Background documents to the Technology and Innovation Report 2023

Assessing Greener Economic Diversification Trajectories

Clovis Freire
UNCTAD
Clovis.Freire@unctad.org

MARCH 2023

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Abstract

This paper examines the opportunities for developing countries to diversify their economies towards sectors associated with lower carbon emissions. The strategies for inclusive and more sustainable growth assume the government's active role in fostering innovation in greener technologies and products that are new to the world. However, in low-income developing countries, economic diversification is usually associated with the innovative process of absorbing technologies to emulate more productive industries resulting from previous innovation in more developed countries.[1] Yet, if countries follow previous growth paths, global greenhouse gas (GHGs) emissions will continue to increase with severe social and economic impacts.[2] Thus, it is critical to find new pathways of economic diversification that are more sustainable.

[1] (Reinert, 2008)

[2] (IPCC, 2007)

Acknowledgements

This paper was produced as a background study for the UNCTAD Technology and Innovation Report 2023. Comments on an earlier draft received from experts attending an ad-hoc informal expert consultation held online in October 2022, and the online peer review meeting of the Technology and Innovation Report 2023 organized in October 2022, are gratefully acknowledged.

For further information about this document, please contact Technology, Innovation and Knowledge Development Branch, UNCTAD, Palais des Nations, CH1211 Geneva 10, Switzerland, e-mail: stdev@unctad.org.

To cite this paper:

Freire, C (2023). Assessing Greener Economic Diversification Trajectories, UNCTAD Background Paper, United Nations Conference on Trade and Development, Geneva

TABLE OF CONTENTS

1. Introduction

Diversification is a quintessential characteristic of development. The more developed the country, the more diversified its economy. Economic diversification, ultimately, is the result of innovation. In developing countries, economic diversification usually means introducing a new product to the country but not the world. Such emulation of more productive activities requires the innovative process of absorbing and adapting technologies to the country's context. Historically, the emulation process is how rich countries got rich.[1] A common feature of diversification strategies adopted by countries that successfully caught up was that they targeted mature industries in countries not far away in terms of income per capita.[2] Emulation is also at the core of the "Flying Geese Model" pattern of economic development, followed by many Asian countries.[3]

Diversification is a path-dependent process, and possibilities for emulation are not equally available at any given time.[4] Path dependence exists because new economic activities tend to exploit the technologies that were previously developed for other activities.[5] Therefore, the activities that are more likely to be emulated require a set of technologies that largely overlaps with the set required by the existing economic activities in the economy. For example, while the production of goods such as machinery and electronics require technologies that can be the building blocks of the output in many other sectors, the production of primary products usually involves technologies that offer fewer possibilities for further combinations and, thus, diversification. More significant "jumps" in innovation, in which some of the technologies combined are not available in the economy and must be learned or transferred from abroad, require more government support to facilitate innovation. In addition, economic institutions and the expected demand for new products shape the incentives for creating and combining technologies.[6]

Recent research uses information about the level of export diversification of countries and how many countries export each product to compute indices of the level of technologies in the economy or the so-called economic complexity.[7] These indices also estimate the level of technology that goes into the production of each product. More complex products are considered to require higher levels of technology, and development is associated with diversification toward products with above-average complexity in the country.

Studies that examined the possibility of countries diversifying towards more complex and greener products have found mixed results (Zhen and Freire, 2023). The analysis of these studies suggests the need for a strategic diversification approach, where potential new sectors for diversification are identified based on their level of complexity, relatedness with the existing productive structure, existing global demand, and the associated impact on carbon emissions.

This paper uses economic complexity and product space analysis to create indices of economic complexity and carbon footprint associated with the production of over 43,000 products exported in international markets.[8]

Therefore, green windows of opportunities in diversifying towards greener sectors require significant capacities in public institutions and policy interventions for identifying sectors, technologies and markets, and creating the conditions for their domestic firms (private and public) to enter into these new sectors. Governments in low and lower-middle-income developing countries have to act fast and decisively; otherwise, they will be left further behind. Given that green productive capabilities are path-dependent, the greener production capabilities a country has, the easier it is to diversify into additional new green products.[9]

This paper is organized as follows. Section 2 describes the methodology and data used to calculate the economic complexity and indices of carbon footprint of economies and products. Section 3 presents the results and examines if there is a path towards more complex and greener production. Section 4 discussed the need for a strategic approach for diversification. Section 5 discusses policy options for facilitating greener diversification and structural transformation. Section 6 concludes.

2. Methodology

This section presents the methodology to estimate the economic complexity of countries and products, their levels of carbon footprint, and the relatedness between products. This paper also identifies the economic activities that are more likely to emerge given the existing set of technologies by using an index of proximity between products and merchandise trade data to proxy production data.

Relatedness

The measure of proximity between products *A* and *B* (Φ_{AB}) in the product space is calculated using a method similar to that proposed by Hidalgo and others (2007) as used in Freire (2017), which does not limit the analysis to the products to which the countries have a revealed comparative advantage. Thus, the relatedness of products is calculated as the minimum value between the conditional probability P(*A*|*B*) of a country producing *A* given that it produces *B* and the conditional probability P(*B*|*A*) of a country producing *B* given that it produces *A*:

$$\Phi_{AB} = \Phi_{BA} = min(P(A|B), P(B|A)) \quad (1)$$

The proximity between two products, therefore, ranges from 0%, in which no country produces both products, to 100% in the case in which all countries that produce one good also produce the other. This paper adopts the threshold of 80% proximity to an existing product of the country's product mix to identify potential new products for diversification.

Economic complexity

The paper applies the method of reflections (Hidalgo and Hausmann, 2009) with the modifications proposed by Freire (2017) to estimate the complexity of economies and products. The method constructs a bipartite network of countries and products they produce and iteratively calculates a generalized measure of diversification and ubiquity, as follows:

$$k_{c,N} = \frac{1}{K_{c,0}} \sum_p M_{cp} k_{p,N-1} \quad (2)$$

$$k_{p,N} = \frac{1}{K_{p,0}} \sum_c M_{cp} k_{c,N-1} \quad (3)$$

for $N > 0$

$k_{c,0}$ is the number of products exported by country c and $k_{p,0}$ is the number of countries that export product p. The method of reflections produces, for each country c, an ordered list of N real numbers ($k_{c,0}$, $k_{c,1}$, $k_{c,2}$, … , $k_{c,N}$), where N is the number of iterations of the method of reflections.

The measure of economic complexity of countries considers all the information in that ordered list as follows:

$$economic\ complexity = \frac{k_{c,0}\times k_{c,2}\times k_{c,4}\times k_{c,6}\times k_{c,8}\times k_{c,10}\times k_{c,12}\times k_{c,14}\times k_{c,16}\times k_{c,18}}{k_{c,1}\times k_{c,3}\times k_{c,5}\times k_{c,7}\times k_{c,9}\times k_{c,11}\times k_{c,13}\times k_{c,15}\times k_{c,17}\times k_{c,19}} \quad (4)$$

The measure of product complexity (*PCOMP*) is taken as the normalized value of the K_p value of the 5th iteration of the method of reflections:

$$PCOMP = \frac{Kp5 - < Kp5 >}{sd(Kp5)} \quad (5)$$

Where $<K_{p5}>$ is the mean and $sd(K_{p5})$ is the standard deviation of the distribution of K_{p5}.

Index of carbon footprint

This paper estimates the average carbon emissions per capita associated with a product by considering the average carbon emissions per capita of countries that produce that product and the structure of their network of technologies. The estimations of carbon footprint is calculated by applying the method of reflections and using $K_{c,0}$ as the carbon emission per capita of country c (in metric tons per capita).[10]

Therefore, the following equation replaces the generalized measure of diversification in the method of reflections for the estimation of carbon footprint:

$$K_{c,N} = \frac{1}{\sum_p M_{cp}} \sum_p M_{cp} K_{p,N-1} \quad (6)$$

For $N \geq 0$, with $K_{c,0} =$ CO_2 emission per capita.

The value of the index of carbon footprint is normalized using the formula:

$$\text{Index carbon footprint} = \frac{K_{p5} - < K_{p5} >}{sd(K_{p5})} \quad (7)$$

Where $< K_{p5}>$ is the mean and $sd(K_{p5})$ is the standard deviation. As the successive iterations of the method proceed, the measure captures the properties of neighbouring nodes in the network connecting countries and products. For example, $K_{c,0}$ is the initial measure of the CO_2 emission per capita of country c, while $K_{c,2}$ is the average CO_2 emission per capita of countries that export the products in the product-mix exported by the country c. Therefore, what the index captures is the average CO_2 emission per capita associated with the productive capacity of a country.

