Rodrik (2014) emphasizes, industrial policy plays a crucial role to foster green growth.

Relatedness & regional diversification

The process of regional diversification is underpinned by the pre-existing local activities and thus it reflects the embedded capabilities of a territory (Balland et al., 2019). One of the ways of measuring these capabilities embedded in a region is through the idea of relatedness. According to Hidalgo et al. (2018:452) "two activities, such us products, industries, or research areas are related when they require similar knowledge or inputs". Then, the notion of relatedness can be adopted in different contexts, depending on the specific analytical perspective and units of analysis under scrutiny. In this vein, Boschma (2017) identifies different domains of application of this theoretical category, including technological-relatedness (Balland et al., 2019; Boschma et al., 2012; Kogler et al., 2013; Rigby, 2012; Whittle & Kogler, 2020), skill-relatedness (Cappelli et al., 2019; Neffke et al., 2017), input-output-relatedness (Essletzbichler, 2015; Morrissey & Cummins, 2016), and product or industrial relatedness (Alonso & Martin, 2019; Boschma et al., 2013; Hidalgo et al., 2007; Neffke et al., 2011).

Recent evidence finds that technological relatedness is one of the main drivers of green industry emergence (Colombelli & Quatraro, 2019; Bergamini & Zachmann, 2021; Parruchas et. al., 2020; Montresor & Quatraro, 2019; Santoalha & Boschma, 2021). By drawing on the concept of technological relatedness, Perruchas et. al. (2020) show that green diversification tends to occur in green technologies related to the existence competences. This view is supported by Montresor & Quatraro (2019) which, in addition, found not only green pre-existing technologies matter but also non-green ones.

However, it remains unclear whether product relatedness is also a driver of the green economy. To address this gap, this paper focuses on product-relatedness[4], which in general terms allows to capture regional capabilities, based on the frequency of co-occurrence of products in the product portfolio (Teece et al., 1997)[5]. In this regard,product relatedness could be used to explain specialization patterns (Hidalgo, 2021), and to infer potential diversification options (Broekel et al., 2021). Within the EEG literature, this process is referred to as regional branching, since the diversification process results in the entry of new products/activities/firms/sectors related to those in which the regions are currently specialized (Boschma & Frenken, 2011). These new entries reflect the embedded capabilities of the territory (Alshamsi et al., 2018; Balland et al., 2019). Therefore, the development of new specializations is related to the existent knowledge bases or regional capabilities, captured by the notion of relatedness. Based on this, I formulate to the following hypothesis regarding the emergence of green products across space:

H1) Argentinean provinces are more likely to develop new specializations in green products related to their pre-existing knowledge bases (green and non-green).

[4] Section 3.3 provides a detailed explanation of how the concept is measured.

[5] The same argument is employed in studies about technological diversification where capabilities are captured by technological relatedness.

▪ Empirical approach

1. Data & Variables

The primary source of information is product export data (6-digit Harmonized System (HS)) for Argentinean provinces between 2008-2019, provided by the National Institute of Statistics and Census (INDEC). This information is the only product-data available across provinces that allow us to compare them and analyze their evolution[6].

In this regard, the literature recognizes the relevance of international trade in the process of technological accumulation (Dosi et al., 1990; Fagerberg, 1987). As a result of the increasing integration of economies, trade profiles represent a good measure of regional industrial structures and specialization patterns (Boschma & Iammarino, 2009). In addition, entry into foreign markets can be perceived as the result of productive, organizational, or institutional capabilities (Castellacci, 2007). In the case of Argentina, the empirical evidence shows that greater regional export openness boosts firms' innovation opportunity (Marin et al., 2015). In addition, one of the features that define different regional innovation systems from Argentina, is their profile of international insertion (Niembro, 2017).

Therefore, trade data seems appropriate for the current analysis considering the relevance of the external market, since sectors opened to international competition are also the most likely to contribute to innovation and economic growth. In this respect, green products present a growing market as the niche of more environmentally conscious consumers is increasing (Cooke, 2010; Kautish & Sharma, 2019).

Green products are identified following Mealy & Teytelboym (2020). They combine the three existing international lists of environmental trade goods into a unique list of 293 products. First, the list from the Organization for Economic Cooperation and Development (OECD) identifies the products under different groups of environmental benefits: air pollution control; cleaner or resource-efficient technologies and products; environmentally preferable products based on end-use or disposal characteristics; heat and energy management; environmental monitoring, analysis, and assessment equipment; natural resource protection; noise and vibration; renewable energy plant; solid and hazardous waste management and recycling systems; soil and water clean-up or remediation; waste management and drinking water

[6] See supplemental data in Appendix 1.

treatment (OECD, 1999). Second, the World Trade Organization (WTO, 2001) identifies a list of products with potential environmental benefits associated with the use of such products, their materials, final disposal, and/or in comparison with another similar product. Then, considering similar benefits, the Asia- Pacific Economic Cooperation (APEC) agreed on a list of environmental goods with the aim of implementing tariff reductions on these goods (APEC, 2012).

In addition, to characterize the economic structure of Argentinean provinces (N: 24) I use population and population density from INDEC and industrial employment from the Employment andBusiness Dynamics Observatory (Ministry of Labor, Employment and Social Security of Argentina)(OEDE). Table 1 summarizes the descriptive statistic of the main regional variables.

