Article

Journal of Environment & Development
XX(X) 1–14

DOI: 10.1177/1070496513482837
jed.sagepub.com

Mapping Green Product Spaces of Nations

Robert Hamwey[1], Henrique Pacini[1,2] and Lucas Assunção[1]

Abstract

As countries transition to a green economy, they will need to identify profitable entry points in which they can favorably compete with other nations in emerging green markets. Identifying and building supply capacity for commercially viable, competitive green product exports can be seen as a fundamental part of supporting green growth and sustainable development. Building on the product space model initially advanced by Hidalgo and Hausmann in 2009, this article proposes a green product space methodology to map the export strengths of countries for a specified set of green products. The methodology does so by identifying green products for which a country is likely to be competitive in the world market based on export performance of related products. Results for Brazil are presented to illustrate the green product space methodology followed by a discussion of its limitations and potential contribution to industrial policy formulation to support emerging green sectors.

Keywords

product space, green products, exports, development, trade

Introduction

Faced with the need to promote an economic transition toward low-carbon, less resource-intensive production and consumption, policymakers in many countries face a number of challenges when designing government initiatives that aim to foster the development of new green sectors. For some countries, green economic activities invoke concerns over development constraints and a widening North–South economic

[1]United Nations Conference on Trade and Development (UNCTAD), Geneva, Switzerland
[2]Royal Institute of Technology (KTH), Stockholm, Sweden

Corresponding Author:
Henrique Pacini, United Nations Conference on Trade and Development (UNCTAD), Royal Institute of Technology (KTH), Brinellvägen 68, Stockholm, 100 44, Sweden.
Email: pacini@kth.se

and technological gap (Roberts & Parks, 2007). However, advocates of "green growth models" point to at least three arguments in favor of green industrial growth strategies: related policies and measures could serve as a short-term Keynesian stimulus, improve trade competitiveness, and boost innovation as national firms react to meet environmental requirements emerging in greening global markets (Huberty & Zachmann, 2011, p. 5).

The first and most critical challenge facing policymakers concerns selecting which, among many, green sectors to promote. The literature on industrial policy shows that this selection process, often referred to as "picking winners," has more often been a failure than it has been a success (Dierickx, Matutes, & Neven, 1991; Eickelpasch & Fritsch, 2005; Niman, 1995; Pack & Saggi, 2006). Importantly, however, it also indicates that industrial policy has been most successful when governments have designed policy packages to support those sectors in which their country has a demonstrated comparative advantage (Rodriguez-Clare, 2007). Following areas of natural and comparative advantage has produced clear successes for some developing countries. For example, in recent years government initiatives helped to successfully spawn IT services in India and Mauritius; the salmon and wine industries in Chile; and the cut flowers sector in Kenya, among others (Ackbarally, 2002; Hughes, 2000; Perez-Aleman, 2005). A common feature behind these success stories was that countries already had requisite infrastructure, human capacities, and natural resources compatible with the development of these industries.

As the global economy increasingly orients itself toward a green economy, many policymakers would like to know which green sectors offer the greatest potential for diversification and growth of their economies. Based on the "Product Space" model pioneered by Hidalgo, Klinger, Barabasi, and Hausmann (2007), this article proposes a data-based analytical approach to help policymakers identify green sectors and green products which a country is best positioned to produce and export. By explicitly displaying and analyzing green goods within the product space of a country, our approach, as outlined here, allows national policymakers and sectoral stakeholders to identify promising green growth options and design sectoral policies needed to support these. This article thus contributes to policymaking by offering a practical methodology which can serve as an additional tool to help countries interpret their own economic complexity, and to design and target green industrial policies in those sectors most likely to produce export gains.

Revealed Comparative Advantage and the Concept of Product Proximity

A country A is said to have a revealed comparative advantage in a product i when its ratio of exports of product i (X_{Ai}) to its total exports of all goods ($\Sigma_j X_{Aj}$) exceeds the ratio of world exports of product i (X_{Wi}) to total world exports of all goods ($\Sigma_j X_{Wj}$). Based on Balassa (1986), this condition is met when:

$$RCA = \frac{X_{Ai} \big/ \sum_j X_{Aj}}{X_{Wi} \big/ \sum_j X_{Wj}} \geq 1$$

When a country has a revealed comparative advantage for a given product (RCA > 1), statistically, it is identified to be a competitive producer and exporter of that product relative to a country producing and exporting that good at or below the world average. We consider a country with a revealed comparative advantage in product *i* to have an export strength in that product. The higher the value of a country's RCA for product *i*, the higher its export strength in product *i*.

