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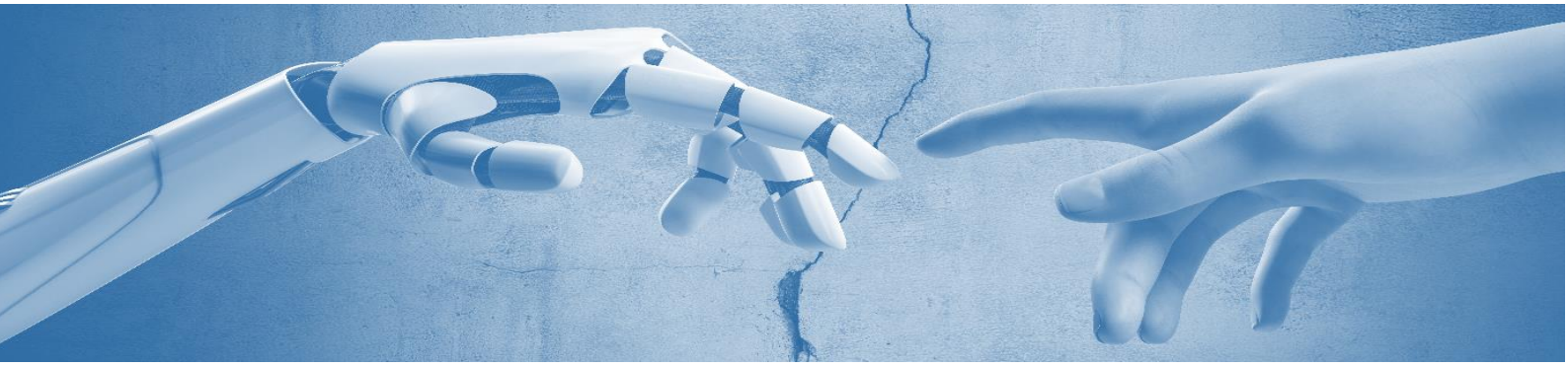

The prospects for low-carbon growth in emerging markets

Working Paper

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Abstract

The world economy is transitioning toward cleaner, environmentally more sustainable forms of growth. Countries need to adjust their economic strategies to this emergent reality. This paper explores what the transition to a low- and ultimately zero-carbon economy means for the competitiveness of emerging markets. We construct two indicators to assess low-carbon competitiveness at the country-sector level: the speed at which country-sectors convert to low-carbon products and processes (measured by low-carbon innovation) and their ability to gain and maintain market share (measured by existing comparative advantages). Taken together the two indicators paint an intuitive picture of the strengths, weaknesses, opportunities and threats faced by different sectors and countries in the low-carbon economy. We find that all countries have low-carbon growth opportunities and comparative advantages in some sectors. However, the low-carbon transition is likely to be disruptive. We find very few sectors where the existing market structure might prevail. East Asian economies like China and South Korea appear best positioned to take advantage of these changes, thanks to their deliberate efforts in promoting low-carbon innovation. Other emerging markets such as Brazil, Mexico and Turkey are less engaged in frontier green innovation. For them the low-carbon transition is more likely to be a threat.

Research Highlights

The low-carbon transition is likely to be disruptive. There are few sectors where the existing market structure might prevail.

The analysis of data on clean innovation and data on current comparative advantages can help to identify likely winners and losers in the low-carbon economy.

All emerging markets have low-carbon growth opportunities and comparative advantages in some sectors.

East Asian economies like China and South Korea appear best positioned to take advantage of these changes, thanks to their deliberate efforts in promoting low-carbon innovation.

Emerging markets in other regions are likely to face threats from the low-carbon transition, unless they accelerate the conversion to low-carbon products and processes.

1. Introduction

The transition of the global economy toward low-carbon products and processes looks all but inevitable. Economically, the change is driven by marked advancements in important low-carbon technologies, such as renewable energy and electric vehicles, which are transforming energy and transport systems. Politically, the low-carbon transition is supported by a strong international commitment to the objectives of the Paris Agreement, which calls for the phase out of greenhouse gas emissions in the second half of this century – even if the pledges countries have made under the agreement remain inadequate (UNEP 2018).

There is now a recognition among policy makers that deep decarbonisation is not just about environmental stewardship, but also economic policy. The low-carbon transition has been described as a deep structural change akin to an industrial revolution (Bowen et al 2016). In the course of such economic disruption current patterns of industrial production and comparative advantage will undergo fundamental change. This creates both winners and losers. High-carbon activities will inevitably contract, but for the well-positioned, action on climate change will generate new opportunities.

Far-sighted policy makers have taken note. South Korea's 2009 *Framework Act on Low Carbon Green Growth* for example, does not just seek to reduce greenhouse gas emissions, but to prepare Korean industry for the coming low-carbon economy. China's five-year plans similarly combine emission targets with growth targets for strategic low-carbon sectors. The full title of the French energy transition law of 2015 is *Law on Energy Transition for Green Growth*. Cambodia, Colombia, Ethiopia, Fiji, Norway, Romania, Rwanda, the United Arab Emirates, the UK and Vietnam are among other countries that have passed explicit policies or strategies on green growth.[1]

The concept of green growth – of which low-carbon growth is one important aspect – is relatively recent (Bowen and Fankhauser 2011; Jacobs 2013). Unlike sustainable development, which calls for a balance between the environmental, social and economic objectives of development, the premise of green growth is that environmental protection can be the driver of future economic growth (e.g., NCE 2018; Rydge et al. 2018). The theoretical argument rests on the possibility of resource-saving rather than resource-augmenting growth, leading ultimately to a weightless economy dominated by services and electronic products (Bowen and Hepburn 2014). Proponents of green growth argue with AC Pigou that the correction of environmental externalities will, by definition, enhance social welfare and make economies more efficient. They emphasise the dynamic benefits of clean innovation, which could trigger a Schumpeterian cycle of "creative destruction", clean investment and economic renewal. In the short term, clean investment could also give a Keynesian boost to economies in which production factors are not fully utilised (Barbier 2010a, b). At the level of firms, these country-level arguments have a parallel in the Porter hypothesis (Porter, 1991, and Porter and van der Linde 1995), which similarly argues that environmental regulation can lead to increased innovation and competitiveness.

