Green product development: What does the country product space imply?

Green product development: Implications from the country product space

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Abstract

The more the economy moves towards a sustainable and green development, the greater the need to identify the green sectors with the highest potential for growth in a country. We address this issue using a recent tool coming from complexity economics, i.e., the *product space* describing countries and the products they co-export. Previous research has shown that countries evolve traversing the product space, adding new products that are close to the products that they produce with a high Relative Comparative Advantage (RCA). The likelihood that a country will develop a particular product depends on how "near" that product is in the product space to the products that the country is already able to produce successfully. Borrowing from this result, we argue that green products that are in close proximity to the products a country produces with high RCA have the highest potential for growth among all green products. We perform a regression analysis to test our hypothesis using as measure of proximity the maximum value of proximity between the green product and the country's high RCA products. The results statistically confirm that green products with high maximum proximity to those with high RCA had the highest growth. We discuss the implications of our findings showing several applications of the method proposed.

Keywords: Green Economy, Green products, Sustainable economic development, Growth, Economic complexity, product space.

1. Introduction

The world population has grown by one billion in the span of the last twelve years, reaching today 7.3 billion people, and it is growing at a rate of 1.18% per year, i.e., an additional 83 million people annually (UN 2015). This growth has been accompanied by a huge increase in the amount of natural resources extracted, to an extent which has never seen before (Krausmann et al. 2009; Wiedmann et al. 2015). Natural resources are essential inputs for production processes and the extraction, treatment, and disposal of such resources are an important source of income and jobs in many countries. However, natural resources are also part of the ecosystems that support the provision of services such as climate regulation, flood control, natural amenities, and cultural services. In this regard, the high consumption of natural resources can cause huge damage to the ecosystem, such as global climate change, landscape change, and loss of biodiversity, (e.g., Donhoe 2003; Weber et al. 2008).

The scenario thus outlined shows that the world today is facing two main challenges: on the one hand, expanding the economic opportunities for a growing global population, but on the other hand, addressing the environmental pressures which, if left unaddressed, could undermine the ability to seize these opportunities. The way to address both these issues at the same time is to promote an environmentally sustainable economic growth (UNEP 2011). Such growth has been defined as "green growth": "*Green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies*" (OECD 2011). In this regard, the role of the public sector in fostering green growth by designing adequate policy measures is fundamental (Baumann et al. 2002; Wüstenhagen and Bilharz 2006; Rehfeld et al. 2007; Fisher and Newell 2008; Hamdouch and Depret 2010; Nesta et al. 2014; Sonnenschein and Mundaca 2016; Wang et al. 2016). For this reason, in June 2009, the OECD Council Meeting at Ministerial Level adopted a Declaration on Green Growth (OECD 2009). This declaration invited the OECD to develop a Green Growth Strategy aimed at promoting the development of green sectors, i.e., those sectors able simultaneously both to contribute to economic growth in the short term and to help reduce environmental pressures in the long term.

In this scenario, it becomes important for policy makers of all countries to support the development of green sectors. This can be done either by direct public investment or by designing strategies to increase private investment in green products (OECD 2012). However,

designing government initiatives that aim to foster the development of the green sectors is a challenging task (Potts 2010). In fact, previous studies show that policy measures might not be equally effective for all green products in every country (Eickelpasch and Fritsch 2005; Pack and Saggi 2006; Huberty and Zachmann 2011). Furthermore, because of the limitation of economic resources, not all green sectors can be supported in a given country. Thus, one of the most critical challenges for the policy makers is the identification of those green products having the highest potential for growth, which therefore should be promoted through targeted policy actions. In this way, by supporting these green products, governments have the possibility of maximizing the return from public and private incentives.
This paper addresses this issue by using a recent tool coming from complexity economics, i.e., the *product space* (Hidalgo et al. 2007; Hidalgo and Hausmann 2009). The product space shows the proximity among products, which in turn captures the relatedness among them. Products require a variety of requisite production capabilities. The proximity between products in the product space is related to the similarity of the requisite capabilities that go into a product. Products that require similar requisite capabilities are thus located in close proximity in the product space. The product space is also a useful tool to analyze a country's dynamics. In particular, it is shown that a country evolves by traversing the product space adding new products that are in close proximity to the products it already makes with high competitiveness compared with the other countries, i.e., those products with high Relative Comparative Advantage (RCA) (Balassa, 1986). Therefore, the likelihood that a country will develop a particular product depends on how "near" that product is in the "product space" to the products that the country is already able to successfully make and export (Hidalgo et al. 2007).
Following this reasoning, we argue that the green products having the highest potential for growth in a given country are those in close proximity to the products that the country produces with high competitiveness compared to other countries. These green products are thus the best candidates for support by means of policy actions. This choice in fact exploits the production capabilities of the country, thereby assuring that policy action will have a high level of efficacy. We test such a hypothesis by using regression analysis. We build the product space for 141 different countries for the years between 2005 and 2013 and for each country we compute the maximum proximity of each green product to the products source of competitive advantage for each country (i.e., the proximity of the product source of competitive advantage closest to the green product considered). Statistical analysis confirms that maximum proximity is positively related to growth in the export performance of green products.
Finally, we develop several applications, useful to both policy makers and scholars, of the concept of maximum proximity of green products to high RCA products. We show how the maximum proximity is a suitable tool to map and plan green product development in any country. We also use it to analyze the diversification of the country's basket of green products and to investigate the role of geography in green product development, deriving interesting implications.
The paper is organized as follows. First, in Section 2 we define the concept of green product, while the green product space and green product space methodology are described in Sections 3 and 4, respectively. In Section 5 the research methodology, the sources of data, and the variables used are presented, while the results of the regression analysis are shown in Section 6. The paper ends with a discussion of some useful applications of the concept of maximum proximity and conclusions.

2. Green Products

The definition of green products is a difficult task, because of the many different dimensions in which the term "green" is used: ecological, political, corporate social responsiveness, fair trade, conservation, new-consumerism, and sustainability (McDonagh and Prothero 1996). These dimensions embrace very different aspects, and each of them formalizes its own meaning of the word "green". Accordingly, no univocal definition of green products exists, but there are many different definitions developed by different parties: industry groups, labor unions, academic, and policy institutions (Dangelico and Pontrandolfo 2010; Duriff et al. 2010).

For the aim of the paper, we will use the definition focusing on the environmental dimension of the term "green". In this respect, the Commission of the European Countries (2001) defines green products as products that "*use less resources, have lower impacts and risks to the environment, and prevent waste generation already at the conception stage*". However, as observed by Pickett-Baker and Ozaki (2008), we recognize that it is not possible to define green products in such absolute terms. Thus, a product can be considered as "green" if it has higher environmental performance than the traditional ones at function parity. This performance is not limited to the production phase but is extended to the product life cycle as a whole (Albino et al. 2009).

As many different definitions exist, several green product classifications have consequently also been developed, driven by different classification purposes. For instance, green products can be classified based on product characteristics (e.g., Rombouts 1998), the level of environmental impact (e.g., Hanssen 1999), and the types of environmental improvement strategies (e.g., Park et al. 1999; Rose et al. 1999). However, to the best of our knowledge, there is no internationally agreed classification of green products to date. Interest in creating such a list has emerged in the World Trade Organization (WTO), but despite more than 10 years of effort by the WTO Committee on Trade and Environment (CTE), a list of green products remains elusive (Vikhlyaev 2004; Kao 2012).

For the purposes of this study, coherently with the definition of green product we adopt, the green product classification "*The environmental goods and services sector*" developed by EUROSTAT (2009) is considered. This classification in fact focuses on the environmental dimension of the "green" concept rather than other dimensions.

3. A Tool from Complexity Economics: The Product Space

The product space is a tool developed by Hidalgo et al. (2007) representing the proximity among products. It is defined as a PxP matrix, where P is the total number of products the countries export and each element *i* x *j* of the matrix denotes the proximity between the products *i* and *j*.