Within the two-dimensional network representation that characterizes product space, products that are situated close to each other, and connected by a link, are known to be strongly correlated in the cumulative export profiles of all countries based on historical world trade data. Empirically, world trade data demonstrate that when one product is produced and exported by a country there is a high propensity for another other product in close proximity to be produced and exported by the country as well. Hausmann and Klinger (2006) present a detailed explanation on this concept of product proximity, which can be summarized by the relation:

$$\phi_{ij} = \min\left\{P(RCA_i \mid RCA_j), P(RCA_j \mid RCA_i)\right\}$$

where $P(RCA_i \mid RCA_j)$ is the conditional probability of a country exporting good *i* given that it already exports good *j*. This metric provides a statistical measure of the distance between products in product space. Intuitively, products that share similar inputs will be situated near each other in product space maps (e.g., "fabric" lies near "yarn," and "wine" are situated near "grapes").

One interesting advantage of using product space maps is the fact that they provide empirical evidence of a rather intuitive concept: countries tend to diversify their economies through closely related products. As a country diversifies its export base it often tends to increase exports in similar products that are in close proximity in product space to those products which it already produces and exports competitively. Much more rarely it diversifies from already exported products into dissimilar products that are located far from the former in product space.[1] If it is to diversify into dissimilar products, it will need to make a big leap across product space, and empirical data based on national experiences show this is uncommon.

There could be many reasons for the close proximity of products in product space. For example, among other reasons, nearby products may require the same inputs, share the same or similar production processes, or in the case of agricultural goods and minerals, they may share common geographical, climatic, or geological factors related to their natural occurrence or production. Factors influencing the proximity of products in product space may also be related to downstream marketing and distribution channels. For example, exporters linked to distribution networks for oranges may also respond to demand in their orange distribution channels for grapefruits by introducing and increasing the production and export of the latter over time.

Green Product Classification

To assess a country's export profile for green goods it is first necessary to define a set of environmental goods. Green goods will generally include those associated to lowering pollution and preserving the environment when compared with conventional counterparts. For an assessment of any country's potential to produce and export green goods, a choice of a set of green goods must be made, and in a national policymaking exercise, stakeholders themselves must make this choice. Certainly, the green product space methodology can be applied to any set of selected green products. To date, there is no internationally agreed definition or list of green or environmental goods. Interest in international agreement on a definition and list of environmental goods emerged in the World Trade Organization (WTO) Doha Round of negotiations with a view of reducing trade barriers, including applied tariffs, for environmental goods at the global level (Vikhlyaev, 2004). Despite nearly 10 years of effort by the WTO Committee on Trade and Environment (CTE), a list of environmental goods for trade purposes remains elusive (Kao, 2012). However, recently in April 2011, the CTE presented, on an illustrative and starting-point basis, without prejudice to the final outcome of negotiations, a sample core list of environmental goods (World Trade Organization, 2011). This core set of environmental goods contains goods occupying 26 tariff lines drawn from the reference universe of goods occupying over 400 tariff lines proposed by members to the CTE.

Within product space, product groups are classified according to trade codes (SITC 4) at the 4-digit level.[2] In the analysis presented herein, 11 environmental goods (at the 4-digit SITC 4 level) have been selected as a representative set of goods serving the renewable energy, energy efficiency, waste management, and environmental monitoring industries. Our selection of course necessarily remains incomplete and arbitrary. For example, it would be possible to select larger sets of goods in these categories or to include goods from other categories such as organic agriculture, environmental remediation or water purification. Of those 11 tariff lines attributed to our 11 selected goods, 9 are from the sample core set of 26 tariff lines proposed by the CTE and 2 are additional products in the expanded CTE list which includes many goods of export interest to developing countries. These 11 tariff lines selected are analyzed here for illustration purposes only, serving as a working subset of green products to demonstrate our methodological approach to scope the product universe for green goods that possess high potential for production and export.

Analyzing Countries' Export Potential for Green Products

For any given country, product space can be visualized in a two-dimensional network representation wherein each product occupies a node (shown as a filled-circle) of size

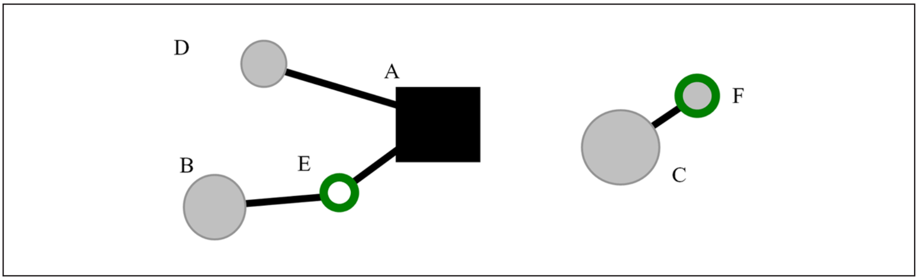

Figure 1. Simplified product space of Terra, where squares represent products displaying comparative advantages (RCA > 1), and circles represent products without comparative advantages (RCA < 1). See text.

proportional to the product's share of the country's total exports (or alternatively by the product's share of world exports), and color corresponding to the category of the product (e.g., textile, machinery, chemicals, electronics, etc.). However, when a country has a revealed comparative advantage for exporting a given product, the product node is depicted as a black square. Also, when a country does not export a particular product it is depicted by an unfilled circle.