Data

To apply the method of reflections and to calculate the proximity between products in the product space, data on country's production is required. Since there are few systematically disaggregated production data that covers the less industrialized developing and least developed countries, this paper uses as a proxy the disaggregated trade data from *United Nations COMTRADE* using Harmonized System code (HS 2002) at 6-digit level covering 233 economies for the year 2018. The data is further disaggregated by quantity unit code and by unit price range using the methodology proposed in Freire (2011). Most recent data on carbon emission per capita measured in metric tons per capita available from the World Bank's World Development Indicators database is for the year 2018.

3. Results

Finding more complex and greener sectors

It is not intuitive to identify the products that are at the same time more complex and greener, which makes any plan for greener diversification a challenging task without the aid of sophisticated analytical tools. For example, a list of products with higher product complexity and that also have the indices related to green production below global averages includes garneted stock of cotton with the unit price range between $145 and $211, yarn of viscose single untwisted ($321 to $1,234), constant weight scales with unit price over $417,709, and titanium unwrought waste or scrap powders of unit price over $4,678. Table 1 lists these and other products that comprise the top 20 in the world in terms of product complexity and greener production. The list is a mix of all sorts of products, from primary commodities such as cocoa paste to precision manufacturing products such as clocks. Even products that could be associated with carbon emissions are included in the list, as in the case of coke, semi-coke of coal, lignite, and gas-fueled pocket lighters, which highlights the difficult task of classifying a greener production. The variety of products also reinforces the message that countries do not need to fight in a competition in the same few sectors to thrive in the production and trade of more complex and greener products. A large range of products are associated with this positive social outcome and countries can strategically plan their diversification process through unique paths.

What is common among the products in this list is that they are relatively expensive - sold at high unit price ranges in the international trade. To be marketed at high price ranges, their production probably involves more technology and a larger number of professions, from design to high precision manufacturing to branding. Still, that production is carried out in countries associated with greener production.

Table 1. complex and greener than global average (<0), 2018

Description	complexity	co2gdp	co2pc
(520291) Garnetted stock of cotton, $145-211	2.41	-1.50	-0.04
(540331) Yarn of viscose rayon, single untwisted nes not retai, $321-1234	2.41	-1.50	-0.04
(842330) Constant weight scales, including hopper scales, $417709+	2.41	-1.50	-0.04
(810810) Titanium, unwrought, waste or scrap, powders, $4678+	2.41	-1.50	-0.04

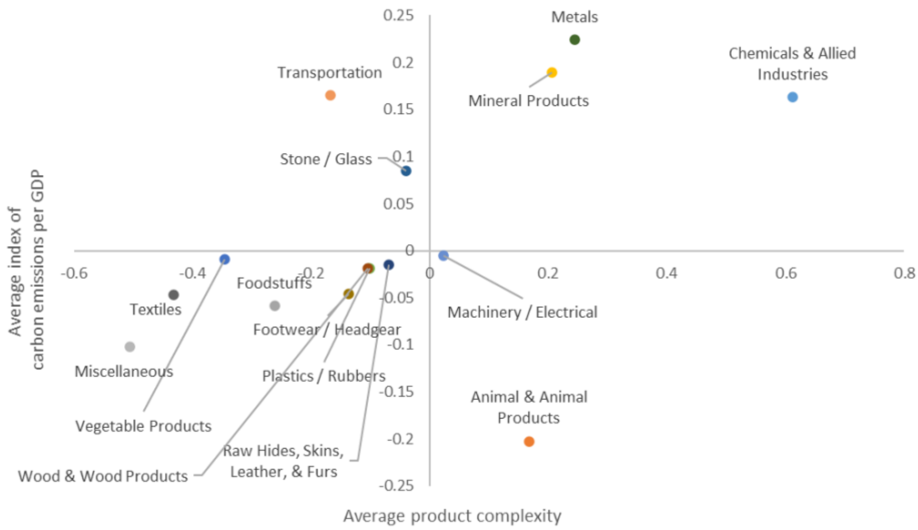
(720943) Cold rolled iron or non-alloy steel, flat, width >600mm, t 0.5-1mm, nes, $13-14	2.41	-1.50	-0.04
(845819) Horizontal lathes nes for metal, $317867+	2.41	-1.50	-0.04
(180320) Cocoa paste wholly or partly defatted, $105-331	2.41	-1.50	-0.04
(520535) Cotton yarn >85% multiple uncombed <125 dtex, not ret, $45-61	2.41	-1.50	-0.04
(845310) Machinery to prepare, tan, work hides, skins, leather, $114096-158773	2.41	-1.50	-0.04
(270400) Coke, semi-coke of coal, lignite, peat & retort carbo, $15-31	2.41	-1.50	-0.04
(160416) Anchovies, prepared or preserved, not minced, $206+	2.41	-1.50	-0.04
(580429) Mechanical lace, other material (piece, strip, motif), $891-948	2.41	-1.50	-0.04
(700232) Tubes of low expansion glass (Pyrex etc), $862-906	2.25	-2.01	-0.14
(961320) Pocket lighters, gas-fuelled, refillable, $414-463	2.25	-2.01	-0.14
(631010) Used or new rags textile material, sorted, $260+	2.14	-1.46	-0.00
(580639) Woven fabric materials nes, < 30 cm wide, $446-555	2.13	-1.53	-0.03
(852210) Pick-up cartridges, $5100-8966	2.09	-1.85	-0.06
(551221) Woven fabric >85% acrylic staple fibres, unbl/bleache, $390-472	2.09	-1.85	-0.06
(950611) Snow-skis and parts, $1505-1920	2.09	-1.84	-0.18
(911280) Clock, etc cases, except metal, $3244-3894	2.09	-1.84	-0.18

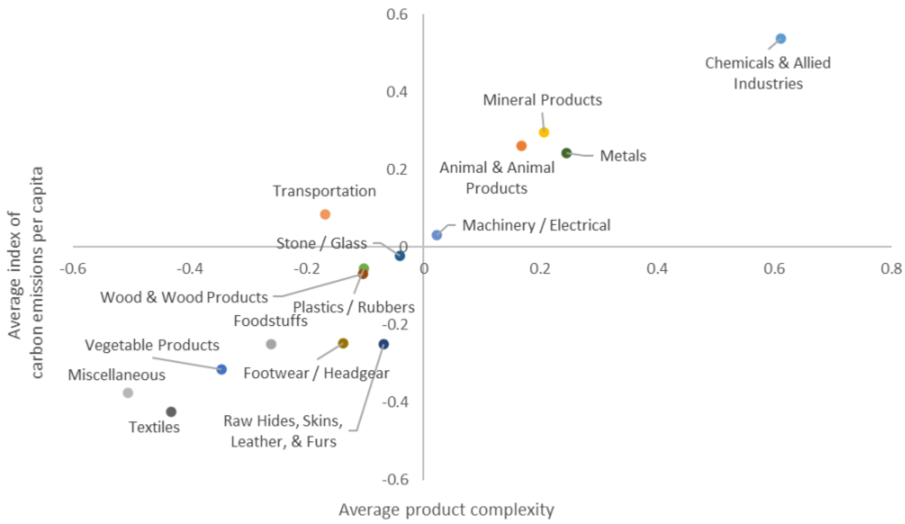
Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

Note: In the measures of complexity, index of CO_2 per capita and index of CO_2 per GDP, zero represents the global average, and 1 is the standard deviation of the distribution.

What are the sectors that are associated with more complex and green? All sectors have products that are in different ranges of complexity and green outcomes. At the same time, on average, more complex sectors are associated with higher emissions per GDP and per capita (Figure 1). The sectors that are more complex and have higher carbon footprint are chemicals and allied industries, metals and mineral products. The sectors less complex and with lower carbon footprint are textiles, vegetable products, foodstuffs and footwear.

Figure 1. Relationship between average indices of green outcomes and complexity, selected sectors, 2018





Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

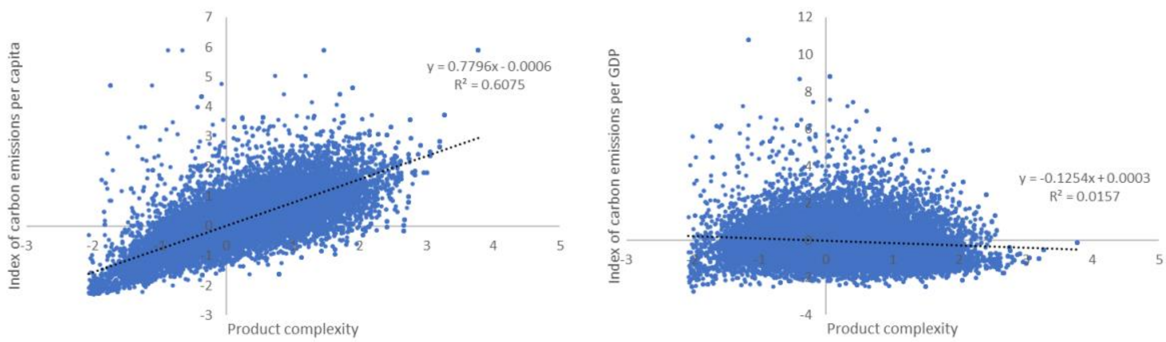
Note: On both axes, zero represents the global average, and 1 is the standard deviation of the distribution.