Table 1 here

Table 2 describes the main variables and their descriptive statistics. Data management and analysis were performed using R EconGeo Package (Balland,2017), following this procedure for the operationalization of each variable:

- Entry: The dependent variable is defined following the contributions of Balland et al. (2019) and Montresor & Quatraro (2019) but considering green products instead of technologies. In this sense Entry is a binary variable that assumes the value of 1 if the province r develops a new Revealed Comparative Advantage (RCA) in a green product i in a four-year period (non-overlapping periods). In the robustness check, other periods are considered. In order to obtain the RCA, I follow the contribution from Balassa (1995) considering provinces (denoted by *r*) and products (denoted by *p*):

$$RCA_{rp} = \frac{x_{rp} / \sum_p x_{rp}}{\sum_r x_{rp} / \sum_r \sum_p x_{rp}} \qquad (1)$$

Where x_{rp} is province *r*'s exports of product *p*. For example, Table 3 shows that Province A has a $RCA > 1$ only in Product 1, while Province B has a $RCA > 1$ in Product 2 and Product 3.

Table 3 here

- Relatedness density: The measure of relatedness has been employed in several empirical studies (Alonso & Martin, 2019; Boschma et al., 2013; Hidalgo et al., 2007; Neffke et al., 2011, among others). It is calculated following these steps: first, compute the product proximity (φ_{ij}) based on the assumption that related products are more likely to be in the country area as they require similar capabilities (Hidalgo et al., 2007). Following Hidalgo et al. (2007), I compute proximity (φ_{ij}) as the distance between each couple of goods i and j as the minimum of the pairwise conditional probability of being co-exported by the same country (province in this case):

$$\varphi_{ij} = min(P(RCA_i > 1|RCA_j > 1), P(RCA_j > 1|RCA_i > 1)) \qquad (2)$$

Where $P(RCA_i > 1|RCA_j > 1)$, is the conditional probability that a province is competitive (RCA > 1) in product i since it is competitive in product j. Then, I compute the relatedness density (ω_j^r) to link the product proximity to the regional specialization portfolio. Following the contribution of Montresor & Quatraro (2019) in technological domains, here product relatedness is considered. Specifically, three measure are defined: 1) Total Relatedness Density (TRelden); 2) Green Relatedness Density (GRelden); and 3) Non- Green Relatedness Density (NGRelden), where $TRelden = GRelden + NGRelden$

1) Total Relatedness Density (TRelden) computes the average proximity between a given product j and all the products that the province r can currently export competitively:

$$\omega_j^r = \frac{\sum_i \rho_i^r \varphi_{ij}}{\sum_i \varphi_{ij}}$$

Where $\rho^r = 1$ if the province r has a $RCA > 1$ in product i and φ_{ij} is the proximity between product j and any other product i.

2) Green relatedness density (GRelden):

$$GRelden_j^r = \frac{\sum_g \rho_g^r \varphi_{gj}}{\sum_i \varphi_{ij}}$$

Where $\rho_g^r = 1$ if the province r has a RCA > 1 in product g. φ_{ij} is the proximity between product j and any other product g, being g is a green product from the list of 293 products with environmental benefits.

3) <u>Non- Green relatedness density</u> (NGRelden):

$$NRelden_j^r = \frac{\sum_n \rho_n^r \varphi_{nj}}{\sum_i \varphi_{ij}}$$

where φ_{ij} is the proximity between product j and any other product i and n is a non-green product.

2. Econometric strategy

Due to the binary nature of the dependent variable, I estimate a logit model to analyze the role of relatedness on the development of a new specialization in a green product in a province. The baseline specification includes new entry (E) as a dependent variable, while relatedness (total, green and non-green) are the main independent variables. The first specification considers the total relatedness density, while the second disentangle this measure between green and non-green relatedness.

$$E_{rit} = \alpha + \beta_1 TRelden_{rit-1} + \beta_2 Controls_{rt-1} + \phi_r + \theta_t + \gamma_i + \varepsilon_{rit}$$

$$E_{rit} = \alpha + \beta_1 GRelden_{rit-1} + \beta_2 NGRelden_{rit-1} + \beta_3 Controls_{rt-1} + \phi_r + \theta_t + \gamma_i + \varepsilon_{rit}$$

where the sub-indices r, i and t, indicate provinces, industries (first two digits of the selected products, according to the international nomenclature for the classification of products (Harmonized System- 2007)) and time (years), respectively. The different specifications include a set of control variables suggested by the literature at provincial level lagged one period. To control for the provincial size, I include population (in logs) as Balland et al. (2019). Following Boschma et al., (2015), as a proxy of the level of urbanization of each province, I consider population density, measured as the quotient between the population of each province and its area in square kilometers (pop-den). Then, I include industrial employment to control for industrial-related factors (Quatraro & Scandura, 2019) and the number of green products in which the province has already specialized (RCA > 1). In addition, the model includes dummies by province, time and industry, and heteroskedasticity-robust standard errors (clustered at province and product level).