An analytical approach to identify green products of export interest to individual developing countries is based on delineating green products in product space and assessing their proximity to products in which a country has export strengths. The closer the proximity of green products to other products for which the country has a revealed comparative advantage, the higher the potential for successful production and export of that green product. Conversely, green products which are located far from products in which the country has a revealed comparative advantage are much less likely to yield positive results. By assessing each green product in this way, policymakers and other stakeholders can identify which green products the country may best be placed to export and in this way help policymakers select winners rather than losers when formulating green economy development strategies and industrial policy to support green growth.

To introduce the concepts described above, we examine the simplified product space of a hypothetical country "Terra" as shown in Figure 1. This allows us to illustrate the basic features of product space.

The product space map of Terra shows that Terra exports all of the products A-F except E (unfilled circle). Green goods are depicted in the figure as product nodes (i.e., circles) with a green colored outline, namely products E and F. It can be seen from Figure 1 that Terra's largest exports are products A and C and its smallest exports are products E and F. Terra has a revealed comparative advantage in the production and export of product A (black square which denotes an RCA ≥ 1), but none of the other products. Noticing the close proximity of products A and E, and recalling that Terra has a comparative advantage in exporting product A, strongly suggests that Terra may be well positioned to build productive capacity in the green product E and competitively export it. Terra policymakers and other national stakeholders could take a closer look at prospects for supporting national firms to produce and export product E through reforms of sectoral policies, regulations and institutional strengthening, and possibly through new industrial policy initiatives. On the other hand, the green product F, which is already exported by Terra in relatively small quantities, is not an export for which Terra has an RCA ≥ 1. Policymakers and other national stakeholders could take a closer look at whether in recent years Terra's RCA for product C or F have increased and are approaching a value of 1. When this is occurring, product F may also be evolving into potential export strength of Terra. When this is not the case, however, our methodology suggests that supporting national firms to produce and export product F would be inefficient and unproductive.

The Product Space Map

A product space map for the world is shown in Figure 2. From an examination of the product space map several observations can be made. First, the size of a product node is proportional to its share of world exports. Second, products are classified by color, using a different color for each product class. Products in the same classes lie close to each other and often form clusters. Third, links between products in different classes are generally weaker than links between products in the same class. Lastly, none of the nodes in Figure 2 are shown as black squares (denoting and RCA ≥ 1) since the world itself does not have revealed comparative advantages in particular products, only individual countries do. It is also important to keep in mind that product space maps describe the situation of product exports at a given instant in time, and that from one year to another, the size of product nodes, as well as their RCA values will change. Keeping in mind these general features of product space, one can examine and interpret the product space map of individual countries.

Examining the Product Space Map of Individual Countries

Since SITC trade data exist for nearly all countries, product space maps can be produced for virtually any country in the world. Using 2009 SITC 4 world trade data, we generated product space plots with the graphics package Cytoscape 2.6, using input from the Product Space Parser application.[3] For the purposes of demonstration, we present the product space map of one country, Brazil, which is a highly diversified developing economy. The product space map of Brazil is presented in Figure 3 using trade data from 2009. The product space map is shown in color in Figure 3a. For ease of viewing, in Figure 3b the colors of all product nodes for which Brazil does not have a revealed comparative advantage have been grayed-out, and all black squares representing product nodes in which Brazil is a competitive producer (i.e., RCA ≥ 1) have been changed to blue. Each product node is labeled by its 4-digit SITC 4 code (only visible when zooming in on product space map at higher magnification). Product node sizes are proportional to Brazil's export volumes.[4]