Is there a path towards more complex and greener production?

Inclusive growth requires the shift of employment towards more complex economic activities, while low carbon growth would require these economic activities to be associated with a lower carbon footprint. However, such a shift is challenging and also depends on the measure of carbon footprint used. For example, complexity is positively and more strongly correlated with carbon emissions per capita but negatively correlated with carbon emissions per GDP.

The graphs in Figure 2 illustrate these relationships, showing on the horizontal axis the measure of complexity and on the vertical axis the index of each product's carbon emission or energy intensity.

Figure 2. Association between carbon footprint and product complexity, 2018

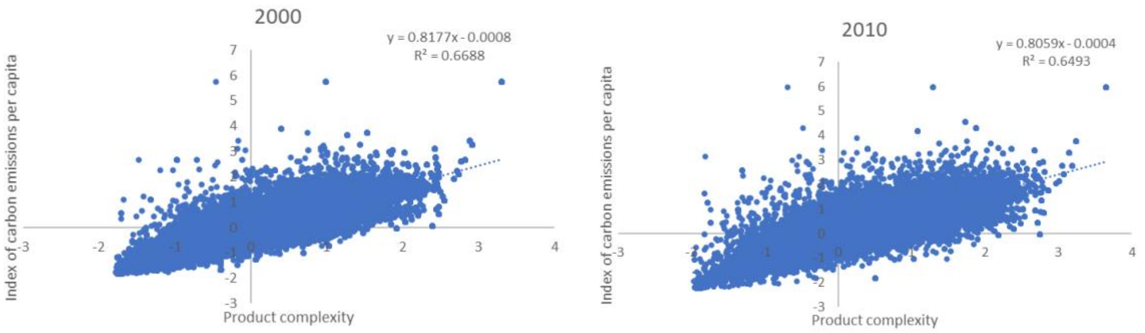


Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

Note: On both axes, zero represents the global average, and 1 is the standard deviation of the distribution.

Over the past two decades, complexity has become slightly less associated with emissions (Figure 3), suggesting a process of decoupling between increasing complexity and increasing emissions.

Figure 3. Association between carbon emissions per capita and product complexity, 2000 and 2010



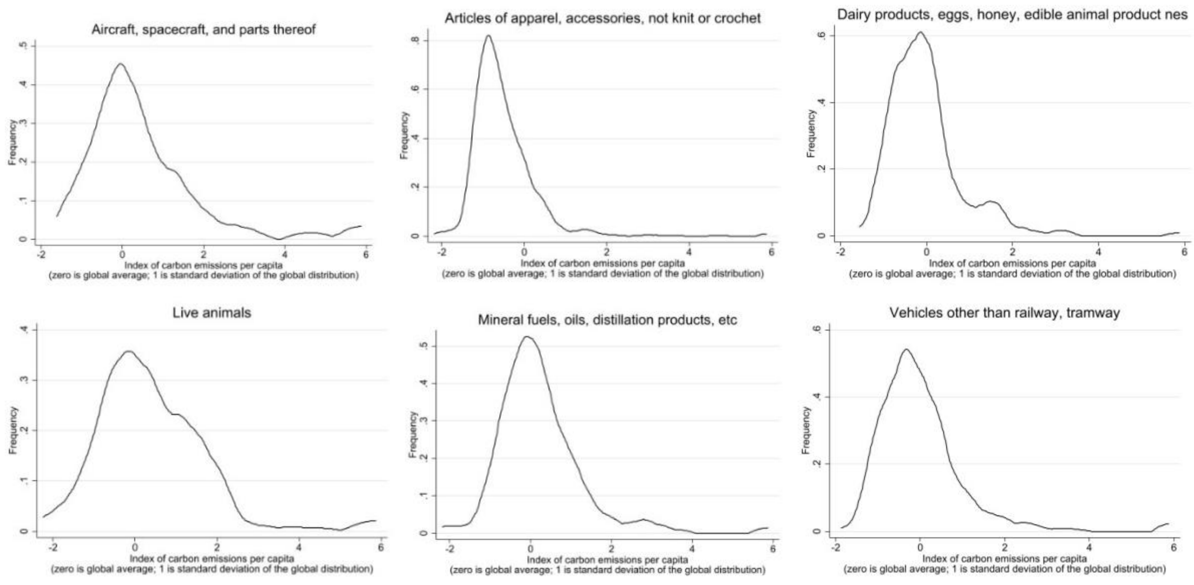
Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

Note: On both axes, zero represents the global average, and 1 is the standard deviation of the distribution.

The graphs in Figure 3 also suggest a path towards more complex and greener production. They show that some more complex products are associated with lower per capita and GDP carbon emissions. The result could be achievable if the diversification is through products below the trendlines in the graphs.

The analysis results show that no particular 'broad' industry category is associated exclusively with higher or lower levels of carbon footprint. For each industry, the distribution of the index ranges from below to above global average carbon emissions per capita (Figure 4).

Figure 4. Density graphs, 2018

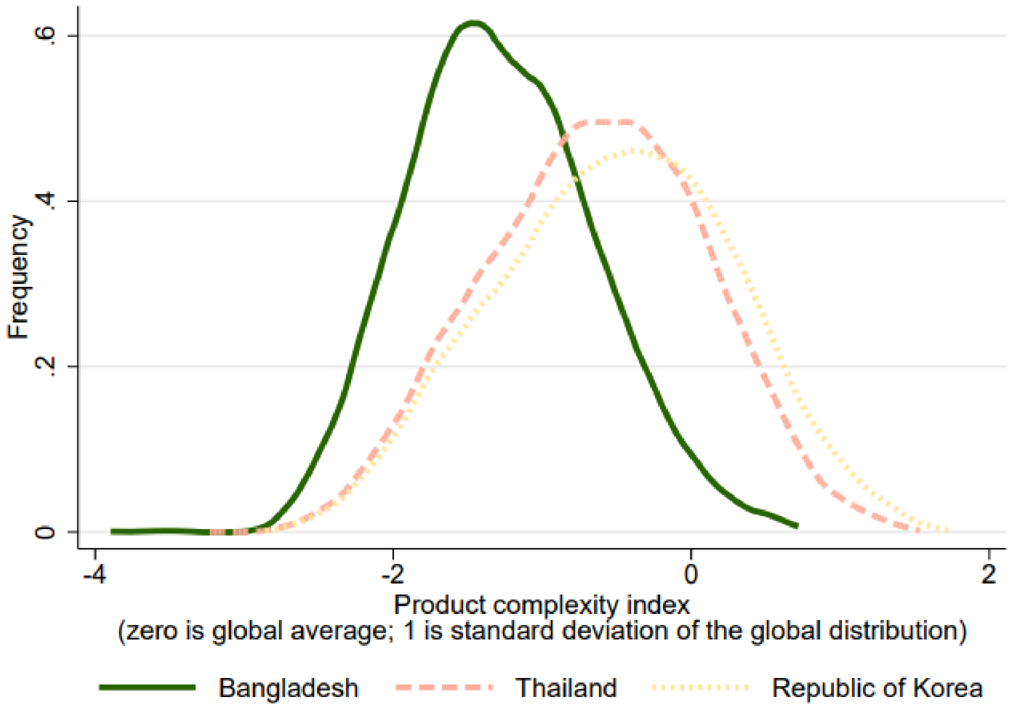


Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

Note: On the horizontal axis, zero represents the global average, and 1 is the standard deviation of the distribution.

Moreover, countries do not specialize in products with a certain level of carbon footprint - they make products within a large range, from low- to high- carbon footprint. This is illustrated in Figure 5, which shows the distributions of the index of carbon footprint of Bangladesh, Thailand and the Republic of Korea in 2018. These three countries are shown to illustrate the distributions of a least developed country (Bangladesh), a middle-income country (Thailand) and a high-income country (Republic of Korea). The difference between the distributions of these countries is not much in the range of values of the index of carbon footprint that they take, but in the shape of the distribution. Bangladesh's product mix is concentrated in products that have lower index of carbon footprint, while the production of Thailand and the Republic of Korea are concentrated in products that are closer to the global average. The distribution of Bangladesh is said to be skewed to the right (positive skewness) while the other two are skewed to the left (negative skewness). The distribution of Bangladesh also has a higher peak and less heave tails than the other two distributions, which indicates a higher kurtosis of the Bangladesh's distribution.