The proximity is a statistical measure of the similarity between goods, which formalizes the idea that similar goods (e.g., apples and pears) are more likely to be produced in tandem than dissimilar goods (e.g., apples and bikes). Therefore, if a country produces (exports) a given type of goods (apples), it is very likely that it also produces (exports) other goods that are very close to this one (pears).

The concept of product similarity is related to the requisite capabilities that go into a product. Hidalgo and Hausmann (2009) propose the idea that products require a variety of non-tradable factors of production, called requisite capabilities, and that countries make all the goods for which they have the requisite capabilities. Therefore, if two goods require similar capabilities such as infrastructure, technology, or physical assets, it is highly likely that they will be produced in tandem. Accordingly, two products requiring similar production capabilities will be characterized by high proximity (Hidalgo et al. 2007). Thus, the proximity between goods *i* and *j* is defined as the minimum of the pairwise conditional probabilities of a country exporting product *i* given that it exports product *j*. Formally, it can be expressed as:

$$\varphi_{ij} = \min\left\{\mathrm{Prob}\left(\mathrm{RCAx_i} > 1 \middle| \mathrm{RCAx_j} > 1\right); \mathrm{Prob}\left(\mathrm{RCAx_j} > 1 \middle| \mathrm{RCAx_i} > 1\right)\right\} \quad (1)$$

where $\text{Prob}(\text{RCAx}_i > 1 | \text{RCAx}_j > 1)$ is the probability that product *i* is exported, since product *j* is also exported. Similarly, $\text{Prob}(\text{RCAx}_j > 1 | \text{RCAx}_i > 1)$ is the probability that product *j* is exported, since also product *i* is exported. Formally, these probabilities are computed as follows:

$$\text{Prob}(\text{RCAx}_i > 1 | \text{RCAx}_j > 1) = \frac{\sum_c M_{ci} \cdot M_{cj}}{\sum_c M_{ci}} \tag{2}$$

$$\text{Prob}(\text{RCAx}_j > 1 | \text{RCAx}_i > 1) = \frac{\sum_c M_{cj} \cdot M_{ci}}{\sum_c M_{cj}} \tag{3}$$

where M_{ci} (M_{cj}) is equal to one if $RCA_{ci}>1$ ($RCA_{cj}>1$), otherwise it is equal to zero. RCA_{ci} (RCA_{cj}) is the Revealed Comparative Advantage of product *i* (*j*) for country *c*, computed using the Balassa (1986) index as follows:

$$RCA_{ci} = \frac{\frac{E_{ci}}{\sum_i E_{ci}}}{\frac{\sum_c E_{ci}}{\sum_c \sum_i E_{ci}}} \tag{4}$$

$$RCA_{cj} = \frac{\frac{E_{cj}}{\sum_j E_{cj}}}{\frac{\sum_c E_{cj}}{\sum_c \sum_j E_{cj}}} \tag{5}$$

where E_{ci} (E_{cj}) is the economic value of product *i* (*j*) exported by country *c*. Generally, country *c* having $RCA_{ci}>1$ is considered to have high competitive advantage in producing type *i* goods. As an alternative to the matrix approach, the product space can be shown using a visual network representation, applying the Maximum Spanning Tree algorithm and following the procedure suggested by Hidalgo et al. (2007). This visual representation shows in an intuitive manner several items of information: 1) the size of the node is proportional to the amount of world trade associated to the product; 2) the color of the node follows the Leamer classification giving information about the class of product; and 3) the length of the link between the nodes is inversely proportional to the proximity between the products.

This representation of the product space is useful in order to model the production structure of a country and study its evolution. The production capabilities possessed by the country can easily be mapped by adding information on the country's products with RCA>1. Thus, the evolution of the country's production capabilities can be traced by following the trajectory of the products with RCA>1 introduced b over time.

Countries evolve by adding new products close to those having high RCA. Two different evolutionary trends can be distinguished. The most industrialized countries are characterized by products with high RCA located in the core of the product space, where they are strongly connected with many other products. For this reason, such countries are able to upgrade their export basket more quickly than other nations, thus showing high potential for growth. On the contrary, the less developed countries have products with high RCA located at the periphery of the product space, characterized by a limited number of connections with other products. Therefore, these countries have more growth problems (poverty trap) (Hidalgo et al. 2007).

Hidalgo et al. (2007) also demonstrate that the likelihood that a country will develop a particular type of goods depends on how near in the product space that type of goods is to the goods that the country is already able to produce successfully. They test this proposition showing that goods able to pass from RCA<0.5 to RCA>1 in five years have a higher density than goods whose RCA stays lower than 1. High density means that those products are surrounded by many developed products. Furthermore, they also show that there is a monotonic relationship between the probability that a product with RCA<0.5 turns into RCA>1 after five years and the proximity of the nearest product with RCA>1.

4. The Product Space Implications for Green Product Development

The proximity between two generic products captures the similarity of the requisite capabilities to produce them and is a proxy of the likelihood that the two goods are produced in tandem. Accordingly, the proximity between a generic product and a green one measures the similarity between the production capabilities required by the generic product and the green one. The closer the green product is to a product with RCA>1, the more likely the country is to possess the requisite capability to produce that green product successfully, and thus the higher the probability is that the country will successfully introduce the green product within its product space.

Based on this argument, we hypothesize that green products closer to the products that a country produces with RCA>1 have greater potential for growth than those with low proximity.

A similar intuition is proposed by Hamwey et al (2013), who develop the "green product space methodology", an analytical approach allowing the green products for which a country is likely to be competitive in the world market to be identified, based on the export performance of related products. This approach is based on delineating the green products in product space and assessing their proximity to products with RCA>1. Green products with high proximity to these products are the best candidates to support. Alternatively, green products located far from products with RCA>1 should not be supported, since they are much less likely to yield positive results. Hamwey et al. (2013) apply such a methodology to the product space of Brazil, built using the export data of the year 2009, and identify green products to sustain with policy actions. Since no statistical test is provided to support the hypothesis, we intend to overcome this limitation.

A further coherent argumentation is provided by Huberty and Zachmann (2011). They investigate whether, and in which countries, industrial policies aimed at supporting green development can improve the competitiveness of their green products in export markets. In particular, they analyze the growth in RCA of two green products (wind turbines and solar cells) exported by European countries from 1996 to 2008 and sustained by national policy measures. They found that the only variable, among those investigated, positively affecting the growth of both the products is their proximity with products that are a source of competitive advantage for the country (RCA >1). In particular, the growth in RCA of a green product is higher for countries in which the green product had strong proximity with other products having RCA>1, *ceteris paribus*. Although this study was conducted for only two green products, it shows interesting results because it suggests that different green products should be sustained in different countries, depending on the country's productive structure. This perfectly matches our theory.

5. Methods

To test our hypothesis, we performed the following steps: 1) we built the product spaces and identified the products with RCA>1 for each country; 2) we classified the green products; 3) we computed the proximity of green products with those with RCA>1 for each country; 4) we identified the regression model to test the hypothesis, defined the measures, and ran the statistical analysis on the collected data. We describe each step below.

To build the product space, we followed the procedure proposed by Hidalgo et al. (2007). First, we collected data on the international trade for years 2005, 2009, and 2013. We used the data from the UN-COMTRADE database (UN, 2016a). It contains the export data (in monetary value) of 1345 products exported by 243 countries toward any other country for each year. We used the product classification SITC Rev 2 at 5-digit level of detail (UN, 2016b), which offers the highest possible level of detail. Based on the export data, we computed the RCA of each product for each country in each year considered, using Equation 4. The proximity between each pair of products was then computed using Equation 1. So doing, we built the product space in the years considered.

For each country, we then identified all the products with RCA >1 for all the years considered. Our study also required the green products within the product space to be clearly identified. As stated above, we adopted the green product classification "*The environmental goods and services sector*" developed by the EUROSTAT (2009). This classification identifies which products of the WTO product list can be considered as green products. Then, we converted these products accordingly with the SITC classification in order to be consistent with the data provided by the UN-COMTRADE database. As a result, we identified 41 green products organized in seven families in accordance with the SITC classification (Table 1). Since the export data on the green products are available in the considered years only for 141 countries, we restricted our analysis to these 141 countries. For these countries, we were able to distinguish the green products from the other products using this classification. Thus, we were able to identify clearly the proximity of the green products from all the other products with RCA>1 in each country and for each year considered.