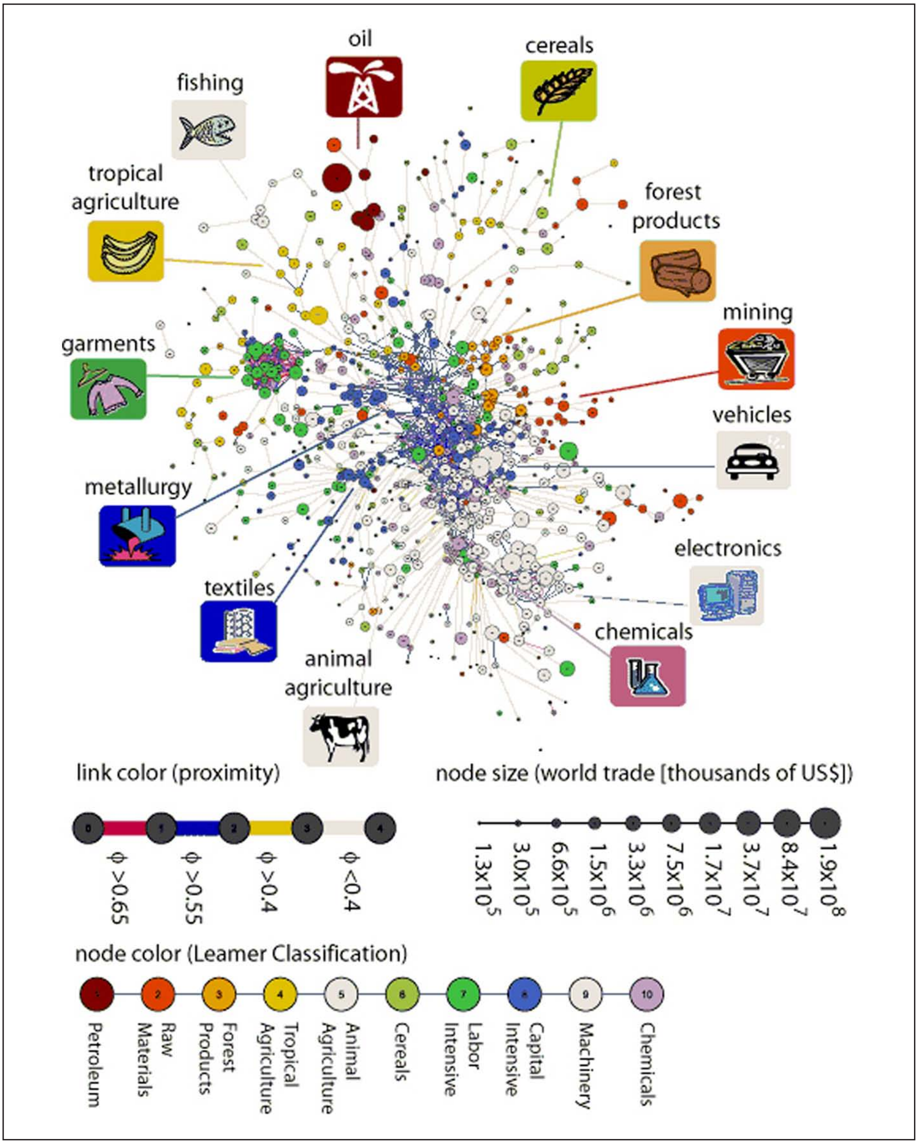

Figure 2. Product space map of the world in 2000.
Source: Hidalgo et al. (2007).

Brazil's product space map clearly shows that Brazil has a very diversified export base with a revealed comparative advantage for products in many different classes across product space. Most of these products are also in close proximity to each other, and many are linked in cluster-like structures, although some of these products seem

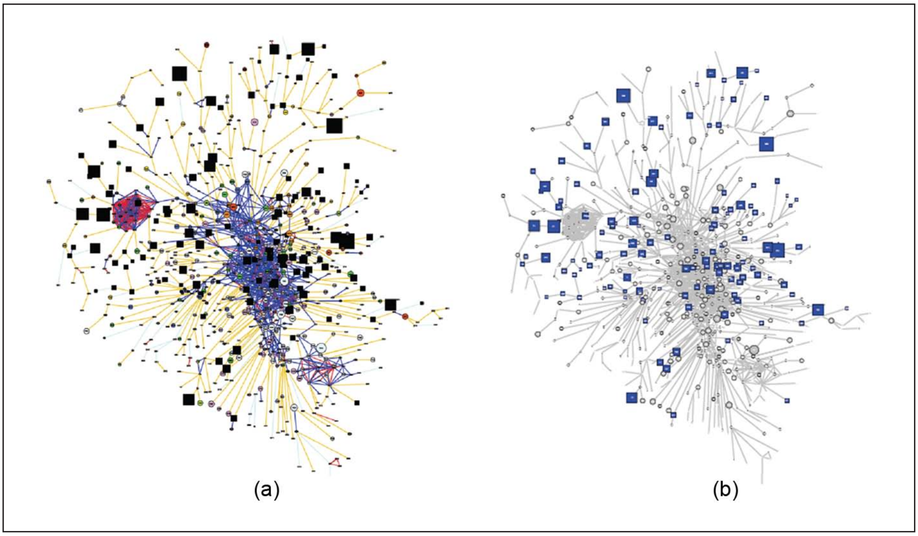

Figure 3. Product space map of Brazil in 2009 (see text).

to be isolated. It also shows that Brazil is an efficient trader because such products account for a predominant share of its total exports, which is expected according to the Ricardian theory of comparative advantage.