3. Green Opportunities: Green Adjacent Possible and Green Complexity Potential

Drawing on relatedness concept and Product Complexity Index (PCI), I follow Mealy & Teyyelboym (2020) to compute the Green Adjacent Possible and the Green Complexity Potential to identify potential diversification opportunities for the Argentinean provinces. The measure of relatedness density was introduced previously. This section employs green relatedness density considering the portfolio of green products. For its part, the Product Complexity Index (PCI) was introduced by Hidalgo & Hausmann (2009) is computed considering a binary matrix M. Each element M_{rp} is equal to 1 if province r has a RCA in product p and 0 otherwise. Then, for each province I can compute the horizontal sum to obtain the diversity, and for each product I can measure the ubiquity (vertical sum). Considering the example from Table 3, for Province A, the diversity is: 1 + 0 + 0 = 1. The diversity (d_r) indicates in how many products province r has a RCA > 1.

$$d_r = \sum_p M_{rp}$$

While the ubiquity (u_p) counts how many provinces have a RCA in a product *p*. Following the example from Table 3, for Product 1 its the vertical sum is: 1 + 0 + 1 = 2. The formula results:

$$u_p = \sum_c M_{rp}$$

The value of PCI is obtained from the eigen-vector associated with the second largest eigenvalue of the transpose of the matrix: $\widetilde{M} = D^{-1}S$, where D is the diagonal matrix from the diversity vector and S is the symmetric similarity matrixthat indicates how similar two provinces' baskets:

$$S_{rr\prime} = \frac{\sum_p M_{rp} M_{r\prime p}}{u_p}$$

Then, the grid of Green Adjacent Possible (GAP) combines the PCI and the green relatedness density (GRD) to identify specific green diversification opportunities for products in which the province does not possess a RCA > 1 but are related to the provinces' current export capabilities (countries for Mealy & Teyyelboym, 2020). For example, Figure 1 illustrates the case of three provinces. The dots represent products that the province is not competitive in. The y-axis plots the degree of PCI of each product and the x-axis plots the products relatedness density. Green relatedness density index averages the productive distance of a product to the set of products in which the province is competitive. The index seeks to capture the degree to whichexisting capabilities are applicable for its production. Province A shows the worst scenario, because its green products have lower level of PCI and lower density. Province B has products with higher PCI, which represent an interesting opportunity in term of economic growth, but they are not related to the current exported products (lower density), so for this province could be also difficult to diversify into these products. Province C presents more possibilities to diversify into these products because present they have higher degree of relatedness density, and also, they have a higher PCI.

Figure 1 here

Then, the measure that summarizes these diversification opportunities is the Green Complexity Potential (GCP). The GCP identifies each province's average relatedness to green products which the province is not yet competitive in.

$$GCP = \frac{1}{\sum_{g(1-} \rho_g^c)} \sum_g (1-\rho_g^r)\omega_g^r \widetilde{PCI}_g$$

$(1-\rho_g^r) = 1$ if the province r has not a RCA > 1 in green product g ω_g^r is the proximity of product g to province r, and $\widetilde{PCI}_g$ is the Product Complexity Index of g normalized between 0 and 1. Higher values of GCP implies higher green complexity potential of the province.

- **Results**

1. The role of relatedness on the development of new green specializations

Table 5 summarizes the models that analyze the role of relatedness on the development of new green specializations, controlling by year, province, and industry effects. The correlation matrix is available on Appendix 2. The coefficient for total relatedness density ($TRelden_{ri}$) is positive and significant across all the specifications. Then, when this measure is disentangled, it is observed that both green relatedness density ($GRelden_{ri}$) and non-green relatedness density ($NGRelden_{ri}$) are positive and significant. Model 1 and 2, test the significance of the variables without controls, while Model 3 and 4 includes regional controls (population, population density, and industrial employment). Following the principle of relatedness (Hidalgo et al., 2018), the results are in line with hypothesis 1: the development of a new green specialization is related to the existing knowledge base in the region. In particular, green relatedness density is more relevant to the development of new specializations in green products than non-green relatedness density. However, the significance of non-green relatedness density deserves particular attention. This result indicates that non-green knowledge should not be underestimated. In fact, it could be applied to foster green specialization in the region. An example of this could be the case of the automobile industry, that set the initial conditions to develop products related to electric mobility.

The control variables also present the expected signs in most specifications. Agglomeration economies, proxied by population density, are positively and significantly associated with the development of new green specializations. Population size is also positive and significant. However, on Model 5 population size and population density are not significant. Their effect could be captured by industrial employment and RCA that are positive and significant in this specification. The number of RCA in green products might reveal a path dependence process on the development of green products.

Table 5 here

Table 6 summarizes the main results from the followings robustness checks. In Model A1 and A2, I restricted the database to OECD's classification of environmental goods, considering 256 green products instead of 293 from the unified list. Then in Model B1 and B2, I computed the number of green products in which the province is already specialized as RCA > 0.70, instead of RCA >1. In both cases, the results remain unchanged.

Table 6 here

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2. Diversification opportunities based on the existence knowledge

The estimations from the precedent section show the relevance of the relatedness on the development of new green specializations. Based on the available disaggregation of data, it is possible to use this measure to detect which products have higher diversification potential for each province. In this regard, the Green Adjacent Possible (GAP) allows to identify future diversification opportunities. In each plot, the dots (N: number of observations) for each province indicates the products in which is currently not competitive. The difference between the total number of products in the list (293) and the number of observations indicates the number of products in which the province is currently competitive. For example, BuenosAires is competitive in 100 green products (293 -193). The y-axis represents the PCI of each product and the x-axis the product's green relatedness density. As it was presented, green relatedness density index averages the productive distance of a green product to the set of green products in which the country is competitive.

The GAP for the Argentine provinces is presented in Figure 2 by groups, according to the rankingof the Green Complexity Potential (2019) available on Figure 3: high (green), medium-high (light blue), medium-low (blue), low (violet). The first row (green) gathers the leading provinces: Buenos Aires (N:193), Cordoba (N:239), CABA (N:135), Santa Fe (N:209), Mendoza (N:215), and (Neuquén (N:210). This group of provinces shows a higher number of products in which the provinces are already competitive. CABA has more possibilities to diversify, given that the products are more related to its current capabilities (higher density). At the same time, they are products with a high degree of complexity (higher PCI) which, according to the Economic Complexity Theory, have a higher probability of growth.