FAMILY	SITC code	Green product
Crude materials, inedible, except fuels	23201	Natural rubber latex; pre-vulcanized natural rubber latex
	23202	Natural rubber (other than latex)
	28201	Waste and scrap metal of iron or steel of pig or cast iron
	28202	Waste and scrap metal of iron or steel of alloy steel
	28209	Waste and scrap metal of iron or steel of other iron or steel
	28821	Copper waste and scrap
	28822	Nickel waste and scrap
	28823	Aluminum waste and scrap
	28824	Lead waste and scrap
	28825	Zinc waste and scrap (other than dust)
	28826	Tin waste and scrap
	28902	Precious metal, waste and scrap
Mineral fuels, lubricants and related materials	34131	Liquefied propane and butane
	34139	Liquefied gaseous hydrocarbons, nes
Animal and vegetable oils, fats and waxes	43143	Vegetable waxes
	43144	Spermaceti, crude or refined; insect waxes
Chemicals and related products	51211	Methyl alcohol (methanol)
	52391	Hydrogen peroxide
	53222	Dyeing extracts of vegetable or animal origin
	58361	Acrylic and methacrylic polymers; acrylo-methacrylic copolymers in primary forms
	58362	Acrylic and methacrylic polymers; acrylo-methacrylic copolymers in plate, sheet, strip, film or foil form
	58369	Acrylic and methacrylic polymers; acrylo-methacrylic copolymers in other forms (including waste and scrap)
Manufactured goods classified chiefly by materials	65121	Wool tops
	65122	Carded sheep's or lambs' wool (woolen yarn), not for retail sale
	65123	Combed sheep's or lambs' wool (worsted yarn), not for retail sale
	65124	Fine hair yarn (carded or combed), not for retail sale
	65125	Coarse hair yarn, not for retail sale
	65126	Yarn of sheep's or lamb's wool or of fine animal hair, for retail
	65127	Yarn of carded sheep's or lamb's wool, blended, not for retail
	65128	Yarn of combed sheep's or lamb's wool, blended, not for retail
	65129	Wool etc. blend yarn for retail
	65498	Fabrics, woven, of other vegetable textile fibers; of paper yarn
	69211	Iron, steel, aluminum reservoirs, tanks, etc., capacity 300 lt plus of iron or steel
	69213	Iron, steel, aluminum reservoirs, tanks, etc., capacity 300 lt plus of aluminum
	71621	Electric motors (including ac/dc motors), other than direct current

Machinery and transport equipment	71881	Water turbines
	71882	Other hydraulic engines and motors (including waterwheels)
	79381	Tugs
	79382	Special purpose vessels, floating docks, etc.
	79383	Floating structures, other than vessels
Miscellaneous manufactured articles	89471	Fishing and hunting equipment

Table 1. The green products classification by EUROSTAT (2009).

5.1 Statistical analysis

To test our hypothesis (the proximity of a green product to products with high RCA positively affects the growth of the green product), we adapted the statistical model used by Barro (1996) to investigate the effect of a few socio-economic parameters on the GDP growth in different countries. He regressed the investigated parameters measured at the *t*-th year (independent variables) with the percentage variation of GDP measured between the year *t* and the year $t+\tau$ and controlled for the value of the GDP in the *t*-th year. In the following subsections, we first describe the dependent, independent, and control variables with attendant measures. Then, we present the regression models.

5.1.1 Variables and measures

Our dependent variable is the growth of a given green product (*GreenProd Growth*). We measured it by computing the percentage variation of the export value of the green product in each country over a 4-year time range. For a given green product *p* exported by the country *c*, it is computed as follows:

$$\Delta \mathrm{E_{cp}}(\mathrm{t}+4) = \frac{\mathrm{E_{cp}}(\mathrm{t}+4) - \mathrm{E_{cp}}(\mathrm{t})}{\mathrm{E_{cp}}(\mathrm{t})} \quad (6)$$

The data on the export value of the green products were obtained from the UN-COMTRADE database. We excluded from the analysis green products having an RCA higher than one at time *t*. In fact, when $RCA_{cp}(t)>1$, the product *p* is already a source of competitive advantage for country *c* at year *t* and therefore it does not need to be sustained by policy measures.

The independent variable is the proximity between the green product and the products the country exports with high RCA. We measured it by using the maximum value of proximity that a green product has to the products with RCA>1 (*Max proximity*) which the country exports. We preferred this measure to the average value of proximity to all the products with RCA>1, because it provides more accurate information than the average value, in cases where the country produces a large number of products with high RCA. In such a case, while the maximum value of proximity can clearly identify whether the country possesses the requisite capability to produce it, the average value could not. A low average value in fact could be possible, even though one product has a high proximity. This limits the validity of the average value, since would imply that the country does not possess the requisite production capability to produce the green product, which is clearly wrong. Thus, for the any given green product *p* exported by the country *c* in the year *t*, we computed the maximum proximity as follows:

$$\Phi_{\mathrm{cp}}(\mathrm{t}) = \max\{\varphi_{\mathrm{pi}}(\mathrm{t})\}_{\forall\, \mathrm{i} \in \Pi(\mathrm{c})} \quad (7)$$

where $\Pi(c)$ is the set of products with RCA>1 for country *c*.

Two control variables were added to the analysis. We considered the effect of the export value of the green product at the beginning of the time range (*LogExport*). In particular, as the control variable, we introduced the logarithm of this value ($\ln[\mathrm{E_{cp}}(\mathrm{t})]$). Consistently with Barro (1996),

we expect a negative impact of this variable, since the percentage export growth is supposed to be lower for products with high export.
We also included the GDP value of the country at the beginning of the time range as a control variable ($GDP_c(t)$). We expect a positive impact of this variable, since countries with a high GDP tend to have more exports than countries with lower GDP (e.g., Narayan and Smyth 2009). Data on GDP were obtained from the World Bank online database (The World Bank 2016).

5.1.2 Regression models
We performed two panel data regressions with fixed effects played respectively by countries (*Model 1*) and products (*Model 2*). The two models correspond to the following equations:

$$\Delta E_{cp}(t+4) = [\alpha_0 + \beta_1 \cdot C_c] + \alpha_1 \cdot \Phi_{cp}(t) + \alpha_2 \cdot \ln[E_{cp}(t)] + \alpha_3 \cdot GDP_c(t) \quad (8)$$

$$\Delta E_{cp}(t+4) = [\alpha_0 + \beta_1 \cdot P_p] + \alpha_1 \cdot \Phi_{cp}(t) + \alpha_2 \cdot \ln[E_{cp}(t)] + \alpha_3 \cdot GDP_c(t) \quad (9)$$

where *C* and *P* stand for the regressors for the countries and the products, respectively.
To run the regression with fixed effects, we added the correspondent dummy variables: 140 in Model 1 and 40 in Model 2.

6. Results

Table 2 shows the correlation matrix among the model variables. No evident correlation appears.

	GreenProd Growth	*Max Proximity*	*LogExport*	*GDP*
GreenProd Growth	1.0000			
Max Proximity	-0.0496	1.000		
LogExport	-0.2748	0.2510	1.0000	
GDP	-0.0700	0.0096	0.4106	1.000

Table 2. Correlation matrix among the variables of the statistical models.

Table 3 shows the results of the regression analyses for models 1 and 2, respectively. The results of both models confirm that the maximum proximity of the green product from the products with high RCA positively and significantly (α_1=4.9382 and α_1=4.8006 for Model 1 and Model 2, respectively) influences the growth of the export of the green product. As expected, the export value of the green product also has a negative and significant effect on the growth of the export of the green product (α_2=-1.8553 and α_2=-2.1162 for Model 1 and Model 2, respectively). As to the effect of the GDP on the green product, we found it to be positive but not significant in Model 1 (α_3=1.07e-12), and positive and significant in Model 2 (α_3=1.35e-11), as expected.