Features of Brazil's export profile as it relates to environmental goods, that is, green products, is not immediately apparent from Figure 3. However, these features can be highlighted by depicting product nodes which contain environmental goods as large green circles in the product space map.[5] Here, for the purposes of illustration, we include the 11 "green" product groups selected above and described explicitly in Table 1. In Figure 4, these 11 product groups are depicted as large green circles in the product space map. This figure can be referred to as a "green product space map." It must be recognized, however, that the green product groups in Figure 4 are only a selected subset of a larger group of environmental products that could be defined.

Figures 4 and 5 allow a visual scoping analysis to be done to identify green product groups with promising export potential. The configuration of Brazil's product exports, relative volume as a share of Brazil's total exports (size of product node), the similarity of products exported (proximity), and the likelihood of exporting two products in proximity (links between the two products) are shown in Figures 4 and 5. The zoom views of Brazil's product space map provide sufficient detail for a visual analysis of Brazil's potential to enhance export capacity in the green products listed in Table 1.

The zoom views of Figure 5 show that Brazil has exports in all of the green product groups listed in Table 1, but that among this set of products Brazil only has a revealed comparative advantage in the export of ethanol. The enlarged views of Brazil's product space map shows several product groups (turbines, optical equipment, plaiting materials, and refrigeration equipments) that are located in close proximity to other

Table 1. Selected Green Product Groups and Their Tariff Lines, in HS and SITC 4 Systems (see text).

SITC 4	HS2002	SITC 4	Category
8997	4601	Basketware, wickerwork and other articles of plaiting materials . . .	Waste management
6973	7321	Cooking or heating apparatus of a kind used for domestic purposes . . .	Energy efficiency
6975	7324	Sanitary ware, and parts thereof, . . . of iron, steel, copper, or aluminum	Waste management
7148	8410/11	Turbines	Energy efficiency
7414	8418	Refrigerating equipment (electric or other), other than household-type . . .	Renewable energy
7162	8502	Electric generating sets	Renewable energy
7763	8541	Diodes . . . and semiconductor devices (including photovoltaic cells . . .	Renewable energy
8841	9001	Optical fibres . . . prisms, mirrors, and other optical elements . . .	Renewable energy
8744	9027	Instruments and apparatus for physical or chemical analysis . . .	Environmental analysis
5121	2207	Acyclic alcohols and their halogenated derivatives	Renewable energy
7782	8539	Electric filament lamps and discharge lamps	Energy efficiency

product groups for which Brazil has a revealed comparative advantage. The green products in these product groups could be examined more closely through additional analyses and investigation as potential candidates for targeted green industrial policy, enhancing competitiveness, and further development of production and exports.

Limitations of Product Space Analysis and Conclusion

Product space analysis is a scoping tool. It is not a substitute for conventional tools guiding industrial policy, but instead a complementary lens through which countries can more quickly and accurately identify green sectors where they appear to have a high chance of developing sustainable and profitable export activity. National firm level analysis and focused discussions between firms and national policymakers would still be needed to validate and extend the scoping analysis provided through the product space mapping exercises presented here.

The analysis of national product space to identify green export strengths has limitations which call for additional tools to complement national assessments. First, the tool limits itself to exports, thus providing no information on total (domestic + export) production and consumption of these goods. This implies that there may be products for which a country is an efficient and internationally competitive producer, however, the country may not be exporting these goods in quantities large