Figure 5. Distribution of index of carbon footprint, selected countries 2018



Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

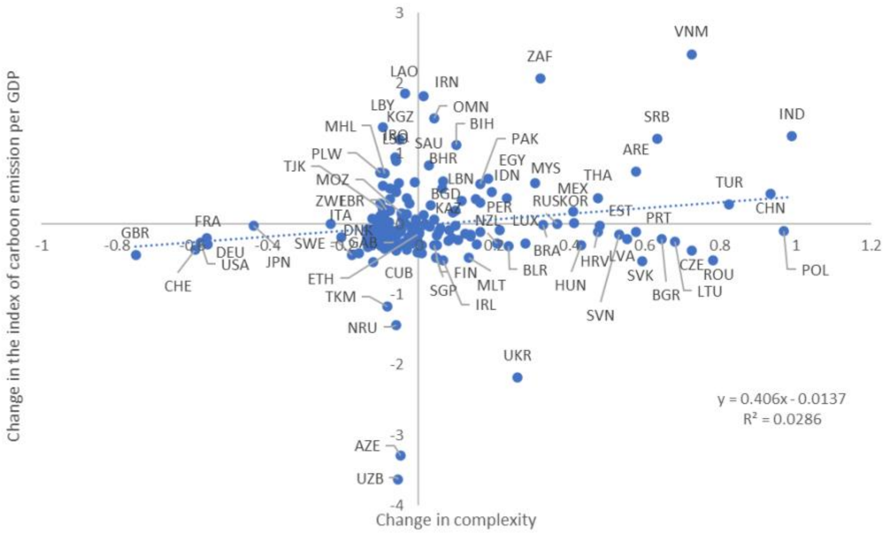
Limited evidence of past greener and more complex paths

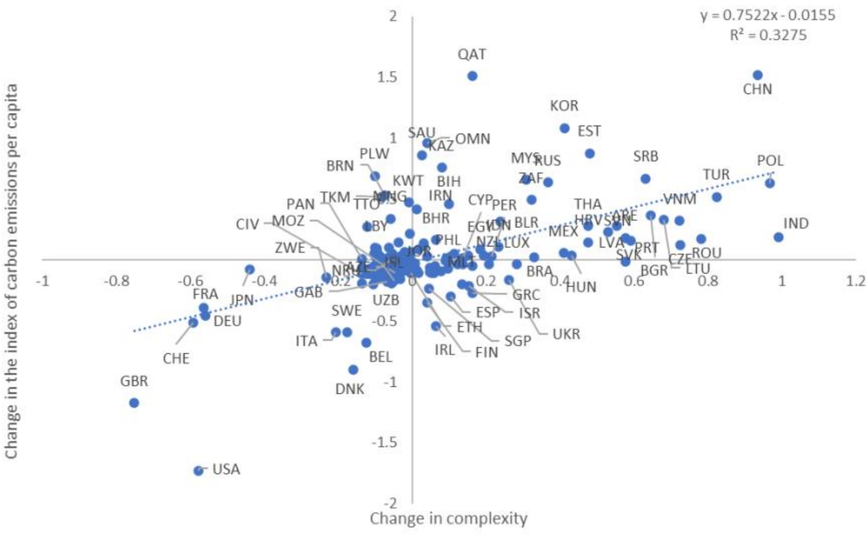
How do countries stand in terms of complexity and green? There is no clear association between the change in complexity and changes in the index of carbon emissions per GDP in the past two decades. The countries that have increased their complexity the most in the period are India, Poland, China, Türkiye, Romania, Viet Nam, Lithuania, Bulgaria, and Serbia. About half of them also increased their index of emissions per GDP, while the other half saw a decrease. Similar pattern is seen in countries that have not increased their complexity much or have their complexity reduced in the period. Although it is seen a high increase in carbon emissions per GDP index for India, Viet Nam, Serbia, United Arab Emirates, and South Africa.

There should be no surprise that countries have increased or decreased their complexity in relation to the global average, by changing (or not) their economic structures, in a way that was not correlated with their change in carbon emissions per GDP. Increases in complexity are associated with innovation and technological change leading to economic diversification and increasing productivity. Increases in the index of emissions per GDP are related to changes in the economic structure towards sectors that have more emissions per GDP. The lack of association between these two reflects the message of Figure 2, in which there are many products with higher complexity and lower index of emissions per GDP.

On the other hand, increases in economic complexity have been associated with increases in the index of carbon emissions per capita. In general, countries have not followed a path of increasing complexity and reducing emissions (Figure 6). This positive association reflects the relationship between product complexity and the index of carbon emissions per capita of products. The countries that have increased their complexity the most in the period are India, Poland, China, Türkiye, Romania, Czech Republic, Viet Nam, Lithuania, Bulgaria, and Serbia. Most of them also increased their index of emissions per capita. Similar pattern is seen many countries that have not increased their complexity much or have their complexity reduced in the period. It is seen a high increase in carbon emissions per capita index for China, Qatar, Republic of Korea, Saudi Arabia, and Estonia.

Figure 6. Change in complexity and carbon footprint, 2000-2018





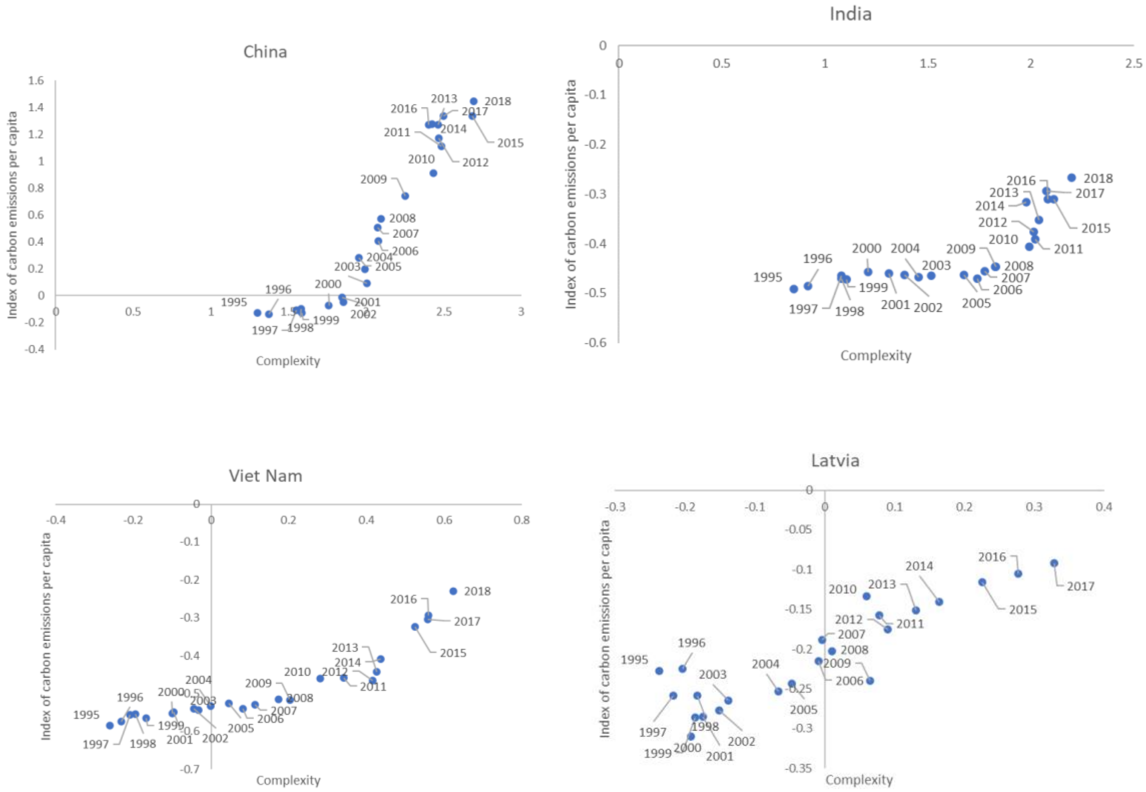
Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

Note: On both axes, zero represents the global average, and 1 is the standard deviation of the distribution.

The movement of countries along the plane of complexity and carbon emissions per capita can inform about the technologies used in their production structure over time. Take, for example, China. The country shows a pattern of increasing complexity from 1995 to 2018, divided into two periods in relation to its change in the carbon emissions per capita index. From 1995 to

2002, complexity increased while the index of carbon emissions per capita remained about the same or increased only slightly, while since 2003, that index has sharply and steadily increased. This pattern suggests that in the period before China entered the WTO, increased complexity resulted from diversification towards products with about the same level of carbon emissions per capita, using somewhat the same technologies. After that, the country diversified its production towards products associated with production in countries with higher carbon emissions per GDP.