Figure 2 here

Provinces with a medium-high degree of complexity are shown in light blue: San Luis (N:246), Chubut (N:220), Santa Cruz (N: 229), San Juan (N:251), Salta (N:251), and Rio Negro (N:223)). Among them, the case of, Rio Negro, and Chubut are the ones with higher density in the products that they can diversify in. It is expected that these provinces present higher values of the Green Complexity Potential that is presented in the next sub-section.

Then, in blue, provinces with a medium-low degree of green complexity are included: Tierra del Fuego (N:252), Tucumán (N:233), Entre Rios (240), Misiones (N:247), Santiago del Estero (N: 279)and, La Rioja (N: 225). Among them, Tierra del Fuego shows higher density.

Finally, in violet is represented the case of, La Pampa (N: 250), Chaco (N:226), Corrientes (N:216), Formosa (N: 227), Catamarca (N:230), and Jujuy (N: 246). These provinces have not only lower green complexity but also lower opportunities to diversity into green products.

From the GAP grids, it is possible to rank the products by degree of relatedness to identify diversification options. Table 4 summarizes the potential product for each province7. Inputs for renewable energy industry (REP) appear as an opportunity for some provinces. In particular, inputs/products related to turbines for marine propulsion (Buenos Aires), refrigerators to geothermal system (Jujuy, La Pampa, Entre Rios), electric motors and generators to generate electricity in renewable energy plants (Rio Negro, Corrientes), and parts for electric motors and generators (Santa Fe). In the case of CABA, San Juan, Formosa, Misiones and San Juan the products with environmental benefits that appear as a diversification opportunity, belong to the category of cleaner or resource-efficient technologies and products (CRE). Then, inputs or products related to waste management and recycling systems (SWM) seems an opportunity for Catamarca, Cordoba, Mendoza, San Luis, Santiago del Estero and Tucumán. Finally, products from heat and energy management (HEM) represent an opportunity for Chaco.

Table 4 here

The information presented about the potential diversification opportunities is summarized by computing the Green Complexity Potential (GCP), which reflects the overall potential of a province to diversify into a new green product (Figure 3). The results suggest that the opportunities for future green diversification are in favour of central regions.

Overall, from a policy perspective, these results emphasize the necessity of merge both sectoral incentives as well as regional policies to foster regional green development.

Figure 3 here

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[7] Appendix 2 presents the top three of products for each province, according to the degree of relatedness.

Final remarks

The green transition has become a relevant issue for many economies around the world. The literature shows the potential benefits of green diversification, not only for economic purposes but also for environmental reasons. In this vein, this research contributes to the current debate by comparing the Argentinean provinces' trajectories over the period 2008-2019 in terms of green complexity as well as identifying their potential green diversification options.

The econometric estimations suggest that relatedness play a significant role in the development of new green specialization. In particular, green relatedness density is more relevant to the development of new specializations in green products than non-green relatedness density. However, the significance of non-green relatedness density deserves particular attention. This result indicates that non-green knowledge does not be underestimated. In fact, it could be applied to foster green specialization in the region. Following Hidalgo et al. (2018), the results suggest that regional knowledge bases (proxied by relatedness) are related to the development of new green specialization. These results also support the existence of a path dependence process in green product development, as argued by Trippl et al. (2020) and Mealy & Teyyelboym (2020). Based on the notion of relatedness, these findings imply that new specializations in other green products can take place within the same sector. In this respect, an interesting angle to analyze in future research is the similarity of technologies shared by green products.

Another intriguing result to explore further is that a new green specialization could be promoted by the existing regional capabilities required to produce "non-green products". Further studies are needed to identify those unsuspected industries that would also foster the development of green industries. For example, Santa Fe presents higher opportunities to diversify into electric motors and generators. Along these lines, a recent study analyzes how a company in the automotive sector (non-green product) from Santa Fe uses its know-how to produce electric vehicles (green product) (Bril Mascarenhas et al., 2021).

The green complexity potential in Argentina is spatially unevenly distributed. The ranking is led by core provinces (Buenos Aires, Ciudad Autónoma de Buenos Aires, Santa Fe and Córdoba), and the pattern remained stable over the sample period, with few exceptions among the southern provinces. Furthermore, the study identifies a list of green products with greater possibilities in each region, based on the existing capacities in each province. This result constitutes an important input for local policymakers to foster the green economy in Argentina.

Opportunities for future green diversification are in favor of local economies that are already strong. Hence, space-blind green policies would only exacerbate regional disparities in terms of green opportunities. From a policy perspective, these findings emphasize the necessity of merging both sectoral incentives and regional policies to foster regional green development. In this regard, considering specifically the case of an emerging economy which faces structural constrains, it is needed to form competences and skills as well as reinforce the absorptive capacity in peripheral areas.

As Balland et al. (2022) argue, regional policies should consider the self-reinforcing nature of economic complexity. In this regard, a critical point to consider in further studies is the role of public policy on green development at the regional level. As it was presented on the introduction, there are some incentives for the green economy in Argentina (Bril Mascarenhas et al., 2021; OIT, 2021). However, the environmental dimension seems to not be a decisive factor in the decision-making process, and even worse, in some cases, seems to be subordinated to the economic dimension. In line with Ferraz et al. (2021), policies should include a broader perspective including social and environmental sustainability. At the regional level, this work constitutes a first advance in a line of research. Further analysis should undoubtedly incorporate the environmental dimension, the role of the public sector and the relevance/impact on the local economy.