Parameters	*Model 1*	*Model 2*
Constant	33.0970***	29.2499***
	(6.8876)	(2.4055)
Max Proximity	4.9382*	4.8006*
	(2.2635)	(2.6450)
LogExport	-1.8553***	-2.1162***
	(0.1309)	(.1234)
GDP	1.07e-12	1.35e-11***

	Model 1	Model 2
	(1.47e-11)	(3.17e-12)
Model fits statistics		
Number of Observations	3117	3117
Degrees of freedom	142	42
F	3.7	8.57
Prob > F	0	0
R-squared	0.1503	0.1070
Adj R-squared	0.1097	0.0946
Root MSE	17.831	17.982

*p<0.1; ***p<0.001; Model 1 contains fixed effect on countries, Model 2 contains fixed effect on products.

Table 3. Fixed Effect Regression Models with GreenProd Growth as dependent variable.

7. Applications

We present several applications of the concept of maximum proximity of green products to products with high RCA, useful to policy makers as well as scholars, in order to map and plan green product development, to analyze the diversification of a country's basket of green products, and to investigate the role of geography in green product development.

7.1 The green product maximum proximity matrix

We define the *green product maximum proximity* matrix Φ^{MAX} as a CxP matrix, where *C* is the number of countries and *P* the number of green products, and whose element contains the value of the highest proximity to the products with RCA>1 for green product *p* in country *c* (Equation 7). As an example, we computed the matrix (see Supplementary Material) using data referring to 2013 and ordered rows and columns for decreasing average values.

The matrix is a map of world green product development in 2013. It shows: 1) the green products that each country currently produces with high competitive advantage ($\Phi_{\mathrm{cp}}^{\mathrm{MAX}} = 1$); 2) the green products that the country could produce given the proximity to products with high RCA ($\Phi_{\mathrm{cp}}^{\mathrm{MAX}} > 0.5$); and 3) the green products that it is very unlikely could be introduced into the country's basket of green products ($\Phi_{\mathrm{cp}}^{\mathrm{MAX}} \leq 0.5$). Figure 1 shows the matrix Φ^{MAX} with the cells colored from red to green as the highest proximity increases for visual analysis.

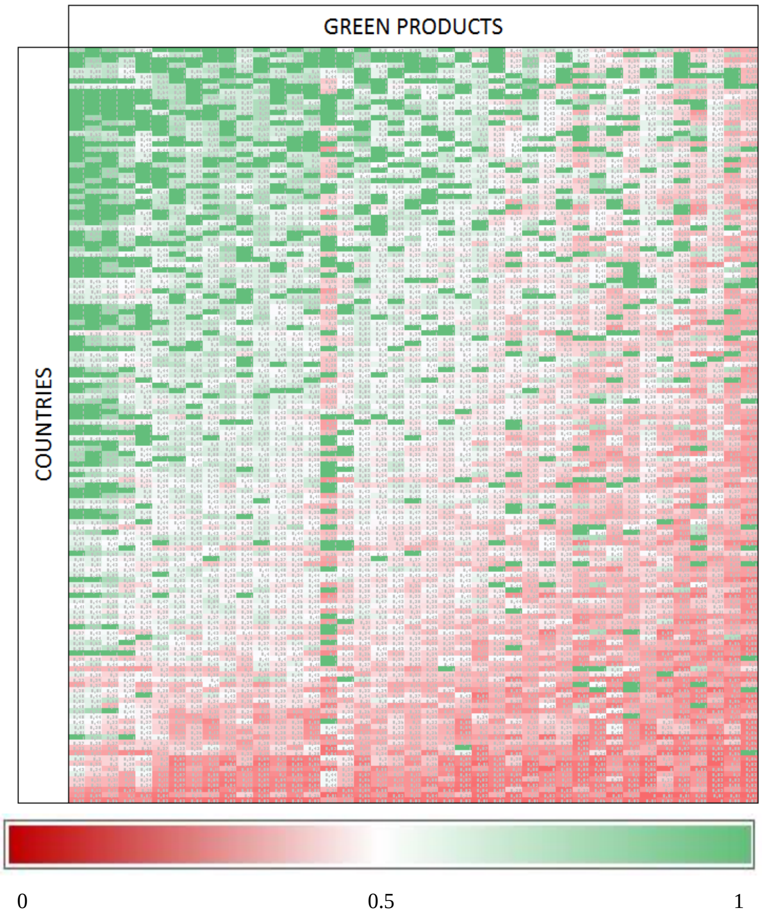


Figure 1. Highest proximity for each green product (columns) to products with RCA>1 for each country (rows) (Data refer to 2013). Green cell: high proximity; Red cell: low proximity.

Because of space limitations, we have extracted data from the matrix for just 8 countries to discuss. The data show that the UK and Germany are currently competitive on 20 and 18 green products, respectively. Italy produces 16 green products with high RCA and France 15. China and US currently and successfully produce a high number of green products (14 and 16, respectively), with no product in common. India and South Korea are competitive in 6 and 4 green products (Table 4).

Looking at green products with $\Phi_{cp}^{MAX} > 0.5$, we note that Italy has the requisite capabilities to produce several green products. Hence, it is highly recommended that Italy should primarily invest in "Waste and scrap metal of iron or steel of other iron or steel", "Aluminum waste and scrap", and "Floating structures, other than vessels". Similarly, for example Germany should invest in "Acrylic and methacrylic polymers; acrylo-methacrylic copolymers in primary forms" and "Yarn of combed sheep's or lamb's wool, blended, not for retail", and the UK in "Wool tops" and "Combed sheep's or lambs' wool (worsted yarn), not for retail sale". China also has a large number of green products with high potential for growth: "Methyl alcohol (methanol)", "Acrylic and methacrylic polymers; acrylo-methacrylic copolymers in primary forms", "Acrylic and methacrylic polymers; acrylo-methacrylic copolymers in plate, sheet, strip, film or foil form", "Iron, steel, aluminum reservoirs, tanks, etc., capacity 300 lt plus of iron or steel", and "Water turbines" (Table 4). By looking at green products with $\Phi_{cp}^{MAX} > 0.5$, similar considerations can be extended to all the other countries.