[1] Details on all these laws can be found in the Climate Change Laws of the World database, http://www.lse.ac.uk/GranthamInstitute/climate-change-laws-of-the-world/.

The possibility of low-carbon growth is not without its detractors. It contradicts empirical evidence that emissions abatement is costly (Blanford et al 2014; Edenhofer et al. 2010; Kriegler et al 2014), and it challenges a long-standing belief among environmentalists that the natural environment will ultimately impose limits to growth, which dates back at least to the 1970s (Boulding 1966; Daly 1974,1991; Georgescu Roegen 1971). More recently, the planetary boundaries of current economic behaviour have been pointed out powerfully by Rockström (2009a, b) and Steffen et al (2015). The environmental case against economic growth has been made by among others Jackson (2009), Kallis (2011), Martinez-Alier et al. (2010) and Schneider et al (2010).

Following the framing of Altenburg and Pegels (2019), this paper takes a different angle on the green growth debate and its application to climate change. We do not take a view on whether the global economy will grow or contract as a result of the low-carbon transition (the core issue of the green growth debate). Instead, we ask about the relative competitive position of different countries and sectors in the emerging green economy, whatever its size turns out to be. We explore who is leading and who is lagging behind in the "green race". A particular focus is on emerging markets, who, more than any other group of countries, need to decide whether they should aim to lead the green race or "grow first and clean up later".

The paper draws on and updates an earlier study by Fankhauser et al (2013). Using current economic output as the starting point, we identify two potential lead indicators of low-carbon competitiveness at the sector level: the speed at which sectors may convert to low-carbon products and processes (measured by low-carbon innovation) and their ability to gain and maintain green market share (measured by existing comparative advantages). Taken together, the two indicators paint a picture of the strengths, weaknesses, opportunities and threats of different countries and sectors in the low-carbon economy (see also Mealy and Teytelboym 2016 and Srivastav et al. 2018 for related analysis).

The paper departs on the earlier analysis (Fankhauser et al 2023) in three ways. First, it provides more recent empirical estimates, updating the original 2007 numbers to 2015. Second, it broadens the scope to include additional countries and regions, offering a much more comprehensive picture (16 countries and regions, compared to the original 8), including most emerging markets. Third, we offer an intuitive new interpretation of our results in terms of strengths, weaknesses opportunities and threats (SWOT) at the level of countries and sectors. As before, the focus is on manufacturing, which accounted for almost half of green firm revenues globally in 2016 (US$ 750bn out of US$1.6trn, Kruse et al. 2018).

In what follows, section 2 recapitulates the methodology used to assess low-carbon competitiveness and introduces the data. Section 3 contains the results. We first look at the low-carbon prospects of different countries and regions, distinguishing 10 emerging market regions and 6 industrial economy comparators. We then explore the global market dynamics in 14 important industries, identifying sectors where there might be disruptions and sectors where incumbents might prevail. Section 4 concludes with some observations about policy.

2. Methodology

2.1 The future size of the green economy

There is an established tradition of measuring the contribution of the environmental goods and services sector to gross domestic product (GDP). In the definition of the OECD, environmental goods and services include all activities that measure, prevent, limit, minimise or correct environmental damage (OECD 1998). According to this delineation, the green economy is worth several hundred billion, and perhaps several trillion US dollars a year globally (EBI 2012; ECORYS 2012; BIS 2011). It is one of the fastest growing sectors of the global economy (Ricardo AEA 2017).

However, the low-carbon transition is about something more radical. Low-carbon activity is not just another economic sector that can be put alongside conventional activity. The economic changes required to combat climate change are not marginal, as traditional models suggest, but transformative and system-wide (Perez 2010; Fankhauser and Stern 2019). The creation of a low-carbon economy will therefore affect not just a few specialised sectors but the product mix and production processes of virtually the whole economy. Some sectors, such as coal mining or petrol refining, will contract, while others, such as recycling or battery production, may grow. But for most sectors, the low-carbon economy is about adjusting existing products and production processes. The construction sector will specialise in green buildings, the financial sector will provide capital for low-carbon projects and the automotive sector will produce zero-carbon vehicles, but generically these sectors will continue to exist and thrive in the low-carbon economy.

Our analytical interest therefore has to be in low-carbon products and processes in all sectors of the economy. We explore how the share of low-carbon output in different sectors could evolve over time. Following Fankhauser et al (2013) we define our variable of int
erest, Γ_{is} , as the share of low-carbon output in sector s and country i, G_{is}, relative to total global output (green and non-green) in that sector, $Y_s = \Sigma_i Y_{is}$. We can further expand Γ_{is} as follows

$$\Gamma_{is} \equiv \frac{G_{is}}{Y_s} = \frac{G_{is}}{Y_{is}} \cdot \frac{Y_{is}}{Y_s} \qquad (1)$$

The permutation, while self-evident, brings out the two key factors which determine low-carbon output in a country-sector at any one point in time: the share of low-carbon output in total output for that country-sector (G_{is} / Y_{is}), and its global market share (Y_{is} / Y_s).

To comment on *future* low-carbon output, we need lead indicators of future trends in these two factors. That is, we require:

- a measure of low-carbon conversion that can anticipate changes in (G_{is} / Y_{is}): this indicator needs to reflect the speed with which the low-carbon segment of the market will grow within a country-sector (e.g. the rise in electric car sales at the expense of conventional cars in the automotive sector);

- a measure of comparative advantage that can anticipate changes in (Y_{is} / Y_s): this indicator needs to reflect the ability of a country-sector to gain market share by

outpacing the overall rate of growth (e.g., national versus global growth in the automotive sector).

We explore each of these factors in turn.

2.2 Anticipating low-carbon conversion

Our preferred indicator for low-carbon conversion is green innovation. Green innovation is a forward-looking indicator which reflects the degree to which research effort is focused on pivoting the economy towards low-carbon alternatives. An alternate way to proxy low-carbon conversion would be through the adoption rate of green technologies. This would acknowledge that an economy can convert to green alternatives by adopting off-the-shelf technologies rather than innovating. However, data for adoption rates is diffused and much harder to get in a comparable and consistent manner across sectors and countries.