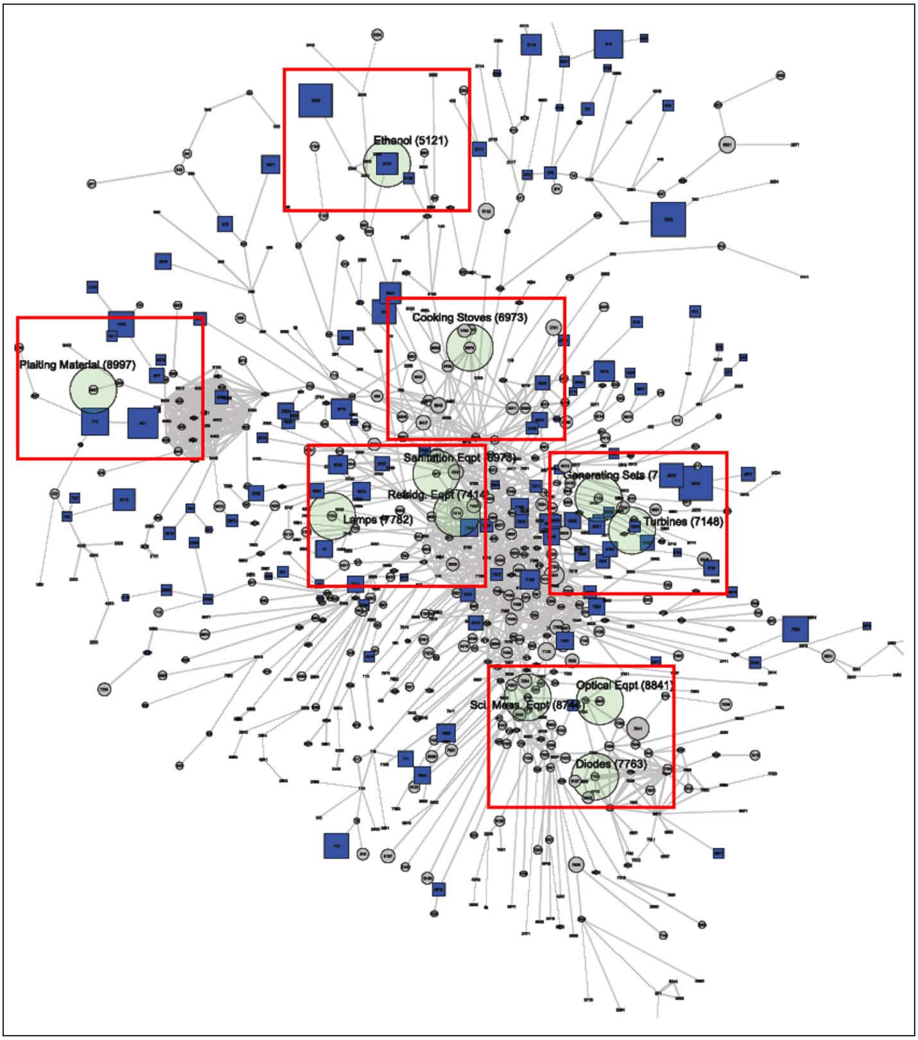

Figure 4. Green product space map of Brazil in 2009. Zoom images of the areas in the red squares are presented in Figure 5. The 11 green product groups depicted in the green product space map are listed in Table 1.

enough for a revealed comparative advantage to emerge (i.e., the product is "under-exported"). Such a situation can be found in Brazil's ethanol trade in 2011; exports were once assumed to grow exponentially, but throughout most of 2011 the country required ethanol imports to meet its internal demand, causing its revealed comparative advantage to shrink.[6] The development of a stronger predictor of sectoral success would necessarily need to take total production (e.g., not only exports) into account.