Figure 7. Examples of changes in complexity and carbon footprint, selected countries



Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

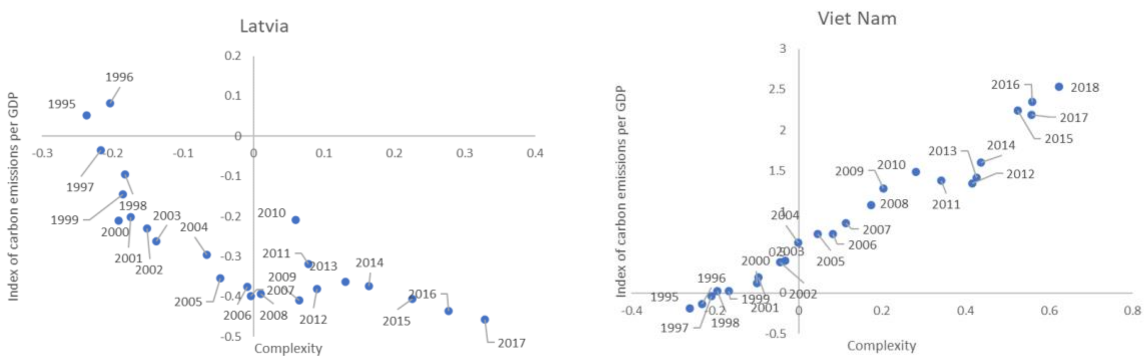
Note: On both axes, zero represents the global average, and 1 is the standard deviation of the distribution.

India shows a somewhat similar pattern, but the period of the rapid increase in carbon emissions per capita associated with its productive structure only started in 2010, and it is less pronounced than the one seen in China. The level of the index of emissions per capita for India is, nevertheless, still much lower than the global average.

Viet Nam and Latvia are also part of the select group of great transformers of economic complexity. They are two of the few countries that were able to move from below to above average economic complexity from 1995 to 2018. They both have increased their economic complexity throughout this period, but that increase has been faster after the global financial crisis in 2008-2009. Both have shown an increase in carbon emissions per capita index in tandem. In Viet Nam, that increase was small from 1995 to 2009. The index level was higher but somewhat constant from 2010 to 2012 and has increased steeply since then. Latvia experienced some complexity volatility in the 1990s, but since the 2000s, complexity and the index of carbon emissions per capita have increased at a more constant rate. In both cases, the levels of the index of carbon emission are still below the global average, and, in the case of Viet Nam, it is as low as in India.

However, Latvia and Viet Nam show opposite patterns in the relationship between complexity and carbon emissions per GDP. In Latvia, the increase in complexity has been accompanied by increasing carbon efficiency, particularly between 1995 and 2007. There was some volatility in the index from 2008 to 2012, but since then, the carbon emissions per GDP index has shown a decreasing pattern. In Viet Nam, increasing complexity has been associated with increasing values of the index of carbon emissions per GDP, with a short break on the series between 2010 and 2012.

Figure 8. Examples of changes in complexity and carbon emission per GDP, selected countries



Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

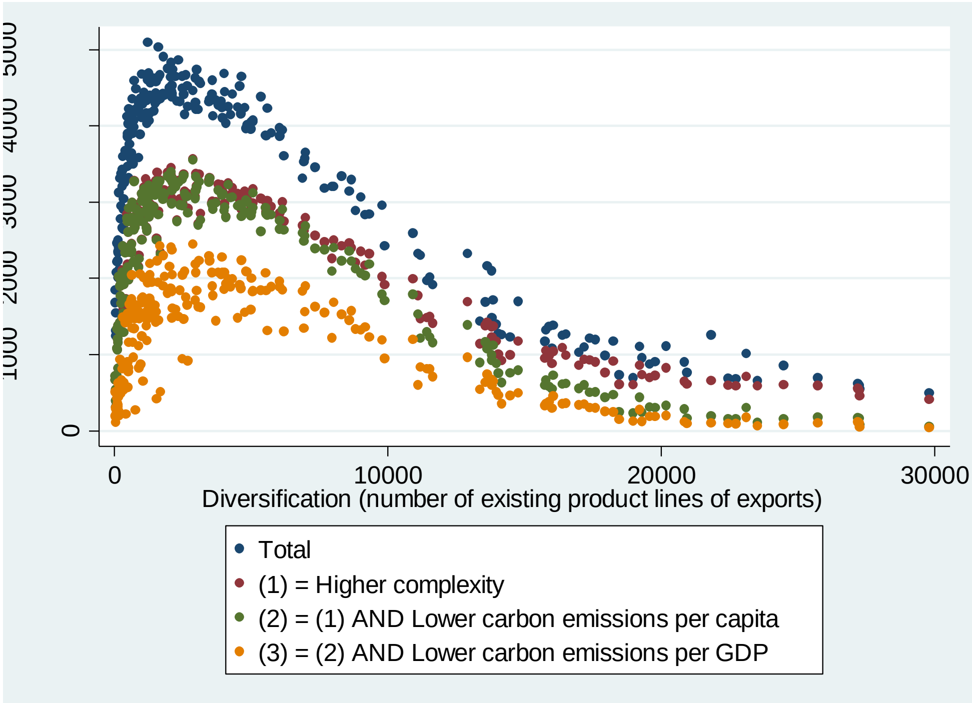
Note: On both axes, zero represents the global average, and 1 is the standard deviation of the distribution.

4. The need for strategic diversification

The opportunities for countries to diversify their economies and promote structural transformation through a green path are in products that are more complex, have below global average carbon footprint and are nearby in the product space to the existing product mix.

The number of these opportunities for a particular country, therefore, depends on its level of diversification – how many products it is already able to produce. This is illustrated in Figure 9, which shows the number of such opportunities relative to the number of exiting products in country's product-mix. Each dot in the figure represents one of the 234 economies included in the analysis. The blue dots represent the pair of number of existing products and the number of potential new products for diversification given its proximity in the product space. The red dots add another requirement. They represent the pair of number of existing products and potential new products that are close in the product space and that have complexity higher than the average complexity of the country's products. The figure shows a sizeable difference between blue and red dots for countries that have lower levels of diversification, but for countries with product-mix with over 10,000 products, the difference becomes smaller. A green path would require adding other requirement in terms of carbon footprint - to have carbon emissions below the global average. In the figure, the green dots represent these opportunities with higher complexity and lower carbon emissions per capita. The figure shows that, this time around, for countries with low levels of diversification, the extra requirement for greener products would not reduce the number of opportunities. On the other hand, as countries diversify it becomes harder to find new products that are both more complex and greener. Orange dots in the figure represent new opportunities for diversification that are more complex and are associated with lower carbon emissions per capita and per GDP. In this case, the extra requirement makes it is harder for less diversified countries to find these opportunities. Therefore, as countries diversify, the likelihood of further diversifying towards more complex and greener products change in a non-liner away, which is summarized in Table 2.

Figure 9. Association between number of existing and potential new products



Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

Table 2. How the number of potential new products for diversification change with the level of diversification of the economy

Number of potential new products for diversification	Economy	
	Less diversified	**More diversified**
Total	High compared with the level of diversification of the economy. It is relatively easy to find	Low compared with the level of diversification of the economy. As countries diversify, there is less opportunities for

	potential new products for diversification.	diversification on products that already exist in the world.
With complexity above country's average	Much lower than the total number of potential new products. It is more challenging to find new products that also contribute to increasing the level of technological capacity of the economy.	Not much less than the total number of potential new products. The opportunities for diversification are likely to also be associated with higher complexity.
With complexity above country's average and carbon emissions per capita below global average	About the same number of potential new products that are more complex. Thus, it is likely that by finding new and more complex products, these would also be associated with lower carbon emissions per capita.	Lower than the potential new products that are more complex. As countries diversify, their firms have to make an extra effort to diversify towards products that are also associated with lower carbon emissions per capita.
With complexity above country's average and carbon emissions per capita and per GDP below global average	The extra requirement of lower carbon emissions per GDP significantly reduces the number of potential new products for diversification.	About the same number of potential new products that have lower carbon emissions per capita.

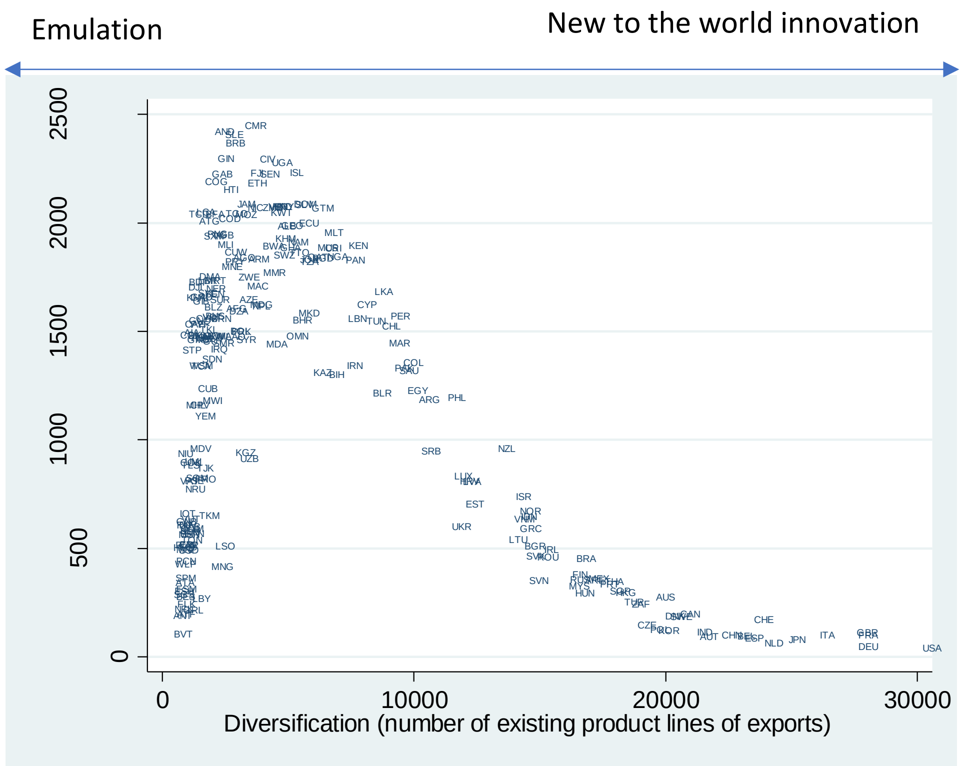
Source: Author.