Green product code	Green products name	Italy	Germany	France	UK	China	USA	India	South Korea
23201	Natural rubber latex; pre-vulcanized natural rubber latex	0.5570	0.3457	0.5570	0.2562	0.5570	0.4216	0.4632	0.5567
23202	Natural rubber (other than latex)	0.4150	0.3189	0.4214	0.3148	0.4214	0.3559	0.4155	0.4155
28201	Waste and scrap metal of iron or steel of pig or cast iron	0.4433	0.2648	1	1	0.4433	0.2573	0.2583	0.1527
28202	Waste and scrap metal of iron or steel of alloy steel	0.4213	1	1	1	0.4559	1	0.4070	0.4070
28209	Waste and scrap metal of iron or steel of other iron or steel	0.6486	1	1	1	0.6486	1	0.64856	0.3825
28821	Copper waste and scrap	0.5613	1	1	1	0.5612	1	0.5613	0.4517
28822	Nickel waste and scrap	0.5349	0.5349	1	1	0.4732	1	0.4698	0.4416
28823	Aluminum waste and scrap	0.5808	1	1	1	0.5808	1	0.5145	0.5119
28824	Lead waste and scrap	1	0.4819	1	1	0.4819	1	0.3917	0.3354
28825	Zinc waste and scrap (other than dust)	0.5599	1	1	0.5757	0.5334	1	0.4678	0.5598
28826	Tin waste and scrap	0.5630	1	1	1	0.5623	1	0.5630	0.4873
28902	Precious metal, waste and scrap	0.4954	1	0.4954	1	0.4954	1	1	0.4954
34131	Liquefied propane and butane	0.3386	0.3191	0.3191	1	0.3191	1	0.3386	0.3386
34139	Liquefied gaseous hydrocarbons, nes	0.2084	0.2203	0.2203	0.2378	0.2203	0.3463	0.3463	0.3463
43143	Vegetable waxes	0.5873	1	0.5487	0.5873	0.6251	1	0.6251	0.8185
43144	Spermaceti, crude or refined; insect waxes	0.4425	0.5618	1	0.2888	1	0.4425	0.4011	0.4425
51211	Methyl alcohol (methanol)	0.3363	0.3316	0.3586	0.4071	0.7038	0.4071	0.3864	0.3586
52391	Hydrogen peroxide	0.5209	1	0.5209	0.4310	0.4654	0.5964	0.5441	1
53222	Dyeing extracts of vegetable or animal origin	1	1	1	1	0.4736	0.7123	0.5151	0.4548
58361	Acrylic and methacrylic polymers; acrylo-methacrylic copolymers in primary forms	0.5978	0.6582	1	1	0.6582	1	0.5978	1
58362	Acrylic and methacrylic polymers; acrylo-methacrylic copolymers in plate, sheet, strip, film or foil form	1	0.5912	0.5912	0.6782	0.6356	1	0.6782	1
58369	Acrylic and methacrylic polymers; acrylo-methacrylic copolymers in other forms (including waste and scrap)	0.5360	0.5289	0.4729	0.2984	0.6136	0.4821	1	0.5987
65121	Wool tops	1	1	0.2738	0.6840	1	0.2738	1	0.1613
65122	Carded sheep's or lambs' wool (woolen yarn), not for retail sale	1	0.2332	0.2965	1	1	0.27573	0.3609	0.4486
65123	Combed sheep's or lambs' wool (worsted yarn), not for retail sale	1	1	0.5457	0.7664	1	0.4456	1	0.5411
65124	Fine hair yarn (carded or combed), not for retail sale	1	0.4954	0.4745	1	1	0.4084	0.4954	0.3799
65125	Coarse hair yarn, not for retail sale	1	1	0.4217	1	1	0.4400	0.3806	0.3806
65126	Yarn of sheep's or lamb's wool or of fine animal hair, for retail	1	0.4147	0.5205	0.2486	1	0.4385	0.4171	0.1998
65127	Yarn of carded sheep's or lamb's wool, blended, not for retail	1	0.4799	0.5671	1	1	0.4374	0.5923	0.4526
65128	Yarn of combed sheep's or lamb's wool, blended, not for retail	1	0.7664	0.6154	1	1	0.5391	1	0.5453
65129	Wool etc. blend yarn for retail	1	1	0.5559	0.5559	0.5559	0.4178	0.4349	0.4099
65498	Fabrics, woven, of other vegetable textile fibers; of paper yarn	0.4910	0.4910	0.4310	0.3128	1	0.3452	0.3401	0.4310
69211	Iron, steel, aluminum reservoirs, tanks, etc., capacity 300 lt plus of iron or steel	1	0.6382	0.4795	0.4634	0.6561	0.6382	0.4779	1
69213	Iron, steel, aluminum reservoirs, tanks, etc., capacity 300 lt plus of aluminum	1	1	1	1	0.3863	1	0.3863	0.3374
71621	Electric motors (including ac/dc motors), other than direct current	1	1	1	0.6418	1	0.6667	0.6536	0.6536
71881	Water turbines	1	1	0.7078	0.6089	0.6710	0.7078	0.6710	0.6572
71882	Other hydraulic engines and motors (including waterwheels)	0.6718	1	1	1	0.5727	1	0.5501	0.5727
79381	Tugs	0.2719	0.2495	0.1945	0.4720	1	0.5746	1	0.6390
79382	Special purpose vessels, floating docks, etc.	0.3340	0.2724	0.1328	0.3186	1	0.2135	1	1
79383	Floating structures, other than vessels	0.6745	0.4226	0.6745	1	0.4591	1	0.4591	0.3640

89471	Fishing and hunting equipment	0.5711	0.5711	0.5711	0.5711	1	0.5711	0.5577	1

Table 4. Data from Figure 1 for selected countries.

7.2 Country diversification on green product development

We define two indices based on the matrix Φ^{MAX}: 1) country green diversity (CGD) and 2) country green diversity development (CGDD).

Country Green Diversity (CGD) is the number of green products with RCA>1 currently exported by the country. The higher the CGD, the more diversified is the green product basket. The CGD is computed as follows:

$$\mathrm{CGD_c} = \sum_{p=1}^{P} \mathrm{A_{cp}} \text{ where } \begin{cases} \mathrm{A_{cp}} = 1 & \text{if } \Phi_{\mathrm{cp}}^{\mathrm{MAX}} = 1 \\ \mathrm{A_{cp}} = 0 & \text{if } \Phi_{\mathrm{cp}}^{\mathrm{MAX}} < 1 \end{cases} \quad (10)$$

Country Green Diversity Development (CGDD) is the number of green products with Φ^{MAX} between 0.5 and 1. This is a measure of how the current green product basket could be further diversified in the next few years. The higher the CGDD, the higher the number of green products that can be added to the current basket. It is defined as follows:

$$\mathrm{CGDD_c} = \sum_{p=1}^{P} \mathrm{B_{cp}} \text{ where } \begin{cases} \mathrm{B_{cp}} = 1 & \text{if } 0.5 < \Phi_{\mathrm{cp}}^{\mathrm{MAX}} < 1 \\ \mathrm{B_{cp}} = 0 & \text{if } \Phi_{\mathrm{cp}}^{\mathrm{MAX}} \leq 0.5 \end{cases} \quad (11)$$

In Figure 2 all countries are depicted as a function of their CGD (x-axis) and CGDD (y-axis). The figure shows that the UK is the country currently exporting the highest number of green products (20), whereas Poland is the country that can expand most its current basket of exported green products (17). On average, each country currently exports 5.95 green products and can potentially add 7.12 green products to its basket. Three clusters are recognizable. The first cluster is made up of the countries having high CGD (i.e., successfully producing a diversified basket of green products) and high CGDD (i.e., that can potentially increase their basket with a high number of green products). The second cluster contains countries having low CGD but high CGDD. These countries currently have quite specialized baskets of green products but they can potentially diversify their basket, adding many other green products to those currently produced. The third cluster involves countries with both low CGD and low CGDD. These countries currently have specialized baskets of green products and do not have the potential to diversify their baskets.