Moreover, the focus on innovation is consistent with the view that Schumpeterian "creative destruction" is the engine of transformative growth (Archibugi et al. 1999, Oltra and Saint Jean 2009, Perez, 2002). There is indeed a well-documented link between innovation, productivity and economic growth (Aghion and Howitt, 1998, 2009; Griliches 1979; Temple 1999), and between innovation, industrial dynamics and industry evolution (Dosi et al. 1988; Malebra 2007, 2002).

Low-carbon innovation in turn is measured by the number of low-carbon patents in each country-sector. The advantages and limitations of patenting as a measure of innovation have been discussed at length (e.g., Griliches, 1990; OECD, 2009). While patents are not a complete manifestation of innovation, they are a core output measure that features prominently even in complex assessments of innovation performance (Dutta 2012, Hollanders and Es-Sadki 2013). Patent data have been used successfully in numerous studies of green innovation (e.g., Dechezleprêtre et al. 2011; Johnstone et al. 2010; Lanjouw and Mody 1996; Popp 2002).

Specifically, we use data from the European Patent Office (EPO) on patenting activity from 2005 to 2015. The EPO classification system includes a code for climate change mitigation patents (the Y02 class of patents), which allows for an easy delineation between green and non-green innovation. The Y02 classification includes radically new low-carbon technologies as well as more incremental inventions to improve resource efficiency. The ten-year period was chosen to ensure there is a sufficiently large stock of patents at the country-sector level and to smooth out idiosyncratic year-on-year variations in patenting activity.

We use these data to construct an index of green innovation (GII) of the following form:

$$GII_{is} = \frac{p_{is}^{G}}{p_{is}} / \sum_{i} \frac{p_{is}^{G}}{p_{is}} \qquad (2)$$

Where p^{G}_{is} is the number of low-carbon patents and p_{is} the total number of patents in sector s and country i. The index thus measures the share of low-carbon patenting in a country-sector, compared to the share of low-carbon patenting in that sector over the entire reference area (that is, all

countries in the sample).[2] The normalisation against broader patenting activity is important to correct for idiosyncrasies in patenting behaviour in particular sectors or countries.

The GII serves as our measure for green conversion, that is, the speed at which country-sectors are expected to move from conventional to low-carbon products and processes. The higher the GII for a sector and country, the higher the share of green innovation in that sector, compared with other countries, and the more rapid (we conjecture) the conversion from conventional to green production.

2.3 Anticipating low-carbon competitiveness

Our chosen indicator of future low-carbon competitiveness is current comparative advantage. The competitiveness literature suggests that future green competitiveness is likely to be derived from existing comparative advantages, skills and production patterns (Hidalgo et al. 2007; Hausmann and Hidalgo, 2010). The premise is that comparative advantage evolves slowly, which means that sectors with a competitive edge today are more likely (but not certain) to be successful in the future. Mealy and Teytelboym (2016) link future comparative advantage to technological proximity and the ability to diversify into related technologies. For example, Germany developed a comparative advantage in wind turbines on the back of its existing expertise in high-precision machining (Huberty et al., 2011). Similarly, Japan leverages its prowess in automotives to lead in the development of electric, hybrid and hydrogen vehicles.

This does not preclude market entry and exit at firm level. Indeed, disruptive market entry, where new firms and new ideas drive out the old, is central to the type of transformative growth that the green economy discourse espouses. However, in their search for the right skills, market entrants are likely to benefit from existing competencies. Documenting these processes would require firm-level data, rather than the sector-level information provided here.

A widely used measure of comparative advantage is the Balassa index (Balassa 1965). The Balassa index measures the revealed comparative advantage (RCA) of a country-sector on the world market by calculating its relative export share. We use trade data for the period from 2005 to 2015 from COMTRADE to construct a Balassa index, which serves as our measure of current comparative advantage. There are several variants of the Balassa index, each with its own advantages and disadvantages (Iapadre 2001; Laursen 1998). We use the standard formulation, which has the following structure:

$$RCA_{is} = \frac{e_{is}}{\sum_s e_{is}} / \frac{\sum_i e_{is}}{\sum_s \sum_i e_{is}} \qquad (4)$$

Where e_{is} is the level of exports from sector s in country i. The numerator measures the share of exports in a country-sector, relative to total exports from that country. This is put in proportion to the same ratio (sector exports over total exports) for all countries in the sample[3]. The focus in the RCA formula is thus on sector exports *relative to* a country's total exports, i.e. on a country's comparative (rather than absolute) advantage.

[2] There are patent data for 81 countries and they constitute the reference area for the GII.

[3] We have a larger reference area of 175 countries for the RCA. The difference in reference areas between GII and RCA is not problematic methodologically.

RCA serves as our measure of future comparative advantage. The higher the relative share of exports in a country-sector, the higher is its RCA and the more competitive is the sector. A high RCA is an indication of the ability of a country-sector to gain and maintain market share in the future.

2.4 A SWOT analysis of low-carbon potential

The interplay between low-carbon innovation (GII) and revealed comparative advantage (RCA) allows us to identify, sector by sector, the potential strengths, weaknesses, opportunities and threats a country may encounter.

The structure of the ensuing SWOT analysis is introduced graphically in figure 1. The figure measures on the y axis the relative performance of different sectors in a country on low-carbon innovation (as measured by GII). The x axis depicts the revealed comparative advantage of those sectors (as measured by RCA). For both indicators, a score above 1 signifies performance above the sample average and a score below 1 means performance below the sample average. The size of the dots measures a sector's current contribution (green and non-green) to national GDP.

<<<Figure 1 here>>>

Figure 1 can then be interpreted as follows:

- Sectors in the top-right quadrant signify *strengths*: these sectors are areas of current comparative advantage (high score on the x axis) and there is substantial low-carbon innovation (high score on the y-axis), which should ease the conversion to low-carbon products and processes. The sectors are thus well positioned to remain areas of competitive strength in the low-carbon economy.

- Sectors in the top-left quadrant signify *opportunities*: these sectors are currently not areas of comparative advantage. However, there is significant low-carbon innovation, which could facilitate the conversion to low-carbon products and processes. The sectors could therefore become areas of future strength, displacing less innovative incumbents.

- Sectors in the bottom-right quadrant signify *threats*: these sectors are areas of current comparative advantage, but there is insufficient low-carbon innovation. The conversion to clean products and processes may stall and market share may be lost as the low-carbon economy grows.