The State has an important role to play in facilitating the creation of new private sector activities that increase the productive capacity of the economy while curbing its environmental impact. That should entail the support of both the emulation and the product innovation strategies. However, the balance between them depends on the level of diversification and productive capacities in the country. This is illustrated in Figure 10, which shows that the number of potential new products increases with the number of existing products in the country's product mix for very low levels of diversification, which with the dataset used was around 3,000 products. After that point, the number of potential new products that are both more complex and greener reduces with the increase of products in the product mix, and the balance between emulation and innovation start gradually to shift towards the latter. As economies become more diversified, there are fewer opportunities for emulation. It is interesting to note that for emerging economies such as China, Brazil, India and South Africa, innovation seems to be a much more important strategy, given the relative lower number of potential new products for diversification through emulation. Therefore, despite their low level of income per capita as compared with developed economies, these emerging economies have to increase support to R&D and creation of original knowledge and new products to facilitate the creation of more productive and greener economic activities.

In addition to the balance between emulation and innovation, it is important to identify the factors that could facilitate or prevent the process of discovery of these new economic activities by the business sector. One factor that is somewhat self-evident is the share of potential new products that have both above country's average product complexity and below global average carbon emissions per capita and per GDP. The higher the share, the higher is the probability that an entrepreneur would select a new economic activity with those desirable social outcomes.

Such analysis shows that most countries have more than 50 per cent of potential new products with above country's average product complexity, which would contribute to pushing the distribution of complexity of the country's product mix towards more complex products. This is illustrated in Figure 11 (A), which shows in the vertical axis the percentage of the potential new products that have above country's average complexity, and in the horizontal axis the number of existing products in the country's product mix. The figure shows that the countries that have lower share of potential new products with above country's average complexity, and therefore with lower opportunity to move up in the complexity ladder, are exactly the less diversified economies, those that in principle could benefit more from an emulation strategy.

Figure 10. Emulation vs innovation



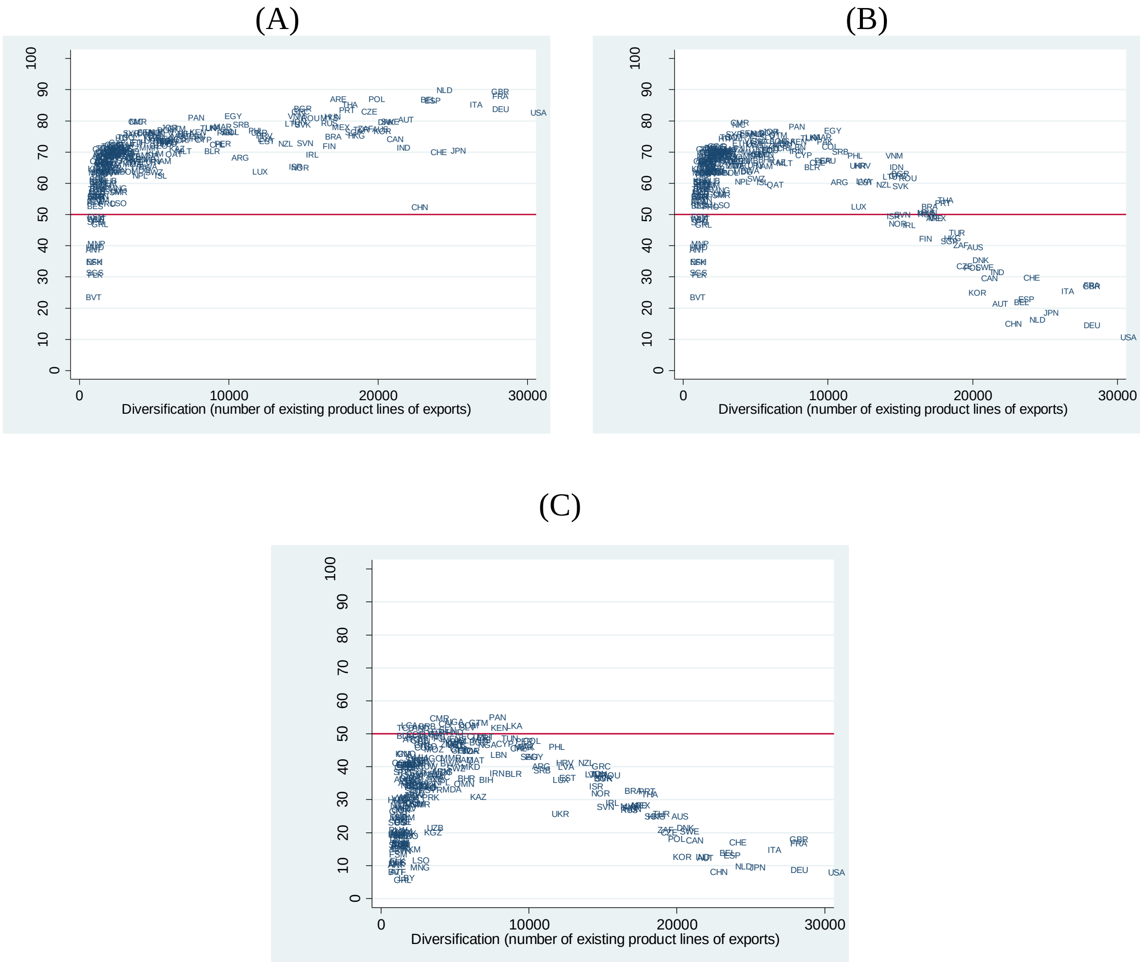
Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

When we add the requirement of diversification towards products that are also associated with carbon emissions per capita below the global average, that also reduces to below 50 per cent the share of these products on the total potential products for diversification of most diversified countries (Figure 11- B). It is less likely that firms and entrepreneurs in the less diversified and the more diversified countries to innovate towards those products with higher social benefits. At the same time, in most developing countries, over half of the potential new products have those desirable characteristics.

However, when the additional requirement of being associated with carbon emissions per GDP that are below global average, most countries have less than 50 per cent opportunities for diversification with that are more complex and greener (Figure 11- C). The countries with over half of potential new products with desirable outcomes are Andorra, Barbados, Cameroon, Chad, Côte d'Ivoire, Dominican Republic, El Salvador, Ethiopia, Guatemala, Honduras, Kenya, Panama, Saint Lucia, Senegal, Sri Lanka, and Uganda.

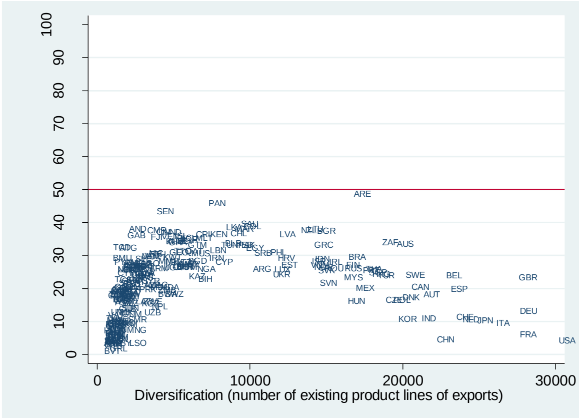
However, the analysis is incomplete if we do not consider the role of demand factors in the diversification process. Products that are in high demand are more likely to attract entrepreneurs and are also more likely to succeed. Figure 12 shows the number of existing products in the country's product mix in the horizontal axis and the share in percentage of the export opportunities of potential new products with the desirable outcome in the vertical axis. The figure shows that the effect of export opportunities is to lower the probability of entrepreneurs discovering those socially desirable products.