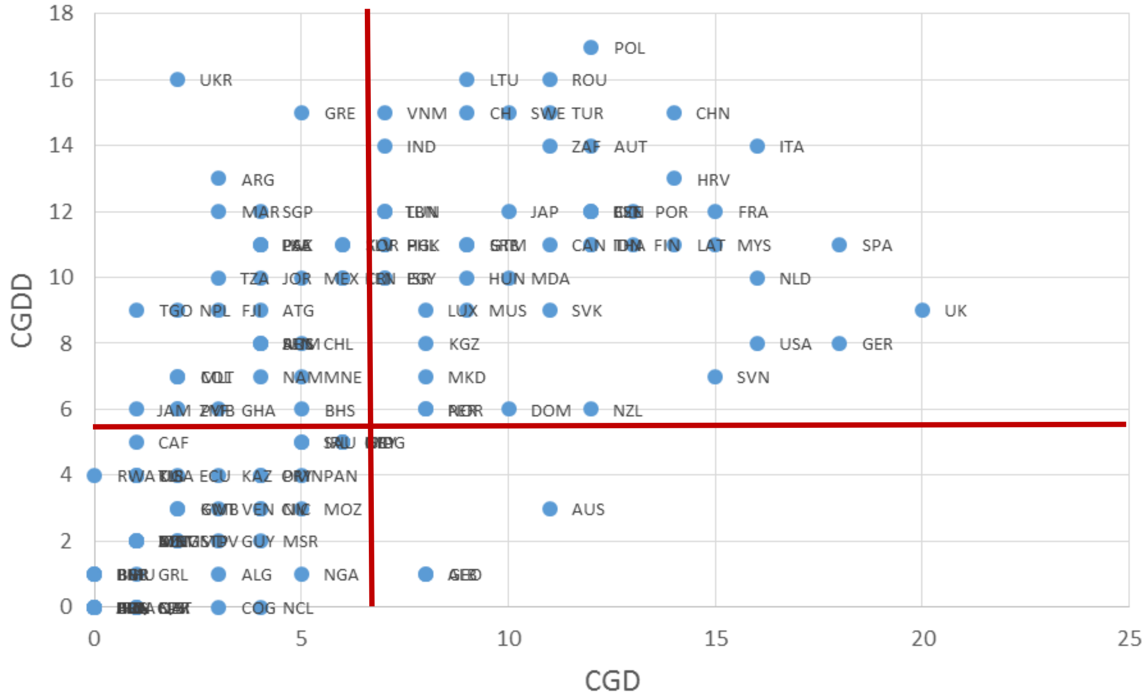
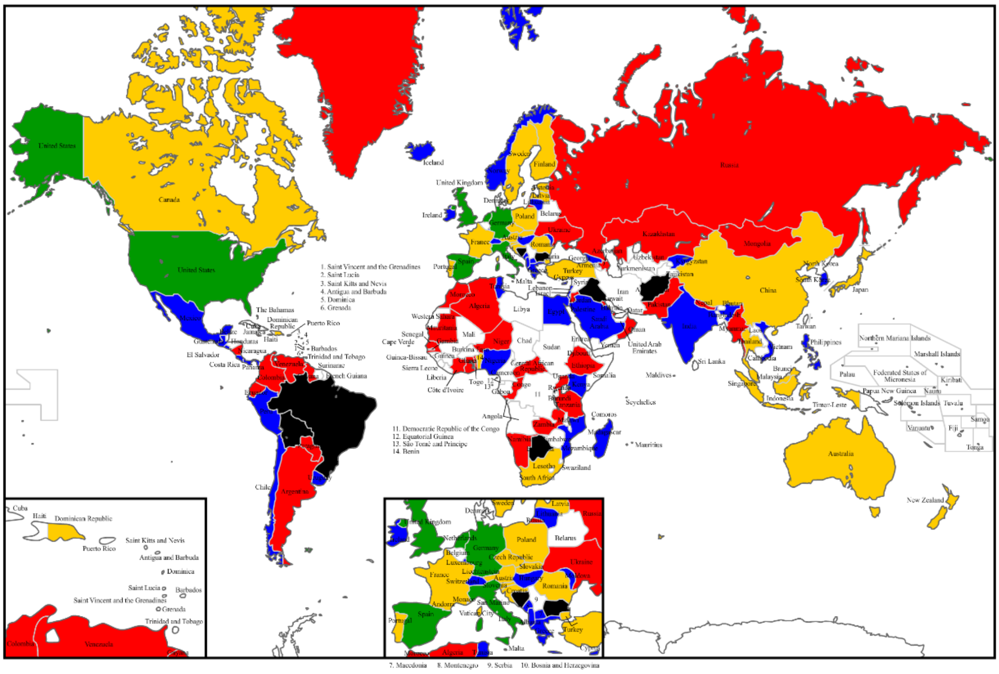
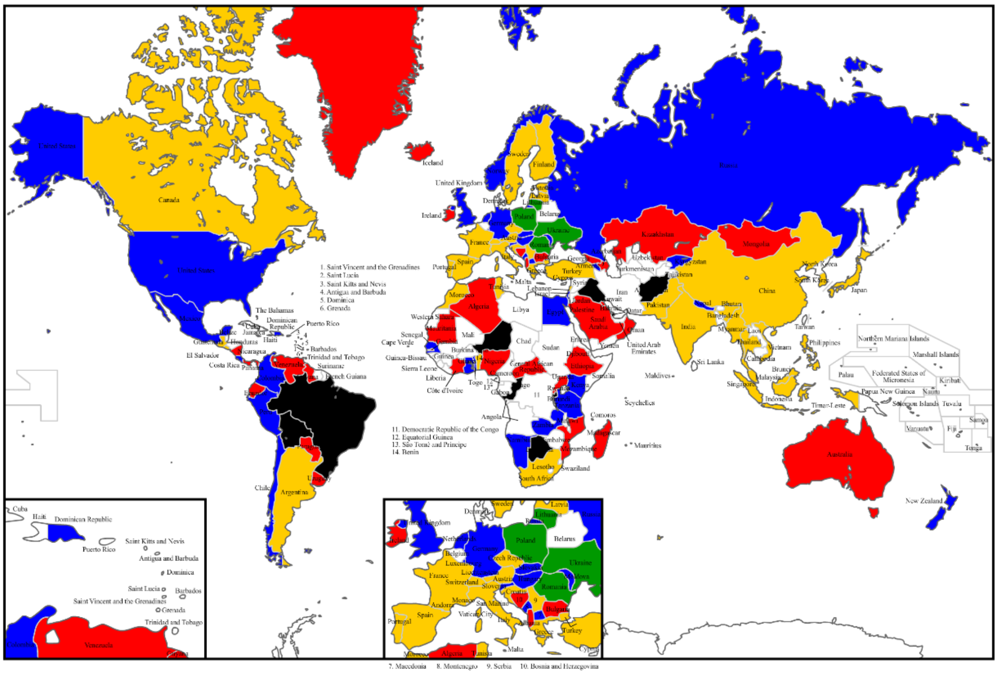


Figure 2. CGD and CGDD for all countries (data refer to 2013).
(Red lines denote the average values of CGD and CGDD)

Figure 3a and 3b show the world map where each country is characterized by its CGD and CGDD, respectively. In particular, Figure 3a shows that the countries with the widest basket of exported green products are located in Europe, North America (Canada and USA), Oceania, and South-East Asia. Alternatively, countries in South America, Africa (except for South Africa), and the Middle East tend to have more specialized baskets. This is in line with general trend that the exports basket (considering not only green products but all the exported products) of African countries are on average 6.5 times lesser wide than the exports basket of European countries (Ofa et al. 2012). Moreover, Figure 3b shows that countries in Eastern Europe have the highest CGDD. Similarly, countries in Western Europe and South Asia also have high CGDD, as well as some African countries, Argentina, and Canada.
Almost all European countries currently have diversified baskets of green products and also have the potential to further increase the number of green products exported. Argentina, El Salvador, Morocco, and Pakistan are examples of countries currently having specialized baskets of green products, but that can easily diversify their baskets. Finally, almost all the African countries have specialized baskets of green products and they cannot diversify them. Moreover, note that almost none of the countries currently producing no green products (black countries in Figure 3) can easily add any green product to their basket.



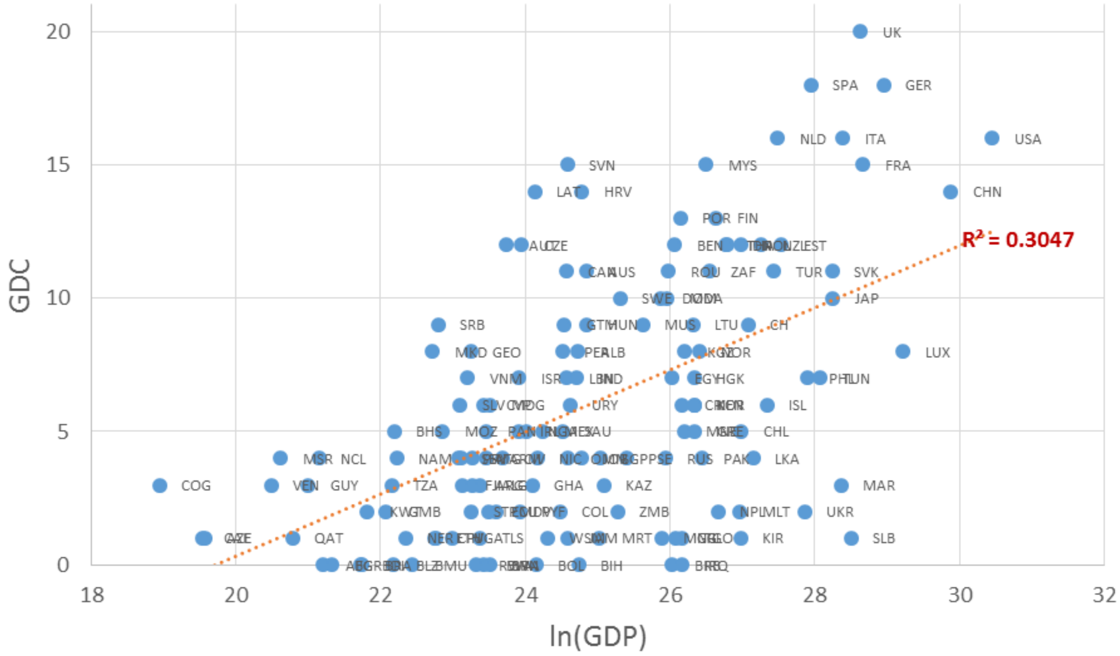
a)