- Sectors in the bottom-left quadrant signify *weakness*: these sectors are neither areas of current comparative advantage, and there is insufficient low-carbon innovation to build up a new area of comparative advantage.

2.5 Empirical approach

We apply the above methodology to the manufacturing sector of 10 emerging markets, comprising of seven individual countries and three regional groupings. The latter consist of countries with lower

patenting activity where an individual calculation of GII would not be meaningful. The emerging market regions are compared to six major industrialised countries (France, Germany, Japan, UK, USA and other industrialised countries as a composite). The country groupings are shown in Table 1.[4]

<<<Table 1 here>>>

For each country / region we considered the 50 or so sectors that comprise the manufacturing section in the ISIC Rev 3.1 industry classification at the three-digit level.[5]
Fankhauser et al (2013) provide analysis at the four-digit level. We chose a higher level of aggregation (three-digit level) to increase the robustness of results and to permit the inclusion of additional countries with lower patent numbers. Country-sectors with fewer than 20 patents in total (green and non-green) were excluded from the analysis.

3. Results

3.1 The low-carbon prospects of different countries

In our main results we adopt a country perspective. Figure 2 provides overview SWOT charts for all the countries and sectors covered. The charts create a visual impression of each country's expected position in the low-carbon economy by plotting the location of each country-sector on the GII-RCA plane.

A complex interplay of factors is responsible for each country and region's position in the low-carbon economy. Having suitable market conditions to encourage entrepreneurship, innovation, and trade are important enabling conditions for economic success in general. In addition, it is important to create a favourable environment specifically for low-carbon technologies. Green industrial policy of this sort might involve targeted subsidies to low-carbon sectors, tax exemptions, R&D grants or quantity-based targets. These measures are justified on the grounds of addressing low-carbon innovation barriers and breaking out of the world's high-carbon 'lock-in' (Acemoglu et al. 2012; see also Aghion et al 2016 on the case of the automotive sector).

Figure 2 suggests that the emerging markets that are best-placed for the low carbon economy are China, South Korea and Emerging Asia. These countries are engaging in the green transformation of products and processes across most industrial sectors and enjoy a strong comparative advantage in key areas. GII measures the relative share of low-carbon to total innovation, but together with the leading industrialised innovators (Germany, Japan and the USA) they are also among the world's top spenders on overall (green and non-green) innovation, dedicating at least 2.7% of GDP to research and development.[6]

<<<Figure 2 here>>>

[4] Fankhauser et al (2013) covered China, France, Germany, Italy, Japan, South Korea, UK and the US.
[5] See https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev3_1e.pdf. The sector codes are reproduced in Annex 1.
[6] See http://uis.unesco.org/apps/visualisations/research-and-development-spending/.

South Korea is an instructive example of how a robust innovation ecosystem and explicit support for low-carbon industries can combine to a favourable position in the low-carbon economy. The country has almost all of its sectors located in the strengths quadrant of figure 2. South Korea is the world's largest R&D spender (4.3% of GDP) and began investing in knowledge industries in the 1960s. Through government-led policies, it diversified into high-skilled industries such as car manufacturing, electronics and shipbuilding, which helped develop a formidable base of human capital. This period saw the emergence of large South Korean conglomerates, which propelled innovation and were at par with top US firms.

In 2009, South Korea became one of the first countries in the world to release a national law on low-carbon green growth. In this strategy, South Korea explicitly highlighted the need to develop eco-friendly growth engines. Targeted policies to improve the position of green industries in South Korea include carbon pricing via an emissions trading scheme (ETS), government-funded R&D in green technologies, and a legal obligation on companies to purchase environmentally-friendly products. These measures have improved the market prospects for low-carbon technologies, making South Korea a potential leader in the green race.

China has pursued a similar strategy with the same success in its five-year plans. Starting with the 12th Five-Year Plan (2011-15) China has adopted increasingly stringent greenhouse gas targets, combined with support for key strategic industries (Stern 2011; Green and Stern 2017). The 12th Five Year Plan put in place a host of preferential policies, such as tax exemptions and reductions, special financing arrangements and favourable loan terms for clean energy and energy efficiency projects. The 13th Five Year Plan (2016-2020) continued the momentum for green growth. It sets peak targets for carbon emissions, energy and water consumption, and has goals for increasing the efficiency of industries, using more renewable energy and developing green infrastructure. China is also experimenting with emissions trading schemes. Much like in South Korea, these measures carve out a space for low-carbon industries to grow and compete with conventional counterparts (World Bank 2017).

Emerging Asia, driven by Taiwan, is also relatively well placed. Elsewhere the picture is less favourable. Brazil and Russia have some key strengths in the low-carbon economy, but also many areas for improvement. Mexico and Turkey clearly lag behind, with hardly any strengths in the low-carbon economy, according to figure 2. Most of these countries, and emerging markets in general, do not have much of a patenting culture. In countries like India (and South Asia in general), innovation is often incremental and open-source, and there is poor patent protection. As such, the GII may not reflect the true extent of low-carbon conversion in these countries. However, the dearth of green growth policies in these countries suggests major challenges remain.

Mexico's case highlights the differences and complementarities between green growth policies, which are aimed at supporting low-carbon business, and climate change policies, which aim to reduce emissions. Mexico is considered a progressive country on climate change, with a thoughtful legislative framework and a willing to assume global leadership, for example by hosting the 2010 Conference of the Parties (COP 16 in Cancun). Its 2012 *General Law on Climate Change* is a model framework for climate change governance, providing clear policy guidance and a statutory long-term objective, and defining the institutional arrangements needed to achieve it (Averchenkova and Guzman Luna 2018). However, in the absence of complementary industrial and innovation policies

(OECD 2008), this has not so far resulted in a favourable competitive position in the low-carbon economy.

3.2 Corroboration and sector specifics

Figure 2 offers a deliberately broad, visual impression of the low-carbon competitiveness of countries, without going into too much sector detail. To complete this high-level analysis we reproduce the SWOT charts of Figure 2 for selected sectors. That is, rather than drawing the location of different sectors on the GII-RCA plane for a country, we locate the position of different countries on the GII-RCA plane of a global sector. Figure 3 shows the results for 14 important sectors.