Figure 11. Percentage of new products with above country's average product complexity and below global average carbon footprint



Source: Author and data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

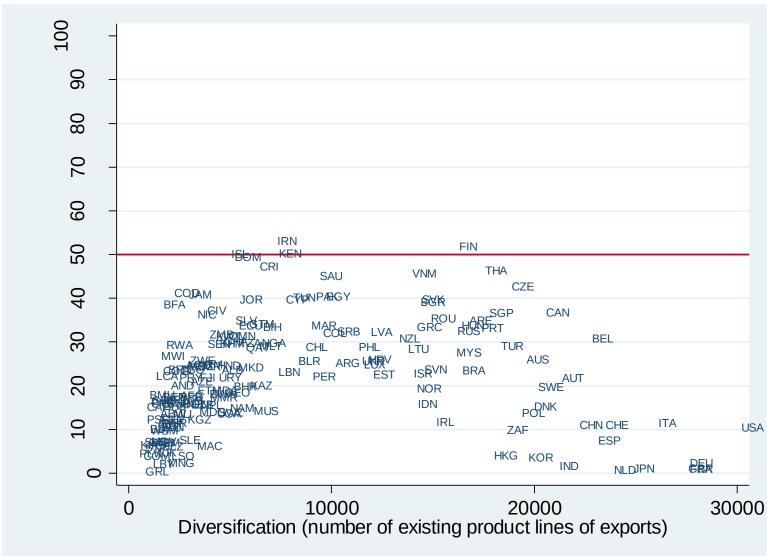
Figure 12. Effect of export opportunities on the incentives for diversification towards products of above country's average product complexity and below global average carbon



Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

Similarly, opportunities for import substitution also create the incentives either for increasing or for reducing the average complexity and carbon emissions of a country's product mix. Figure 13 illustrates this effect by showing the number of existing products in the countries' product mix in the horizontal axis and the share in percentage of the import substitution opportunities of potential new products with higher complexity and lower carbon footprint in the vertical axis. The figure shows that Finland and the Islamic Republic of Iran are more likely to benefit from a laissez-faire approach to import substitution.

Figure 13. Effect of import substitution opportunities on the incentives for diversification towards products of above country's average product complexity

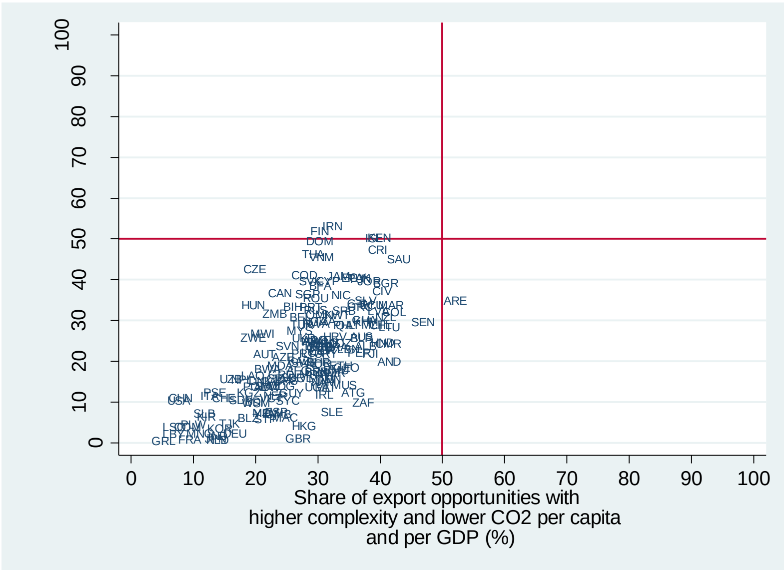


Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

The joint analysis of export and import substitution incentives is illustrated in Figure 14, which shows in the vertical axis the share in percentage of the import substitution opportunities of potential new products with above country's average product complexity and the share of export substitution in the horizontal axis. The graph is divided in four quadrants. In the first quadrant are the countries that could adopt a laissez-faire approach to import substitution but should adopt a strategic diversification approach towards new export opportunities to facilitate the private sector's discovery of new economic activities leading to the desirable social objective of increasing the economy's productive capacity. Finland and the Islamic Republic of Iran are located in this quadrant.

No country is located in the second quadrant, where would be placed countries with higher probability of the market to pick the socially desirable new economic activities. These countries could adopt a laissez-faire approach that focuses on facilitating the discovery process by providing an enabling environment for business that creates incentives for entrepreneurs to start new economic activities.

Figure 14. The role of the state



Source: Author based on data from the United Nations Commodity Trade Statistics Database (COMTRADE) and Freire (2017).

The United Arab Emirates is in the third quadrant. New exports, therefore, are likely to have product complexity above the country's average and carbon emissions below global average, and the country could adopt a laissez-faire approach towards export diversification and let the market guide the identification of new export opportunities. On the other hand, import substitution is likely to result in new products that have below the country's average product complexity and above global carbon emissions. Therefore, the State has a role to play in nudging discovery towards economic activities that result in higher long-term gains.

Practically, all countries are located in the fourth quadrant. They are in the difficult position of not being able to rely on the market incentives to drive the economy towards increasing productive capacities that also have a lower carbon footprint. If let to the market alone, the new economic activities, either exports or import substitution that emulate the production of richer countries, are more likely to have below the country's average product complexity. These countries have to adopt an approach based on strategic diversification to nudge the private sector and create incentives towards economic activities with higher complexity and lower carbon footprint. The implementation of such strategic diversification requires the selective promotion of new economic activities through the use of targeted technology and innovation, industrial, infrastructure, trade, investment and private sector development policies.

5. Facilitating greener diversification and structural transformation

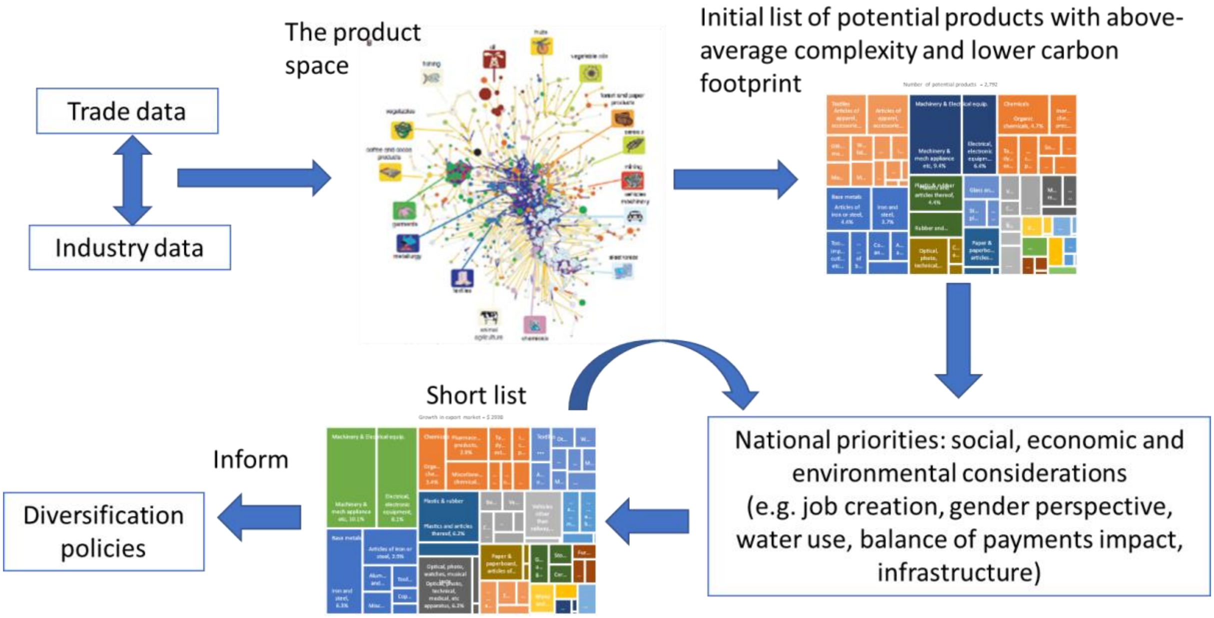
Developing countries need to build their capacities to identify potential new sectors for more complex and more sustainable diversification. The identification and selection processes for green technologies and new green sectors need to be combined with assessing existing technological and productive capacities, global and domestic demand, the potential for natural resources (e.g. wind conditions or agricultural waste for bioenergy), supply creation and dynamic learning curves. Given the increasing importance of Global Value Chains for value addition and trade, the process of identification should also consider in which GVCs and in which parts of the GVCs to target for diversification.[11]

Critical in this process is the adoption of participatory methods of assessment involving: 1) policymakers (especially those closely related to innovation in Ministries of Science, Technology and Innovation, Trade, Industry, and Education) who have broad decision-making power and the ability to design and implement public policies to increase national STI capacity and effectively support systems of innovation; 2) private sector actors who have an understanding of the challenges faced in building firm-level technology and innovation capacity, the local knowledge of the business environment and the effects of policies in place as well as clear ideas on actions needed for upgrading and innovating; 3) academic and research institutions who know of specific technologies and R&D capacity; and 4) civil society organizations who know the concerns and priorities of those in vulnerable situations, and can voice these concerns and increase awareness in public institutions. Any such participatory method should also ensure the balanced contribution of men and women to consider the gender perspective.