As for the limitations, we should consider that HS nomenclature was designed for trade purpose, then has been employed to identify potential environmental benefits. However, the production process remains a black box. In addition, it is possible to miss relevant cases for the domestic economy. For instance, periphery regions maybe do not export green products, but they could be suppliers of those products that export them. Nevertheless, this data allows contributing with a first comparative study of regional green complexity in Argentina, given the lack of information at the regional level (input-output, green patents, green jobs). Future research might also consider alternative approaches (theoretical and empirical) to discuss and propose a context-based study. Through a qualitative analysis will be possible to enrich the research by studying different experiences of green diversification. For example, considering the availability of natural resources and the country's productive pattern, it is relevant to identify agroecological products and other firms/entrepreneurs' initiatives that came from the circular economy, which undoubtedly are part from the green economy and constitute a step forward towards a more sustainable environment.

At the international level, there is a growing number of more stringent environmental policies that affect also emerging economies (Padilla, 2017). In this regard, an interesting challenge for Argentina and other Latin American countries is to advance in the construction of a nomenclature that allows for the identification of a wider range of "green products", which could constitute a point of international differentiation and a way of anticipating the legislation changes that importing countries are discussing or in approval process (for example, agrochemicals-free products, deforestation-free products).

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Tables & Figures

Table 1: Variables

Variable	Description	Source	Period	N*	MeanSD	Min.	Max.
lpop	Population (log)	INDEC	2010-2019	240	13.9301.06	11.84	16.67
pop-den	Population density	INDEC	2010-2019	240	16.6518.26	0.14	74.34
emp-ind	Registered industrial employment	OEDE	2008-2019	312	66.53126.41	2	532

*Considering 24 provinces and the available data for each period.

Table 2: Descriptive statistics

Variable	Description	N	Mean	SD	Min.	Max.
Entry	Entry = 1 if the province r develops a newRCA in a green product i in 4-year period; Entry = 0 otherwise	7759	0.21	0.41	0	1
TRelden	Total Relatedness density -between a green product and the over- all portfolio	7759	9.59	13.63	0.33	100
GRelden	Green Relatedness density -between a green product and the over- all green portfolio	7759	0.93	1.15	0	17.12
NGRelden	Non-Green relatedness density -between a green product and the non-green portfolio	7759	8.66	12.60	0	99.22
lpop	Population (log)	7759	13.92	1.05	11.84	16.67
pop den	Population density (population/surface)	7759	16.55	18.20	0.14	74.34
emp ind	Registered industrial employment	7759	65.11	124.67	2	532
RCA	Number of green products in which the province has a RCA > 1	7759	40.15	29.87	6	140

Table 3: Example - Binary province-product matrix

	Product 1	Product 3	Product 3
Province A	1	0	0
Province B	0	1	1
Province C	1	0	0

Table 4: Diversification opportunities – Main product by degree of relatedness

Ranking	Province	Product description	Env. benefit
1	Mendoza	Articles of lead	SWM
2	Buenos Aires	Steam turbines and other vapor turbines	REP
3	Cordoba	Articles of lead	SWM
4	Santa Fe	Parts suitable for uses with the machines of heading	REP
5	CABA	Surveying, hydrographic, or geophysical instruments and appliances	CRE
6	Neuquen	Sulfites	PM
7	Chubut	Taps, cocks, valves and similar appliances for pipes, boiler shells	WAT
8	Salta	Sulfites	PM
9	Santa Cruz	Taps, cocks, valves and similar appliances for pipes, boiler shells, tanks	WAT
10	Tucuman	Articles of lead	SWM
11	Rio Negro	Electric motors and generators (excluding generating sets)	REP
12	San Luis	Other articles of lead	SWM
13	Entre Rios	Refrigerators or freezing equipment, electric or other	REP
14	Catamarca	Articles of lead	SWM
15	Chaco	Amino-resins, phenolic resins and polyurethanes, in primary forms	HEM
16	San Juan	Surveying, hydrographic, or geophysical instruments and appliances	CRE
17	Corrientes	Electric motors and generators (excluding generating sets)	REP
18	Santiago del Estero	Articles of lead	SWM
19	La Rioja	Binoculars, monocular, other optical telescopes	MON
20	Tierra del Fuego	Taps, cocks, valves and similar appliances for pipes, boiler shells	WAT
21	Jujuy	Refrigerators or freezing equipment, electric or other	REP
22	Misiones	Surveying, hydrographic, or geophysical instruments and appliances	CRE
23	La Pampa	Refrigerators or freezing equipment, electric or other	REP
24	Formosa	Surveying, hydrographic, or geophysical instruments and appliances	CRE

CRE: Cleaner or more efficient technologies, HEM: Heat and energy management, REP: Renewable Energy, APC: Air pollution control, EPP: Environmental preferable products, NVA: Noise and vibration, MON: environmental monitoring,NPR: Natural resources protection, SWM: Management of solid waste and recycling systems; SWR: Clean up or remediation of soil and water, WAT: Wastewater management and potable water treatment (OECD, 1999); PM: Pollution Management (WTO, APEC)

Table 5: The role of relatedness on the development of new green specializations

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Trel_den	0.0663***		0.0672***		
GRel_den		0.2099*		0.2610*	0.2625*
NGRel_den		0.0550***		0.0522***	0.0522***
Pop			4.402**	4.592***	1.6951
Pop den			0.126**	0.1261**	0.0931
Ind empl			0.0143	0.0164	0.0310***
RCA					0.0370***
Controls	No	No	Yes	Yes	Yes
Log L	-3.577	-3.676	-3.570	-3.568	-3548.82
Pseudo R2	0.0999	0.993	0.1010	0.1014	0.1063
N	7,599	7,599	7,599	7,599	7,599

The dependent variable entry equals 1 if a region r gains a new relative comparative advantage (RCA) in a green product i during four-year window; and 0 otherwise. Independent variables lagged by one period.
Coefficients are statistically significant at the *p< 0.05, **p< 0.01 and ***p< 0.001 level
Heteroskedasticity-robust standard errors (clustered at province and product level)
Dummies by province, year and industry are included.