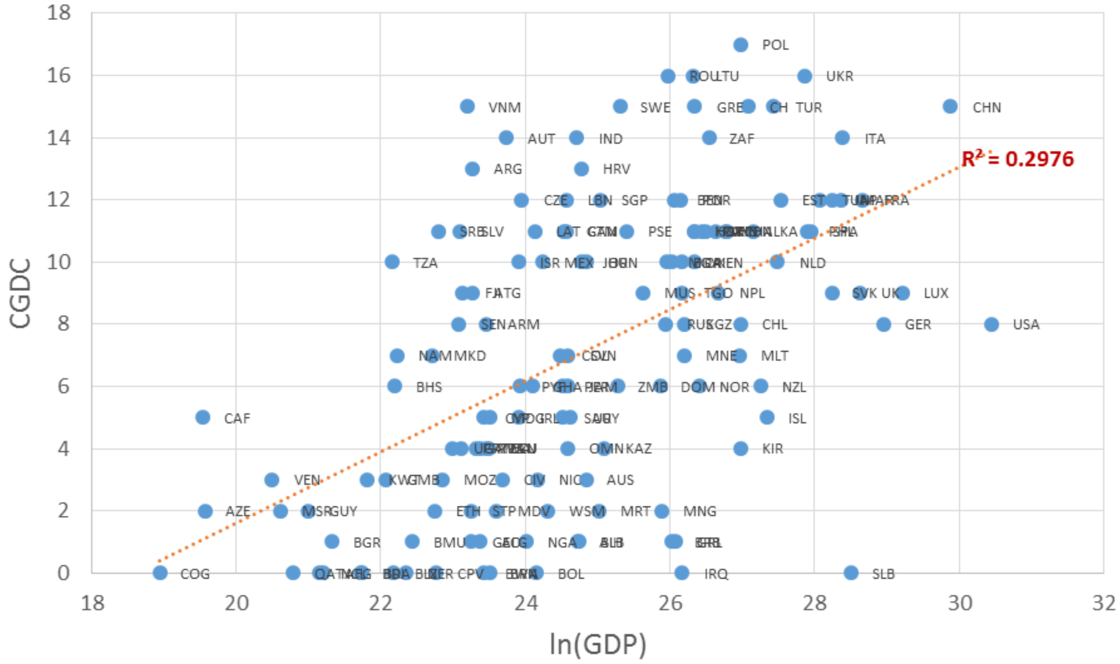
b)

Figure 3. CGD (a) and CGDD (b) for each world country (data refer to 2013).
(Legend: black = 0 green products; Red = 1÷5; Blue = 6÷10; Yellow = 11÷15; Green >15)

An interesting finding is shown in Figure 4a (4b), which depicts country's CGD (CGDD) as a function of the GDP. In both cases, a positive and significant correlation is found between the two variables. This suggests that the richest countries are currently characterized by the widest basket of green products. This evidence is in line with the results of other studies, which highlighted the positive relationship between the country GDP and the number of products exported by that country (Amurgo-Pacheco and Pierola 2008; Hu et al. 2012). Furthermore, the richest countries have also the highest likelihood to add a large number of green products to their current basket. Conversely, less developed countries are not competitive in green products and also have difficulty in adding new green products to their basket, because they lack the production capability required for their production. Hence, poor countries will be unable to develop green products, unless the country makes intensive investments on the requisite capabilities currently lacking. This situation identifies a green development trap for these countries.



a)



b)

Figure 4. Correlation between country GDP and CGD (a) and between country GDP and CGPD (b) (Data refer to 2013).

7.3 Country similarity on green product development

We computed two indices comparing all couples of the countries in order to analyze their similarity in terms of green products currently co-produced and that could be co-produced.
We define the *Similarity Green Product* index (SGP) as the normalized number of green products currently co-exported by two countries. This index ranges between 0 and 1: the higher the index, the higher the similarity between the two countries in terms of green products successfully produced. It is computed as follows:

$$\mathrm{SGP}(i,j) = \frac{1}{41}\sum_{k=1}^{41}\sum_{\substack{l=1\\ l\neq k}}^{41} A_{ki}\cdot A_{lj} \tag{12}$$

where $A_{ki} = 1$ ($A_{lj} = 1$) if $\Phi_{ki}^{MAX} = 1$ ($\Phi_{lj}^{MAX} = 1$), otherwise it is equal to zero.

We also define the Similarity Green Product Development index (SGPD) as the normalized number of green products that two countries could potentially co-add to their green product baskets. Also this index ranges between 0 and 1: the higher the index, the higher the similarity between the two countries, in terms of green products that can be potentially added. It follows that:

$$\mathrm{SGPD}(i,j) = \frac{1}{41}\sum_{k=1}^{41}\sum_{\substack{l=1\\ l\neq k}}^{41} B_{ki}\cdot B_{lj} \tag{13}$$

where $B_{ki} = 1$ ($B_{lj} = 1$) if $0.5 < \Phi_{ki}^{MAX} < 1$ ($0.5 < \Phi_{lj}^{MAX} < 1$), otherwise it is equal to zero.

In Figure 5, the SGP and SGPD values are shown in network graph form. In particular, in these graphs, two countries are linked to each other if they currently co-export (Figure 5a) or are potentially able to co-export (Figure 5c) at least five green products.
The analysis of the SGP index for each couple of countries reveals that that geography matters in green production. In fact, countries in close geographical proximity to each other currently co-export a high number of green products. For instance, France, the Netherlands, and the UK currently co-export 11 green products as well as France and Slovenia. Italy co-exports at least 5 green products with 21 countries, 14 of them are European countries (Figure 5b). The Netherlands co-export 10 green products with Spain and Germany. Moreover, China co-exports at least five green products with four relatively nearby countries (India, Hong Kong, Thailand, and Malaysia), while Indonesia co-exports at least five green products with three neighboring countries (Malaysia, Thailand, and Japan).
Moreover, geography seems also to affect green product development. In fact, from the analysis of the SGPD index for each couple of countries, we found that India can potentially co-export at least five additional green products with China, Sri Lanka, Indonesia, Malaysia, Pakistan, South Korea, Hong Kong, Singapore. Moreover, Italy could co-exports at least five green products with 43 other countries, 18 of them are geographically neighbors (Figure 5d). This information could be useful to develop green product supporting policies at transnational level suggesting where there is potential for growth. A policy targeted to support the development of a green product with high SGPD can in fact be beneficial for several countries.