<<<Figure 3 here>>>

3.2.1. Large scope for disruption

Sectors can be split roughly into those where countries are concentrated in the bottom-left and top-right quadrants (that is, the GII and RCA scores are positively correlated) and those where countries are concentrated in the top-left and bottom-right quadrants (the GII-RCA correlation is negative). The transition dynamics in the two cases could be fundamentally different.

In most sectors we find a broadly negative GII-RCA correlation. These are sectors where the low-carbon transition is likely to be disruptive. The high prevalence of threats to some countries (bottom-right quadrant), combined with opportunities for others (top-left quadrant), suggests that incumbent operators could lose market share to low-carbon newcomers. Sectors in this category include refined petroleum products (sector code 232), ICT equipment (322), electric motors (311), non-metallic mineral products such as cement, concrete and ceramics (269), chemical products (242) and textiles (171 and 181).

In the chemical sector, French firms might lose market share to newcomers from Japan or China who are innovating in catalysts, electrolysis and CO2 absorption methods. On petroleum products, Russia could lose market share to China, Japan and Europe whose notable innovations include biofuel improvements and in some cases carbon capture and storage. In electric motors, Brazil, South Korea and the UK may overtake China by producing more efficient motors, generators and transformers, all of which are key products in a low-carbon economy.

In the clothing industry green innovation relates mostly to the use of more energy-efficient methods rather than more salient or radical low-carbon innovation. Giants such as China are doing little to convert their processes to energy-efficient and low-carbon alternatives while Japan and South Korea are innovating slightly above the world average. However, the takeover is likely to be slow and gradual, if it happens at all, given that China commands a very high share of the global textiles market. This speaks to the need for detailed sector corroboration of our high-level analysis.
There are much fewer sectors with a positive GII-RCA correlation. Here existing market structures are more likely to prevail. Incumbent countries have considerable strengths (top-right quadrant) and they face few apparent challenges from weak newcomers (bottom-left quadrant). However, as noted above, a stable constellation at the level of countries does not preclude market entry and exit at the level of firms.

Sectors in this category include general purpose and special purpose machinery (sector codes 291 and 292) and notably motor vehicles (341 and 343). Countries that have an entrenched comparative advantage in conventional automotives find it easier to diversify into low-carbon vehicles, leveraging their existing manufacturing capabilities and skills. This is also why the market for motor vehicles parts shows little signs of disruption.

3.2.2. Resource efficiency and cost savings as drivers of incremental innovation

The trade and innovation patterns that lead to those dynamics are diverse and dispersed across many activities. There is not one cohesive narrative of green transformation.

In sectors like chemicals (242) and iron and steel (271), green innovation is often associated with process optimisation, which are difficult to discern from the outside. The improvements are often incremental and not always motivated by low-carbon objectives. Process-related inventions can simply stem from a desire to reduce costs via resource efficiency. Even so, incremental innovation can have a palpable impact, given that activities like steel-making are one of the largest sources of industrial greenhouse gas emissions.

Several emerging markets, including Russia, Brazil, India and Turkey have strengths in iron and steel, alongside more established economies such as South Korea and Japan. Green innovation in this sector relates for example to the re-use of slag (a by-product of steelmaking), switching to electric arc furnaces which re-use scrap steel, CO2 capture, and recycling of CO2 rich gases. India's position of strength in this sector may come from its tradition of 'frugal innovation', which involves recycling and stripping products and processes down to their most necessary components. Such cost savings may help explain why many emerging markets have sought to innovate in the area; the emission reductions potential is a convenient by-product.

Similarly, Brazil's strong position in iron and steel can be traced back to historical policies from the 1940s that were predominantly aimed improving the current account deficit by reducing steel imports. The drive for self-sufficiency encouraged innovation in methods to recycle scrap steel and there was a push for Brazil to export. While the motivation was not explicitly environmental, it had ancillary green economy benefits.

3.2.3 Capitalising on existing skills for transformative innovation

Elsewhere, innovation may be driven more explicitly by climate objectives, and the low-carbon transition is creating radically distinct new markets. For example, in refined petroleum products (232), the green transformation has created a new market for biofuels; in the automotive sector (341 and 343), it has created a market for electric and hybrid vehicles. These are separate, well-defined green industries with a distinct final product that disrupts existing markets.

With the notable exception of China and South Korea, emerging markets often lack the institutional strength to lead such transformative change. Radical green transformations tend to be led by advanced economies that have a long history of innovation in these sectors. For example, the development of hybrid and electric vehicles has been led by Japan, the USA, Germany and other

European countries that have an entrenched comparative advantage in the auto industry and could leverage their existing skills base to develop an 'adjacent' green technology.

Sometimes emerging markets benefit from their proximity to these innovation hubs through scientific collaboration, trade and technology diffusion. The biofuel market in Brazil and the United States is a case in point. The USA plays a leading role in the transformation of refined petroleum products (232), helped by policies to encourage the development of biofuels, which date back to the late 1990s. The US government ramped up mandatory quantity targets for biofuels thereby creating the space for growth and innovation in the sector. Brazil similarly made space for the biofuels industry to develop by mandating quantity targets on the ethanol content in gasoline. It explicitly put forth a National Biofuels Policy to stimulate private investment and innovation.

4. Conclusions

The global economy is undergoing a transition toward cleaner, less carbon-intensive products and production processes. Like all structural change, the low-carbon transition will create both winners and losers. This paper explores, at the level of countries and manufacturing sectors, who might struggle and who might thrive in the low-carbon economy.

Our analysis suggests that all emerging markets have existing strengths and new opportunities in the low carbon economy, but many of them also face threats to some currently well-performing sectors. We find that disruption is likely in most global sectors, with clean newcomers gaining market share from higher-carbon incumbents.

It is worth emphasising that we can only offer broad indications of potential trends. There are no firm forecasts. The ultimate outcomes will depend on the far-sightedness and determination of business leaders, whose actions in turn will be influenced by the business environment in which they operate and by policy interventions that either help or hinder the low-carbon transition. Business excellence and policy performance are hard to predict. Some companies will fail despite a favourable starting point, while others might turn weakness into opportunity and eventually strengths.