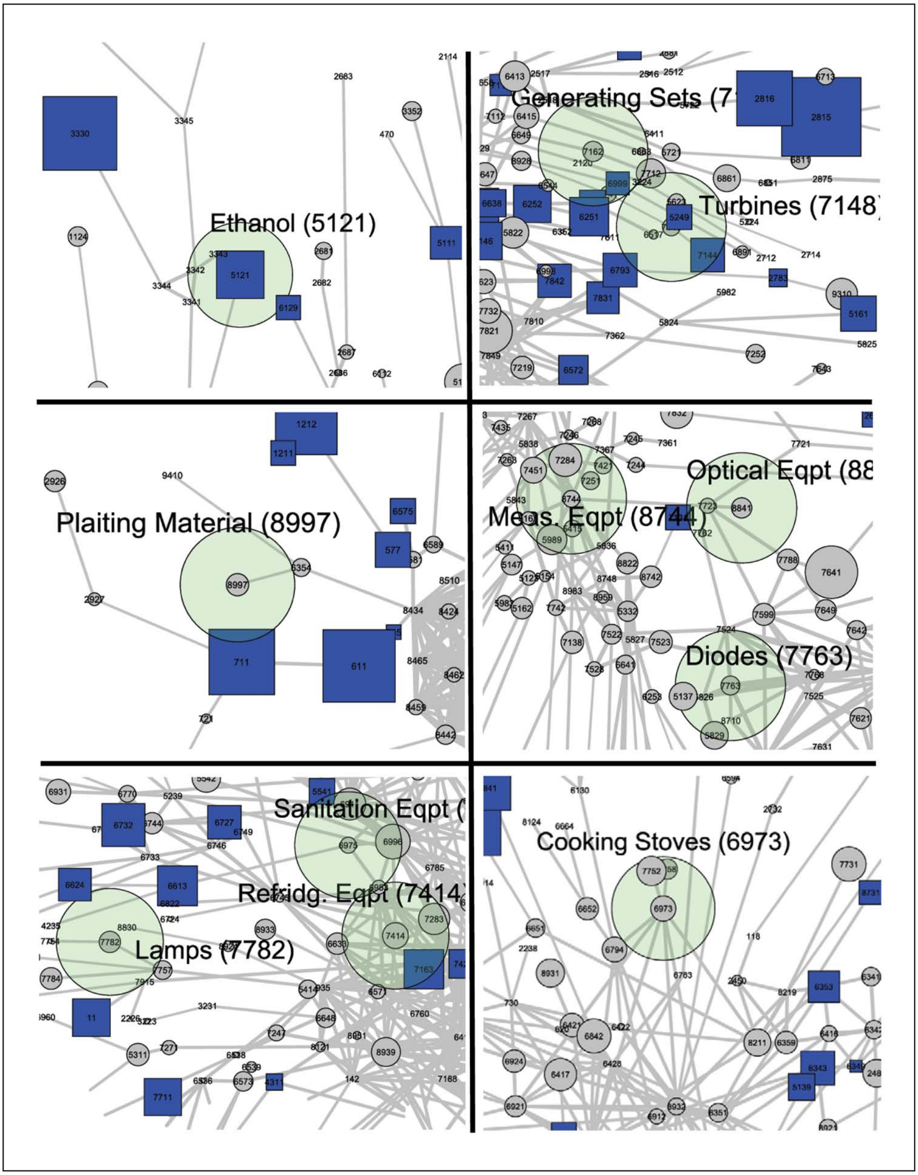

Figure 5. Enlarged views of green product space map of Brazil in 2009.

Second, the resolution and characteristics of data used to create product space maps should be taken into consideration. In this article, maps were created using 4-digit SITC tariff lines, and many different subtypes of products exist for each 4-digit code. Although featuring in the CTE list, many of 4-digit categories lines encompass products with multiple possible usages (only some of which are green, i.e., supporting environmental objectives). They may also encompass products which have been produced by different process and production methods, not all being environmentally beneficial Stein (2009). In both the SITC 4 and HS product classification systems, there is no code differentiation for products which can be produced in different ways (e.g., conventional vs. organic food products or conventional vs. certified sustainable ethanol).[7]

Third, the magnitude of RCAs and their intertemporal evolution are other factors which should be considered in addition to product space map scoping exercise described above. Considering the magnitude of RCAs, while a square is plotted for any RCA above one, the map provides no indication of the relative strength of RCAs. Since, for example, an RCA value of 3.5 would indicate a much stronger competitive position in a certain sector than an RCA of 1.1. Although not indicated on the map, RCA magnitudes are known accurately from the trade data and these can be consulted separately. Consideration should also be given to the recent evolution of RCAs. Product space maps are static and do not capture changes in RCAs which might have taken place in recent years. International trade is highly competitive and shares of countries' exports in different markets often vary considerably over time, including from one year to another for some products and countries. For a product or product group within a country, the RCA might be greater than 1 but steadily decreasing over time (the country is losing its competitive edge to other world producers) or less than one but steadily increasing over time (the country is gaining a competitive edge over other world producers). Additional analysis—including nonvisual metrics—of multi-year data is therefore needed to discern such trends.

Finally, the choice of what constitutes an environmental good is certainly not bound to WTO classifications. Countries can elect themselves which product categories they consider important within their own green economy context. The analysis can be subsequently shaped to explore the potential for competitiveness spillovers from products with existing comparative advantages to any selected set of green products of national interest.

Given these limitations, candidate sectors for green industrial policy should not be selected solely based on product space maps. Instead, this methodology can be very useful when coupled with a broader sectoral analysis of specific green sectors of national interest encompassing global and domestic policy, regulatory and institutional frameworks influencing their production and trade. Inputs from stakeholders along relevant supply and value chains should be an integral part of the broader sectoral analysis. Identifying promising green sectors also involves analyses of dimensions not captured in the product space maps, such as green services, production methods and resource intensities, as well as the supply and demand trends for green products in domestic and international markets. Nevertheless, despite these limitations, green product space maps represent a powerful visual tool for identifying a country's potential export strengths in green sectors and thus the methodology can complement and inform other approaches used by policymakers to pick winners when seeking to streamline regulation, strengthen institutional support, and formulate industrial policy for green sectors.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Notes