Table 6: : Robustness check

Variable	Model A1	Model A2	Model B1	Model B2
Trel_den	0.0656***		0.0672***	
GRel_den		0.2459*		0.2680*
NGRel_den		0.0517***		0.0516***
Population	0.655	0.836	2.298	2.286
Population density	0.112*	0.111*	0.1211**	0.120**
Industrial employment	0.024**	0.0260**	0.0234**	0.0365***
RCA >1	0.0365***	0.0363***		
RCA >0.7			0.0268***	0.0269***
Log L	-3.050	-3.049	-3.558	-3.556
Pseudo R2	0.0989	0.0992	0.1040	0.1045
N	6422	6422	7,599	7,599

The dependent variable entry equals 1 if a region r gains a new relative comparative advantage (RCA) in a green product i during four-year window; and 0 otherwise. Independent variables lagged by one period.
Coefficients are statistically significant at the *p< 0.05, **p< 0.01 and ***p< 0.001 level
Heteroskedasticity-robust standard errors (clustered at province and product level)
Dummies by province, year and industry are included.

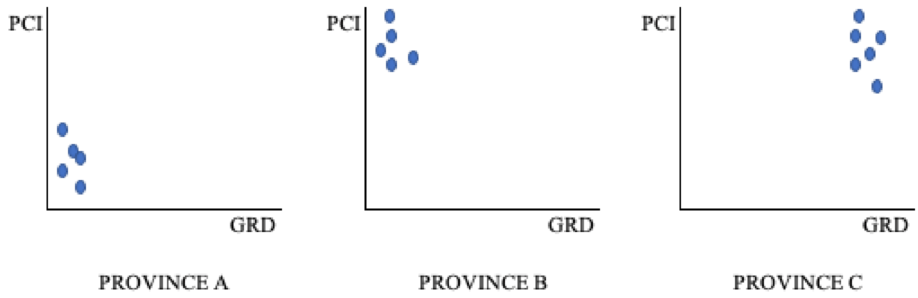

Figure 1: Example - Grid of Green Adjacent Possible

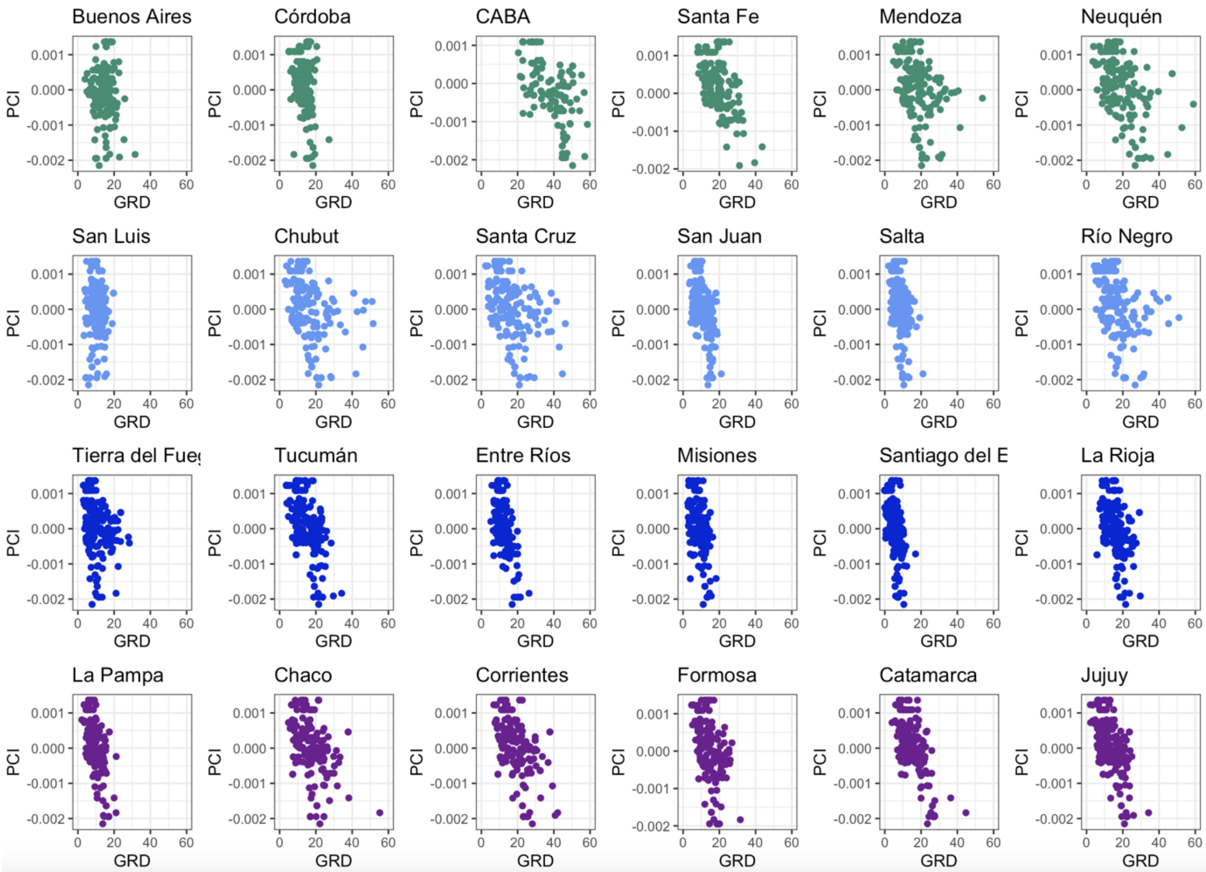

Figure 2: Grid Green Adjacent Possible (2019)