Public policy therefore matters. The literature still disagrees on the value of industrial policy. Some authors argue that industrial policy has played only a minor part in recent industrial successes (Pack and Saggi, 2006), while others point to the need to overcome information and other externalities (e.g., Hausmann and Rodrik, 2003). There is much stronger evidence in support of clean innovation policy and its societal benefits (e.g., Dechezleprêtre et al 2014) and on the need for strong environmental policies. Environmental regulation can boost clean innovation, leading to improved resource efficiency and ultimately higher growth (Porter 1991; Porter and van der Linde 1995). Economies of scale and the expertise developed in the domestic market may then boost export opportunities through a home market effect (Krugman 1980; Hanson and Xiang 2004).

Enabling the growth of low-carbon sectors is not the same as being on track to meet the objectives of the Paris Agreement. There are clear complementarities, but countries may be successful in one while failing in the other. Examples such as the USA and China demonstrate how a country can have policies to boost low-carbon industries whilst emissions flatline or even rise. On another hand, a country like the UK have seen emissions fall without yet having taken full advantage of low-

carbon business opportunities. While this paper emphasises low-carbon competitiveness, one must not ignore the imperative of bringing down emissions.

Finally, it is worth remembering how changes in business competitiveness links to national prosperity. What ultimately matters for prosperity are real incomes and productivity. As the relative demand for low-carbon products rises globally, the countries with a comparative advantage in them will benefit from improved terms of trade and thus higher real incomes. But other countries benefit, too, if their demand in clean products can be met more cheaply and efficiently by suppliers with a comparative advantage in producing them. This is the basic tenet of green growth. Producers and consumers alike will benefit from an efficient low-carbon economy.

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Annex: ISIC Rev 3.1 Sector Codes (Manufacturing)

Division 15 Manufacture of food products and beverages
151 Production, processing and preservation of meat, fish, fruit, vegetables, oils and fats
152 Manufacture of dairy products
153 Manufacture of grain mill products, starches and starch products, and prepared animal feeds
154 Manufacture of other food products
155 Manufacture of beverages

Division 16 Manufacture of tobacco products
160 Manufacture of tobacco products

Division 17 Manufacture of textiles
171 Spinning, weaving and finishing of textiles
172 Manufacture of other textiles
173 Manufacture of knitted and crocheted fabrics and articles

Division 18 Manufacture of wearing apparel; dressing and dyeing of fur
181 Manufacture of wearing apparel, except fur apparel
182 Dressing and dyeing of fur; manufacture of articles of fur

Division 19 Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
191 Tanning and dressing of leather; manufacture of luggage, handbags, saddlery and harness
192 1920 Manufacture of footwear

Division 20 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
201 Sawmilling and planing of wood
202 Manufacture of products of wood, cork, straw and plaiting materials

Division 21 Manufacture of paper and paper products
210 Manufacture of paper and paper products

Division 22 Publishing, printing and reproduction of recorded media
221 Publishing
222 Printing and service activities related to printing
223 Reproduction of recorded media

Division 23 Manufacture of coke, refined petroleum products and nuclear fuel
231 Manufacture of coke oven products
232 Manufacture of refined petroleum products
233 Processing of nuclear fuel

Division 24 Manufacture of chemicals and chemical products
241 Manufacture of basic chemicals
242 Manufacture of other chemical products
243 Manufacture of man-made fibres

Division 25 Manufacture of rubber and plastics products
251 Manufacture of rubber products

252 Manufacture of plastics products

Division 26 Manufacture of other non-metallic mineral products
261 Manufacture of glass and glass products
269 Manufacture of non-metallic mineral products n.e.c.

Division 27 Manufacture of basic metals
271 Manufacture of basic iron and steel
272 Manufacture of basic precious and non-ferrous metals
273 Casting of metals

Division 28 Manufacture of fabricated metal products, except machinery and equipment
281 Manufacture of structural metal products, tanks, reservoirs and steam generators
289 Manufacture of other fabricated metal products; metalworking service activities

Division 29 Manufacture of machinery and equipment n.e.c.
291 Manufacture of general-purpose machinery
292 Manufacture of special-purpose machinery
293 Manufacture of domestic appliances n.e.c.

Division 30 Manufacture of office, accounting and computing machinery
300 Manufacture of office, accounting and computing machinery

Division 31 Manufacture of electrical machinery and apparatus n.e.c.
311 Manufacture of electric motors, generators and transformers
312 Manufacture of electricity distribution and control apparatus
313 Manufacture of insulated wire and cable
314 Manufacture of accumulators, primary cells and primary batteries
315 Manufacture of electric lamps and lighting equipment
319 Manufacture of other electrical equipment n.e.c.

Division 32 Manufacture of radio, television and communication equipment and apparatus
321 Manufacture of electronic valves and tubes and other electronic components
322 Manufacture of television and radio transmitters; apparatus for line telephony and line telegraphy
323 Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods

Division 33 Manufacture of medical, precision and optical instruments, watches and clocks
331 Manufacture of medical appliances and instruments and appliances for measuring, checking, testing, navigating and other purposes, except optical instruments
332 Manufacture of optical instruments and photographic equipment
333 Manufacture of watches and clocks

Division 34 Manufacture of motor vehicles, trailers and semi-trailers
341 Manufacture of motor vehicles
342 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
343 Manufacture of parts and accessories for motor vehicles and their engines

Division 35 Manufacture of other transport equipment
351 Building and repairing of ships and boats
352 Manufacture of railway and tramway locomotives and rolling stock
353 Manufacture of aircraft and spacecraft
359 Manufacture of transport equipment n.e.c.

Division 36 Manufacture of furniture; manufacturing n.e.c.
361 Manufacture of furniture
369 Manufacturing n.e.c.