In this process, methodologies such as growth diagnostic, economic complexity and product space could be used to identify new sectors with higher potential of success and policy interventions required to facilitate diversification. Government, private sector and development partners should use their combined experience to look at trade data combined with industry data and have realistic information about what the country is producing and exporting (Figure 15). They should then use this information to build a product space for the country, identify products that are close in the product space and have an above-average complexity and lower carbon footprint, and obtain an initial list of potential new products for diversification.

Government, the private sector and development partners could then consider each product on the list against national priorities. These social, economic and environmental considerations could guide the preparation of a shorter list of possible products. For example, some of the priorities could be the potential for job creation, the potential for boosting women's employment, the limited use of water, a scarce resource, and the potential positive impact on the balance of payments and the requirements in terms of infrastructure. This is expected to be an interactive process until the short list of potential products for diversification is consolidated. This list can then inform the development of the diversification policy instruments. This exercise could also consider diversification opportunities for national and regional markets, focusing on resource-based industrialization, FDI-based light manufacturing, or any other strategy for industrialization. This whole process is dynamic, and one should expect that after a couple of years, it will be repeated to consider the new production structure of the country, the opportunities in international markets, and the changes in the product space.

Figure 15. Identification and selection of realistic opportunities for diversification



Source: Author.

The international community could support countries to implement such institutional mechanisms to identify potential new products for diversification. Some examples are UNCTAD's Catalogue of Diversification Opportunities 2022,[12] the ITC Export Potential Map[13] and the Atlas of Economic Complexity provided by Harvard Center for International Development.[14]

The promotion of new sectors in developing countries needs the use of infant industry policies to foster the nascent sector and give it time to build the required productivity levels to compete in a levelled playfield with incumbent firms from more technologically advanced countries. These policies usually include production and export subsidies and targeted import tariffs, which are needed to introduce new technologies and production processes and shield the new entrant firms from foreign competition just until domestic capacity is built. After which, support should be phased down to allow competition and market incentives to guide further increases in productivity.[15]

National and local governments could foster the domestic development of green technology sectors and greener economic sectors through vertical policy instruments and strategies such as clusters, smart specialization initiatives,[16] pilot and demonstration projects and areas, and technology roadmaps. In non-mature industries such as CSP and green hydrogen, demonstration projects are vital for developing new technologies and designs. In the CSP case in China, the industry development has been supported by promoting "megaprojects of science-research". Through these projects, the Government aimed to build knowledge and experience within domestic firms, developing industrial and commercial projects that could facilitate learning through experimentation with different technical designs on the ground.[17] Similarly, to support the development of a domestic green hydrogen industry, the Chilean National Development Agency (CORFO) is also setting up several pilot projects with the significant involvement of international investors.

Prioritizing new technologies and sectors will also require the associated financial support. For example, in Austria, the Ministry of Climate Protection and Environment will implement a EUR 300 million investment subsidy budget for green energy in 2022.[18] in Belgium, the Walloon Government plans to invest more than 160 million euros to support the development of green hydrogen sector as part of its initiatives to lay the foundations for the hydrogen and synthetic fuels economy.[19]

Participation in Global Value Chains can offer opportunities for economic diversification through the production and export of new products or the upgradation of production towards more valued-added segments of the value chain.

Policies in this area aim at facilitating firms to integrate into GVCs or upgrade within a value chain.[20] Policies for promoting integration into GVCs are usually horizontal (less targeted). Some examples are aid for trade and trade facilitation mechanisms, transportation infrastructure reforms lowering the cost of cross-border trade, lowering tariff and non-tariff barriers to trade and investment flows, in particular to intermediate goods needed for participation in the GVCs, and lowering barriers to trade in services in GVCs that facilitate supply chain management.

Policies for increasing the value-added and upgrading the participation within values chains can be more targeted. Some examples are financing the demand for new machinery and other expenditures required for upgrading, which is a key obstacle for small and medium-sized enterprises in developing countries, or the creation of training or demonstration centres and industrial institutes. Other less targeted policies are investing in basic and dedicated education, fostering university-industry linkages, and reforming intellectual property laws and patent processes.[21]

These two sets of policies should be more targeted to specific GVCs and tasks within GVCs to ensure that increasing GVC participation returns the double benefit of diversification towards GVCs intermediate products and services with a higher value-added a lower carbon footprint.

6. Conclusion

This paper examines whether an inclusive and low carbon growth path for developing and least developed countries exists. It argues that such path consists of the process of economic diversification towards products that are more complex in terms of overall technological set required for production and are associated with low carbon emissions. The paper uses empirical methods to identify the potential new products for diversification given the current production base of a country and to estimates their complexity and carbon footprint. The results show that: product complexity is positively correlated with carbon footprint. Given that higher complexity products are associated both with higher output and higher carbon emissions, these results suggest that there is no absolute decoupling of carbon emission from growth when countries follow an emulation strategy of diversifying towards the products produced by more diversified economies.

Nevertheless, an inclusive and low carbon growth would be possible under an absolute decoupling approach if countries at different stage of diversification follow different innovation strategies, with more diversified countries focusing on low carbon innovation and less diversified countries climbing the ladder by emulating those low carbon economic activities.

This finding is relevant for the formulation of inclusive and sustainable development policies. To avert the long-term threat of climate change, less diversified economies should have the policy space to emulate the production of more diversified economies, regardless of their carbon footprint, while these more diversified economies should take responsibility to spearhead the transformation towards a low carbon economy by fostering innovation towards the development of low carbon technologies and products.

---

[1] (Reinert, 2007).

[2] (Lin, 2012)

[3] (Akamatsu, 1962)

[4] (Hausmann and Hidalgo, 2011).

[5] (Arthur, 2011).

[6] (Lall, 1992; Freire, 2019).

[7] Freire (2017)

[8] Based on the methodology described in the Annex E, the indices of carbon emissions per capita and per GDP for each of the 43,272 products were considered in the analysis and compared with the product complexity index.

[9] (Mealy and Teytelboym, 2020).

[10] Hidalgo and Hausmann (2009) argue that the method of reflections can be generalized by using different values for the variables $K_{c,0}$ and $K_{p,0}$. They state, for example, that the measure of product sophistication PRODY proposed by Hausmann, Hwang and Rodrik (2005) is a special case of the use of the method of reflections in which $K_{c,0}$ is the GDP per capita of a country.

[11] (UNCTAD, 2018).

[12] https://unctad.org/webflyer/catalogue-diversification-opportunities-2022

[13] https://exportpotential.intracen.org/en/

[14] https://atlas.cid.harvard.edu/

[15] (Reinert, 2009).

[16] For in depth analysis of smart specialization strategies and their implementation, see (Foray, 2014, 2016).

[17] (Liliestam et al., 2019).

[18] https://renewablesnow.com/news/austria-passes-eur-300m-subsidy-budget-for-green-energy-780126/

[19] Contribution from the Government of Belgium.

[20] (UNCTAD, 2018).

[21] (UNCTAD, 2018).

References

Arthur WB (2011). *The Nature of Technology: What It Is and How It Evolves*. Free Press. New York.

Foray D (2014). *Smart Specialisation: Opportunities and Challenges for Regional Innovation Policy*. Routledge. London.

Foray D (2016). On the policy space of smart specialization strategies. *European Planning Studies*. 24(8):1428–1437, Taylor & Francis.

Freire C (2017). *Diversification and Structural Economic Dynamics*. UNU-Merit/MGSoG dissertation series, No. 191. Boekenplan. Maastricht.

Freire C (2019). Economic diversification: A model of structural economic dynamics and endogenous technological change. *Structural Change and Economic Dynamics*. 4913–28.

Hausmann R and Hidalgo CA (2011). The network structure of economic output. *Journal of Economic Growth*. 16(4):309–342.

Lall S (1992). Technological capabilities and industrialization. *World Development*. 20(2):165–186.

Reinert E (2008). *How Rich Countries Got Rich . . . and Why Poor Countries Stay Poor*. PublicAffairs. New York.

Reinert ErikS (2009). Emulation versus comparative advantage: Competing and complementary principles in the history of economic policy. *Industrial Policy and Development: The Political Economy of Capability Accumulation*. Oxford University Press. New York: 79–106.

UNCTAD (2018). Climate Policies, Economic Diversification and Trade. UNCTAD/DITC/TED/2018/4. UNCTAD. Geneva.

Zhen N and Freire C (2023). The interlinks between the economic complexity and carbon footprint: differentiated analysis for developed and developing countries. Background paper for the Technology and Innovation Report 2023.