1. While countries with high revealed comparative advantages in the production of organic food products might attempt to develop export capacities in, say, wind turbines, this is highly unlikely to be done in a cost-efficient manner. Diversification in export strengths is statistically more likely to occur in similar product categories. See Jovanovic and Nyarko (1996).
2. This nomenclature and level of disaggregation was used by Hidalgo and Hausmann (2009). In principle, however, product groups can be plotted in product space using any nomenclature (i.e., HS) and at any level of disaggregation. See Hidalgo (2011).
3. Available at: http://www.chidalgo.com/productspace/data.htm
4. This choice differs from the network representations of Hidalgo and Haussmann in which node sizes are proportional to world rather than country export volumes.
5. Such representation required modifications in the software responsible for plotting product space maps, whose source code is public.
6. Brazil's ethanol exports fell due to climatic conditions which affected sugarcane fields, as well as attractive sugar opportunities and relative low gasoline prices, which altogether made the production of ethanol, while efficient, unattractive for producers. See Pacini and Silveira (2011) and Businessweek (2011).
7. The current classification trade systems do not take into account, for example, differences between organic and nonorganic agricultural products in international trade and thus are unable to accommodate the application of different tariffs to organic versus nonorganic agricultural products.

References

Ackbarally, N. (2002). *Mauritius: A cyber-island in the making*. London, UK: Panos Features.

Balassa, B. (1986). Comparative advantage in manufactured goods: A reappraisal. *The Review of Economics and Statistics*, *68*, 315-319.

Businessweek. (2011, November 22). *Brazil to become net importer of U.S. ethanol*. [Online edition]. Retrieved from http://www.businessweek.com/news/2011-11-22/brazil-to-become-net-importer-of-u-s-ethanol-czarnikow-says.html

Dierickx, I., Matutes, C., & Neven, D. (1991). Cost differences and survival in declining industries: A case for "Picking winners?" *European Economic Review*, *35*, 1507-1528.

Eickelpasch, A., & Fritsch, M. (2005). Contests for cooperation: A new approach in German innovation policy. *Research Policy*, *34*, 1269-1282.

Hausmann, R., & Klinger, B. (2006). *Structural transformation and patterns of comparative advantage in the product space* (CID Working Paper No. 128). Cambridge, MA: Center for International Development.

Hidalgo, C., & Hausmann, R. (2009). The building blocks of economic complexity. *Proceeding of the National Academy of Science*, *106*, 10570-10575.

Hidalgo, C. (2011). *Discovering Southern and East Africa's industrial opportunities* (Economic Policy Paper Series, The German Marshall Fund of the United States). Retrieved from http://www.chidalgo.com/Papers/HidalgoCA_GMF_2011.pdf

Hidalgo, C., Klinger, B., Barabasi, A. L., & Hausmann, R. (2007). The product space conditions the development of nations. *Science*, *317*(5837)482-487.

Huberty, M., & Zachmann, G. (2011). *Green exports and the global product space: Prospects for EU industrial policy*. Brussels, Belgium: Bruegel.

Hughes, A. (2000, May). Retailers, knowledges and changing commodity networks: The case of the cut flower trade. *Geoforum*, *31*, 175-190.

Jovanovic, B., & Nyarko, Y. (1996). Learning by doing and the choice of technology. *Econometrica*, *64*, 1299-1310.

Kao, P. K. (2012). *Environmental goods and services negotiations*. Geneva, Switzerland: WTO. In International Trade Policies and Climate Change Governance. SpringerBriefs in Economics.

Niman, N. B. (1995). Picking winners and losers in the global technology race. *Contemporary Economic Policy*, *13*, 77-87.

Pacini, H., & Silveira, S. (2011). Consumer choice between ethanol and gasoline. Lessons from Brazil and Sweden. *Energy Policy*, *39*, 6936-6942.

Pack, H., & Saggi, K. (2006). *The case for industrial policy: A critical survey* (World Bank Research Working Paper No. 3839). Washington, DC: World Bank.

Perez-Aleman, P. (2005). Cluster formation, institutions and learning: The emergence of clusters and development in Chile. *Industrial and Corporate Change*, *14*, 651-677.

Roberts, J. T., & Parks, B. C. (2007). *A climate of injustice. global inequality, North-South politics, and climate policy*. Cambridge, MA: MIT press.

Rodriguez-Clare, A. (2007). Clusters and comparative advantage: Implications for industrial policy. *Journal of Development Economics*, *82*, 43-57.

Stein, J. (2009). The legal status of eco-labels and product and process methods in the World Trade Organization. *American Journal of Economics and Business Administration*, *1*, 285-295.

Vikhlyaev, A. (2004). *Environmental goods and services: Defining negotiations or negotiating definitions*.(Article 2 of UNCTAD Trade and Environment Review, 2003). New York, NY: UNCTAD.

World Trade Organization. (2011, April 21). *Committee on Trade and Environment in Special Session* (Document TN/TE/20). Geneva, Switzerland: Author