Division 37 Recycling
371 Recycling of metal waste and scrap
372 Recycling of non-metal waste and scrap

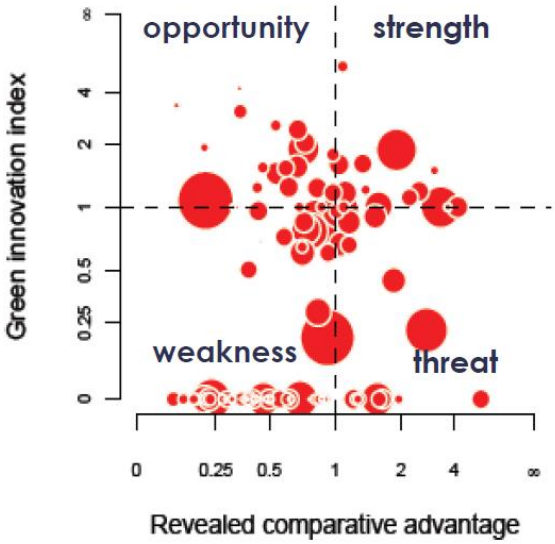
Source: https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev3_1e.pdf

Figures and Tables

Table 1: Country groupings

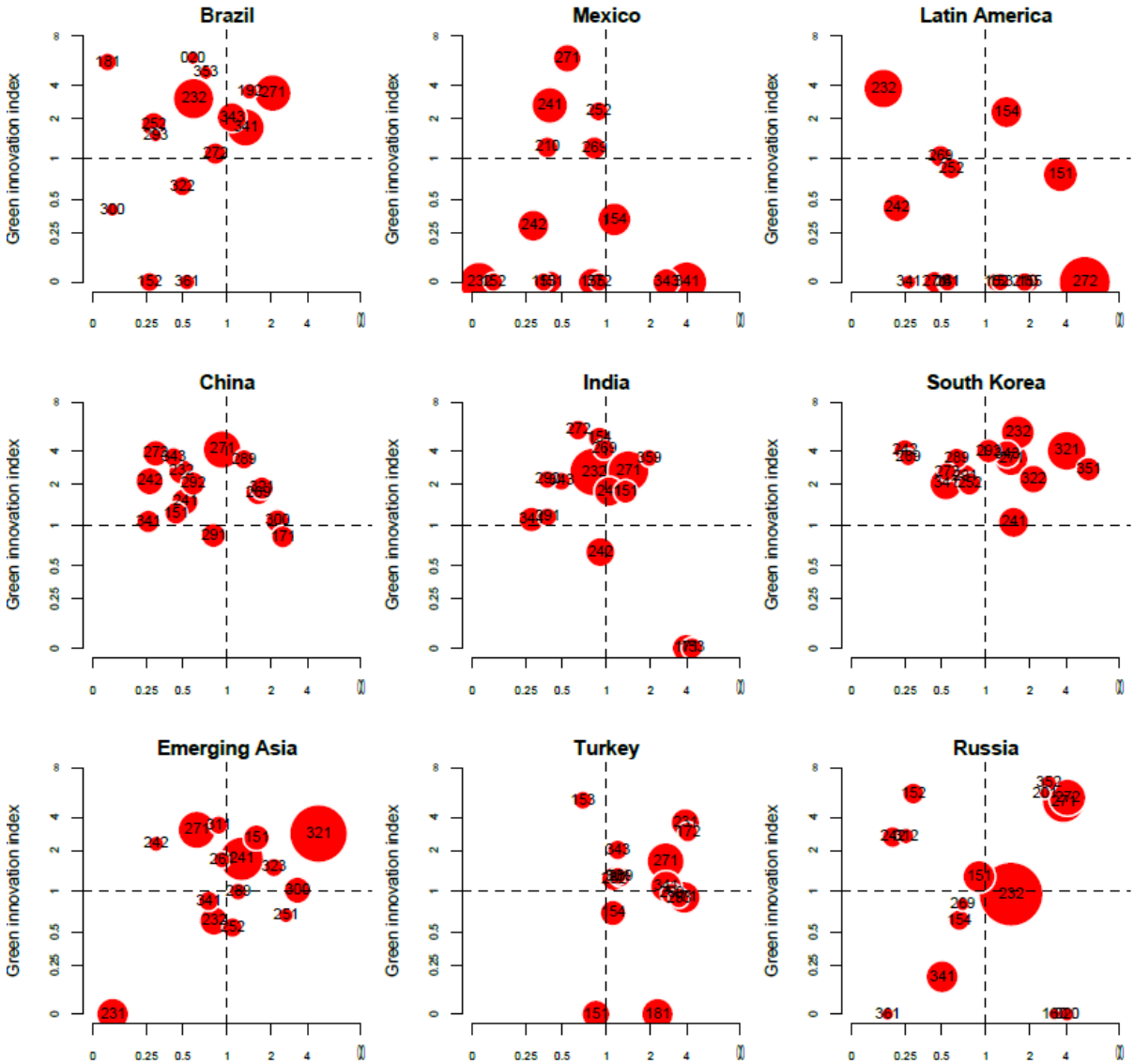
Emerging Markets	Industrialised countries
China (CHN) *India* (IND) *South Korea* (KOR) *Emerging Asia* (AAA - Thailand, Myanmar, Philippines, Taiwan)	*France* (FRA) *Germany* (DEU) *Japan* (JPN) *United Kingdom* (UK) *United States* (USA) *Other industrialised countries* (OIC – remaining OECD member states)
Brazil (BRA) *Mexico* (MEX) *Latin America* (LLL - Columbia, Chile, Uruguay, Peru, Ecuador)	
Russia (RUS) *Turkey* (TUR) *Emerging Europe* (EUE - Albania, Bulgaria, Belarus, Romania, Poland, Ukraine, Moldova, Macedonia, Slovenia, Slovakia, Hungary)	