PCI: Product Complexity Index, GRD: Green Relatedness Density. The provinces are grouped by degrees of green potential presented in Figure3 1: high (green), medium-high (light blue), medium-low (blue), low (violet).

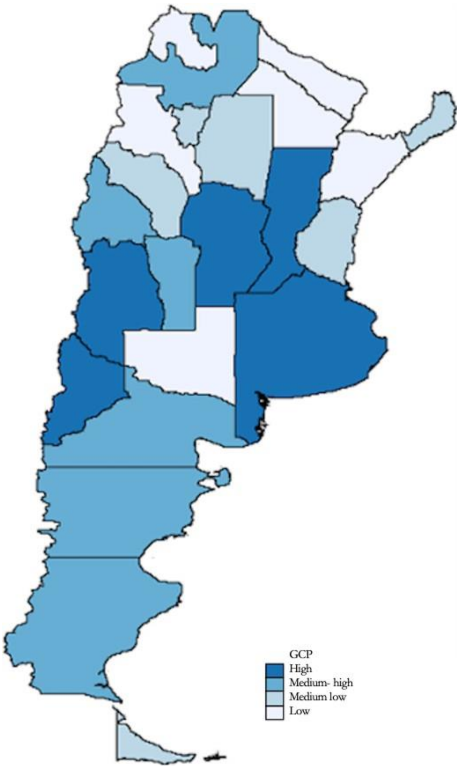

Figure 3: Regional Green Complexity Potential (2019)

Appendix 1

Green export performance

Overall, the 2008-2019 trend of provincial green exports is downward. A period of growth 2009-2011 and a period of recovery between 2017-2018 is observed. The national trend is mainly explained by the evolution of green exports in Buenos Aires. For their part, the only provinces that experienced growth in their green exports are Chaco and Corrientes (Figure 5). Indeed, recent results at the national level indicate that Argentina has been decreasing its exports of green products and consequently has lost competitiveness at the global level (Mealy & Teyyelboym, 2020; Palazzo et al., 2021).

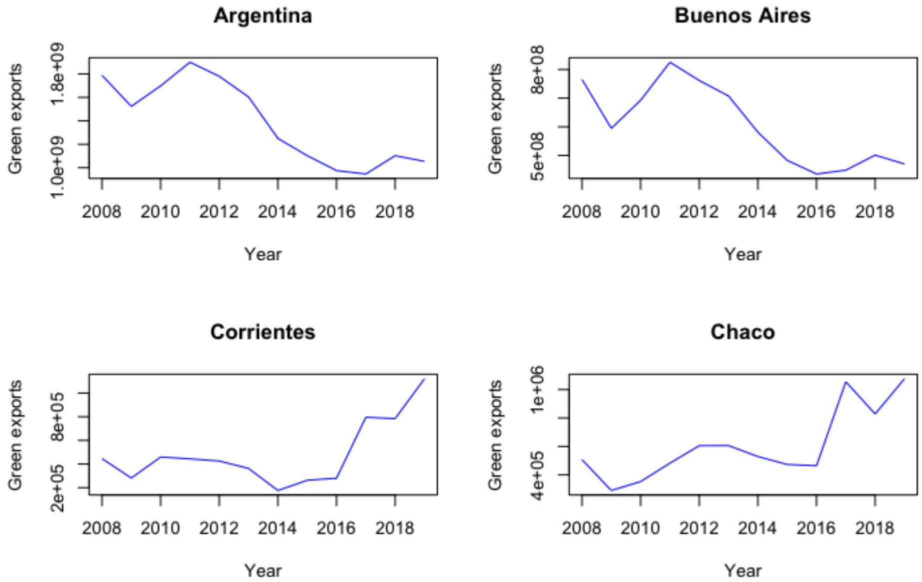

Figure 5: Green export performance.

Green Specializations in 2019

Argentina's pattern of specialization is based on resources and traditional activities associated with them. In fact, comparative advantages are mainly concentrated in raw materials, agricultural products, and food industry (Caselli & Zaghini, 2005). Of total exports, the percentage of specializations (RCA>1) in products with environmental benefits (green products) is relatively low for the national total and all provinces (Table 9). In relative terms, the southern provinces (Chubut, Neuquén, Rio Negro and Tierra del Fuego) have a greater number of specializations in products with environmental benefits.