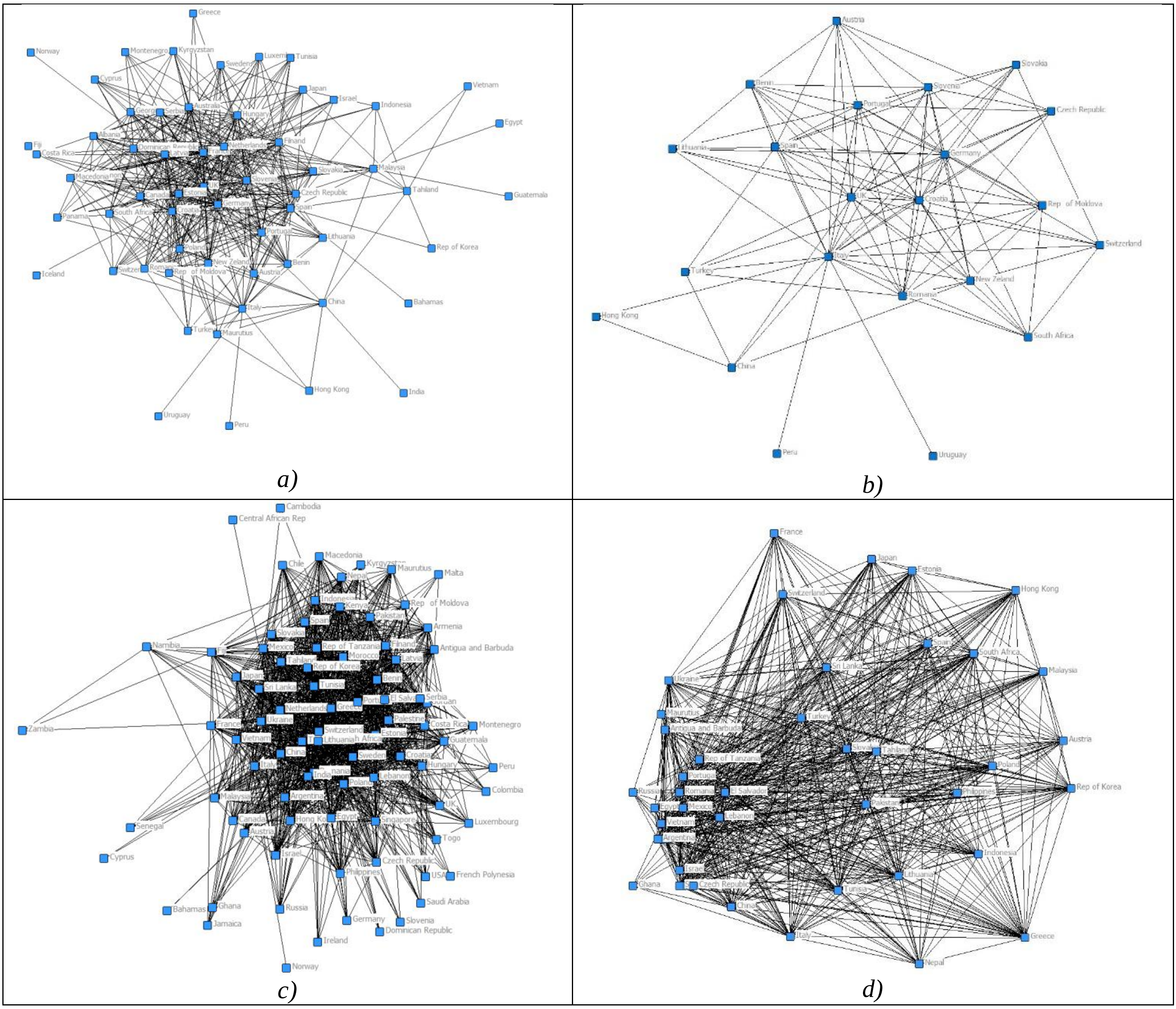


Figure 5. Network representation of SGP among countries (a), with special focus on Italy (b) and SGPD among countries (c), with special focus on Italy (d) (Data refer to 2013).

8. Conclusions

Which green products should the policy makers of a country support by means of policy actions so as to meet both the economic and environmental aims, or in other terms reaching sustainable economic development?

Our analysis proves that the green products with the highest potential for growth in a given country are those in close proximity to the products that the country produces with high competitiveness compared with other countries. Choosing to support these products make sense because it would exploit the requisite capabilities the country already possesses in terms of infrastructure, human capacities, and natural resources for economic development in an environmental direction. In fact, those countries where a given green product has high proximity to products with RCA>1 have already the requisite capabilities within their productive structure to successfully produce it. Hence, policy measures should be devoted to supporting investments into this product, because it has a great likelihood of growing in the next few years. In this way, high efficacy is assured to the policy action. On the contrary, countries where a given green product has low proximity to the products with RCA>1 do not have the requisite capabilities needed for its production. Therefore, sustaining such a product by simply "pumping money" will not be enough to assure its development. For these products, governments should take "strategic bets" by focusing their efforts on accumulating the capabilities required to produce green products (Abdon and Felipe 2011; Hausmann and Hidalgo 2011; Felipe et al. 2014). This outcome is important especially considering that literature is often limited to highlighting the benefits of green development and the need to support it, with little or no emphasis on the capabilities required for green development. With this work, we hope to contribute to the recognition that product capabilities are important prerequisites for green development.

This study also wishes to contribute to the literature on the application of the *product space* as a policy making tool for green development. First, it provides statistical significance to the intuition of Hamwey et al. (2013) who, by developing the green product space of Brazil and using this tool, identified the green products that should be supported by means of policy actions. Moreover, it also extends the application by Huberty and Zachmann (2011), who used the concept of product proximity to green products and provided preliminary results for two green products exported by two countries. In particular, from a methodological point of view, we offer a more detailed and structured approach to compute the green product space. Compared with Hamwey et al. (2013) who use the SITC product classification at 4-digit level of detail, we adopt the product classification SITC Rev 2 at 5-digit level of detail. This allows us to provide a more accurate analysis and, consequently, more precise policy implications. Furthermore, whilst Hamwey et al. (2013) limited their work to the identification of the basket of green products to sustain with policy actions, our study allows policy makers to distinguish which ones to sustain with high priority.

As implications of our study, we developed a set of indices based on the concept of maximum proximity, useful for policy makers as well as researchers interested in green product development. In particular, we defined the map of the current world green product development. This provides important information to policy makers in a user-friendly form: 1) it shows the green products in which the country is already competitive and 2) it shows which green products have the best chance of becoming competitive in the country in the next few years. In particular, the latter information offers very useful implications for the policy makers of a country, because it suggests which green products should be supported by targeted policy measures and which green products are ineffective to sustain. For example, our analysis suggests that Italian policymakers should invest in "Waste and scrap metal of iron or steel of other iron or steel", "Aluminum waste and scrap", and "Floating structures, other than vessels". Conversely, for Italy it could be ineffective to invest in "Liquefied gaseous hydrocarbons, nes" and "Tugs". In fact, the low proximity of these products to other products with RCA>1 suggests that Italy does not have sufficient capabilities to self-sustain the development of these green products. Similar arguments can be developed for all the countries analyzed, based on information provided in the green product development matrix (see Supplementary Material). Thus, the contributions of our study are not limited to one country (Italy) but are extendable to all the countries analyzed, confirming the importance of this study and the usefulness of the matrix proposed.

We also proposed measures of country green product diversity and similarity. By using them, some interesting relationships with country development were derived. We noted that countries with the highest current and future diversification on green products are those with the highest GDP. This confirms that the diversification of the export basket can be a fundamental strategy to enhance the economic competitiveness of developing countries (Kilnger and Lederman 2006;

Cadot et al. 2011). Developing countries can improve their economic performance by investing in green sectors. In this regard, our study provides an interesting implication because we can advise developing countries in which green industries to invest, by identifying those green products for which the countries have requisite production capabilities. Simply by computing the proximity of green products to the products with RCA >1 and choosing those which are closest, our study can be used to identify in which green sectors developing countries should invest, to increase the efficacy of their policy actions and at the same time improve their GDP. Moreover, we found that countries which are geographically close by show high current and future similarity on the production of green products. This confirms that geography matters for green product development and provides an interesting direction for future research suggesting that attention should be concentrated on the role of geography in green development.

There are certain limitations to this study that should be borne in mind. Firstly, since there are several classifications of green products, the results obtained may be contingent to the specific list adopted. Secondly, we have considered the maximum proximity as a measure of proximity of green products to the country's high RCA products, i.e., the proximity to only one product. Although this measure has its merits, it does not take into account the effect when a given green product has high proximity to more than one high RCA product. Although this does not change the main outcome of our study, i.e., that the maximum proximity is positively related to the growth potential, it might be possible that the green products in close proximity with more than one product may have a better potential to grow than products in close proximity with only one product, *ceteris paribus*. Further research is needed to address this issue and more sophisticated measures could also be developed to combine, for example, average and closest proximity.

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