Table 9: Green Specializations in 2019

	Share of RCA>1		
Province	Green	Non-green	Total
Buenos Aires	8%	92%	100%
CABA	8%	92%	100%
Catamarca	10%	90%	100%
Chaco	6%	94%	100%
Chubut	21%	79%	100%
Córdoba	8%	92%	100%
Corrientes	4%	96%	100%
Entre Ríos	7%	93%	100%
Formosa	3%	97%	100%
Jujuy	8%	92%	100%
La Pampa	3%	97%	100%
La Rioja	14%	86%	100%
Mendoza	11%	89%	100%
Misiones	4%	96%	100%
Neuquén	21%	79%	100%
Río Negro	18%	83%	100%
Salta	9%	91%	100%
San Juan	8%	92%	100%
San Luis	7%	93%	100%
Santa Cruz	11%	89%	100%
Santa Fe	8%	92%	100%
Santiago del Estero	6%	94%	100%
Tierra del Fuego	14%	86%	100%
Tucumán	6%	94%	100%
Argentina	9%	91%	100%

Appendix 2

Table 9: Correlation matrix

	entry	TRelden	GRelden	NGRelden	lpop	popden	empind	RCA
entry	1							
TRelden	0.30^{**}	1						
GRelden	0.28^{***}	0.89^{***}	1					
NGRelden	0.30^{***}	0.99^{***}	0.87^{***}	1				
lpop	-0.05^{***}	0.65^{***}	0.44^{***}	0.52^{***}	1			
popden	-0.05^{***}	0.52^{***}	0.22^{***}	0.32^{***}	0.69^{***}	1		
empind	-0.04^{***}	0.31^{***}	0.54^{***}	0.63^{***}	0.82^{***}	0.58^{***}	1	
RCA	0.045^{***}	0.63^{***}	0.61^{***}	0.64^{***}	0.67^{***}	0.35^{***}	0.83^{***}	1

$*p < 0.05, **p < 0.01, ***p < 0.001$

Appendix 2

Table 6: Diversification opportunities – Top 3 products by degree of relatedness

Province	Ranking	Product description	Env. benefit
Buenos Aires	1	Sheet/film not cellular/reinf polymers	SWM
	2	Glass mirrors, whether or not framed	REP
	3	Articles of iron or steel,	WAT
CABA	1	Glass mirrors	REP
	2	Articles of iron or steel	WAT
	3	Aluminum casks, drums, boxes	SWM
Catamarca	1	Aluminum reservoirs, vats, tanks	REP
	2	Electrical multimeters	MON
	3	Refrigerating or freezing equipment	REP
Chaco	1	Parts of centrifuges	SWR
	2	Gas/smoke analysis apparatus	MON
	3	Primary cells, primary batteries	CRE
Chubut	1	Glass mirrors, whether or not framed	REP
	2	Articles of iron or steel,	WAT
	3	Aluminum casks, drums, boxes	SWM
Cordoba	1	Glass mirrors, framed	REP
	2	Articles of iron or steel	WAT
	3	Aluminum casks, drums, boxes	SWM
Corrientes	1	Glass mirrors	REP
	2	Articles of iron or steel	WAT
	3	Aluminum casks, drums, boxes	SWM
Entre Rios	1	Chandeliers, other electric ceiling, or wall lights	HEM
	2	Parts, accessories, metal shaping machine tools	SWM
	3	Photograph, picture, frames, mirrors of base meta	REP
Formosa	1	Sheet/film not cellular/reinf polymers of ethylene	SWM
	2	Parts of machines and mechanical appliances	SWM
	3	Transformers electric	REP
Jujuy	1	Structures and parts of structures	REP
	2	Water filtering or purifying machinery or apparatus	WAT
	3	Activated carbon	WAT

Table 7: Diversification opportunities – Top 3 products by degree of relatedness

Province	Ranking	Product description	Env. benefit
La Pampa	1	Iron/non-alloy steel pipe	WAT
	2	Air compressors	APC
	3	Aluminum reservoirs, vats, tanks	REP
La Rioja	1	Iron or steel tubes, pipes	WAT
	2	Refrigerating or freezing equipment	REP
	3	Electrical control and distribution boards	REP
Mendoza	1	Glass mirrors	REP
	2	Articles of iron or steel	WAT
	3	Aluminum casks, drums, boxes	SWM
Misiones	1	Air compressors	APC
	2	Water filtering or purifying machinery	WAT
	3	Electrical multimeters	MON
Neuquén	1	Glass mirrors	REP
	2	Articles of iron or steel	WAT
	3	Aluminum casks, drums, boxes	SWM
Rio Negro	1	Glass mirrors,	REP
	2	Articles of iron or steel	WAT
	3	Aluminum casks, drums, boxes	SWM
Salta	1	Glass mirrors	REP
	2	Articles of iron or steel	WAT
	3	Aluminum casks, drums, boxes	SWM
San Juan	1	Pumps nes	WAT
	2	Equipment to measure, check gas/liquid	MON
	3	Surveying levels	MON
San Luis	1	Generating sets	HEM
	2	Electric generating sets	REP
	3	Transformers electric	REP
Santa Cruz	1	Parts of wash machinery	SWM
	2	Gas turbine engines nes	REP
	3	Aluminum structures and parts	REP
Santa Fe	1	Glass mirrors	REP
	2	Articles of iron or steel	WAT
	3	Aluminum casks, drums, boxes	SWM
Santiago del Estero	1	Pipes etc nes, iron/steel	WAT
	2	Parts for spark-ignition engines except aircraft	NVA
	3	Parts for diesel and semi-diesel engines	NVA
Tierra del Fuego	1	Parts, laboratory/industrial heating/cooling machiner	REP
	2	Parts of centrifuges, including centrifugal dryers	SWR
	3	Centrifuges nes	SWR
Tucuman	1	Glass mirrors, framed	REP
	2	Articles of iron or steel	WAT
	3	Aluminum casks, drums, boxes	SWM

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