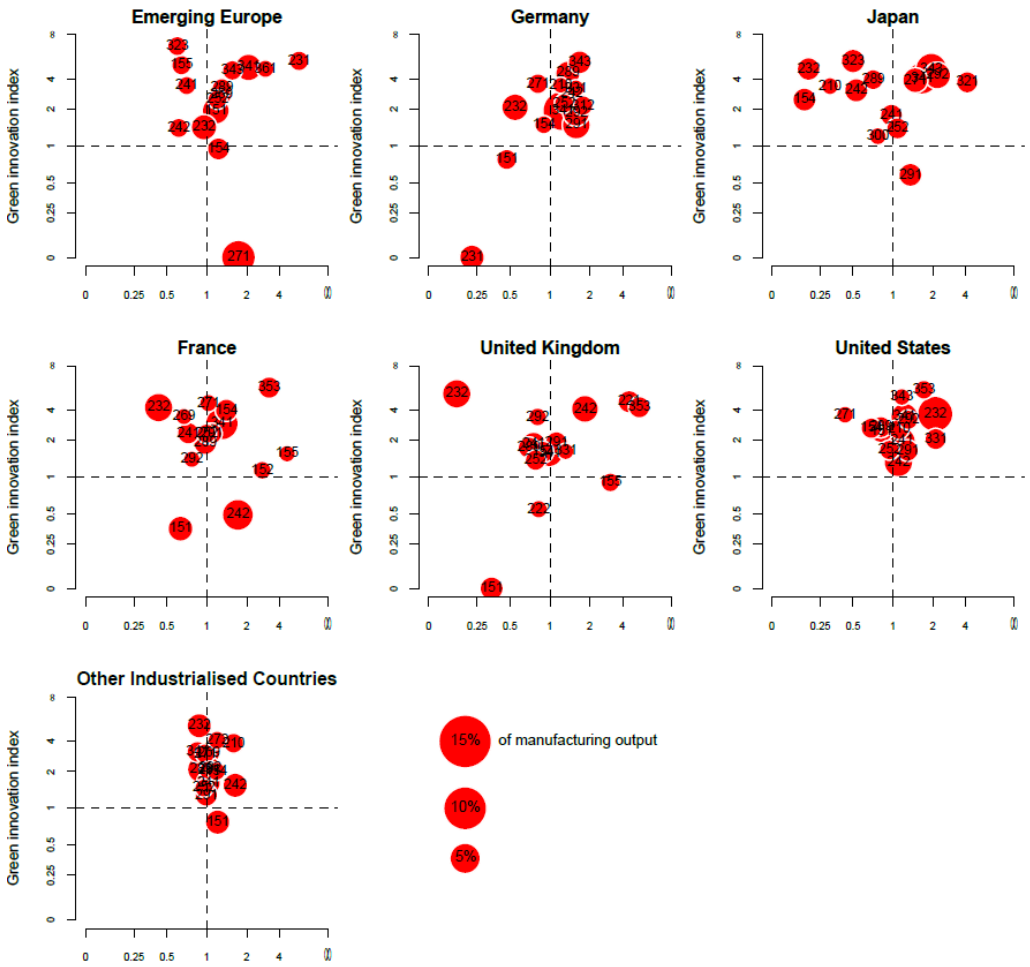
Figure 1: A graphical SWOT analysis for the green economy



Note: Each bubble indicates the location of a country-sector on the GII-RCA plane. The size of the bubble indicates the size of the country sector.

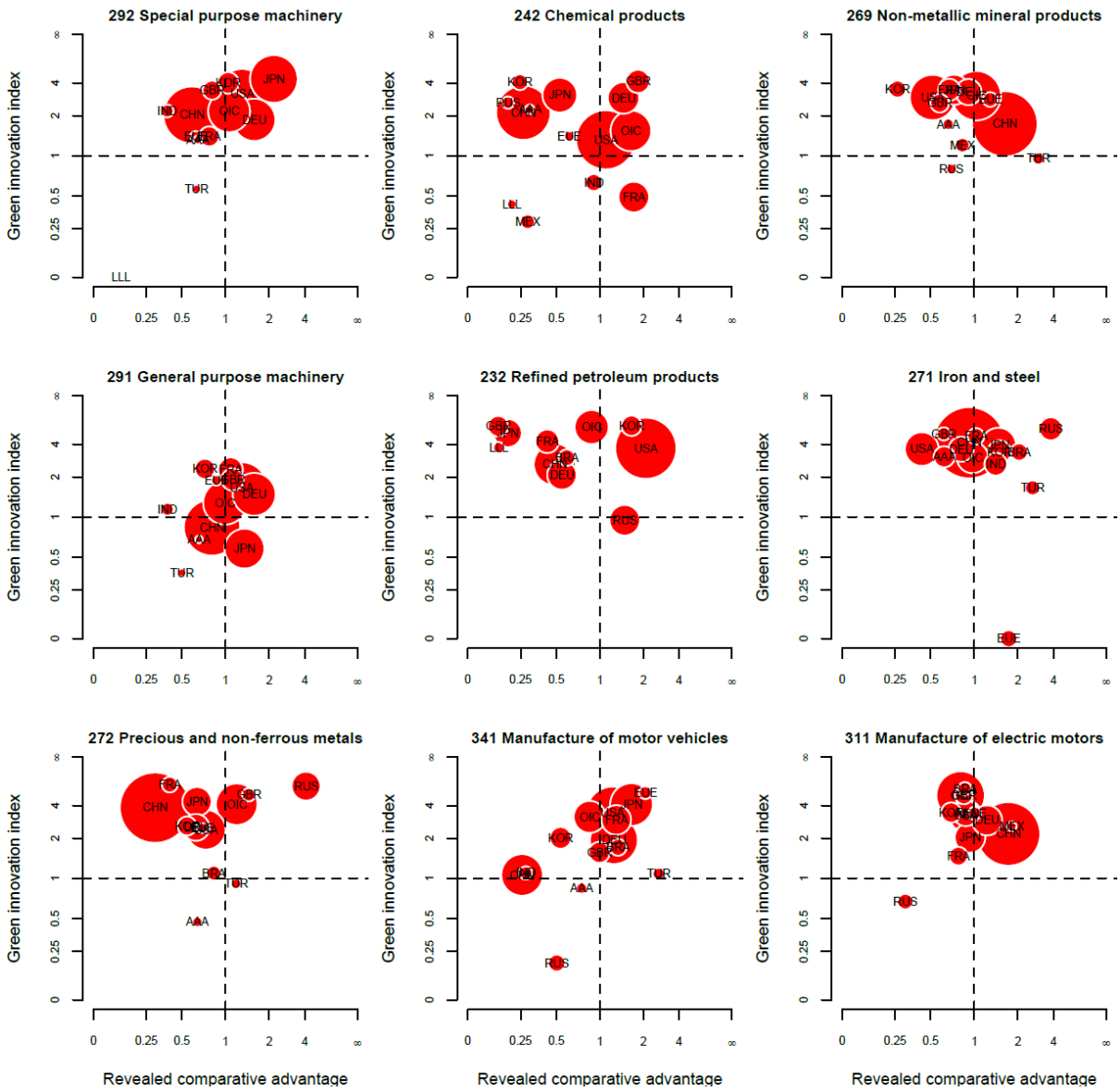
Figure 2: A low-carbon SWOT: country analysis

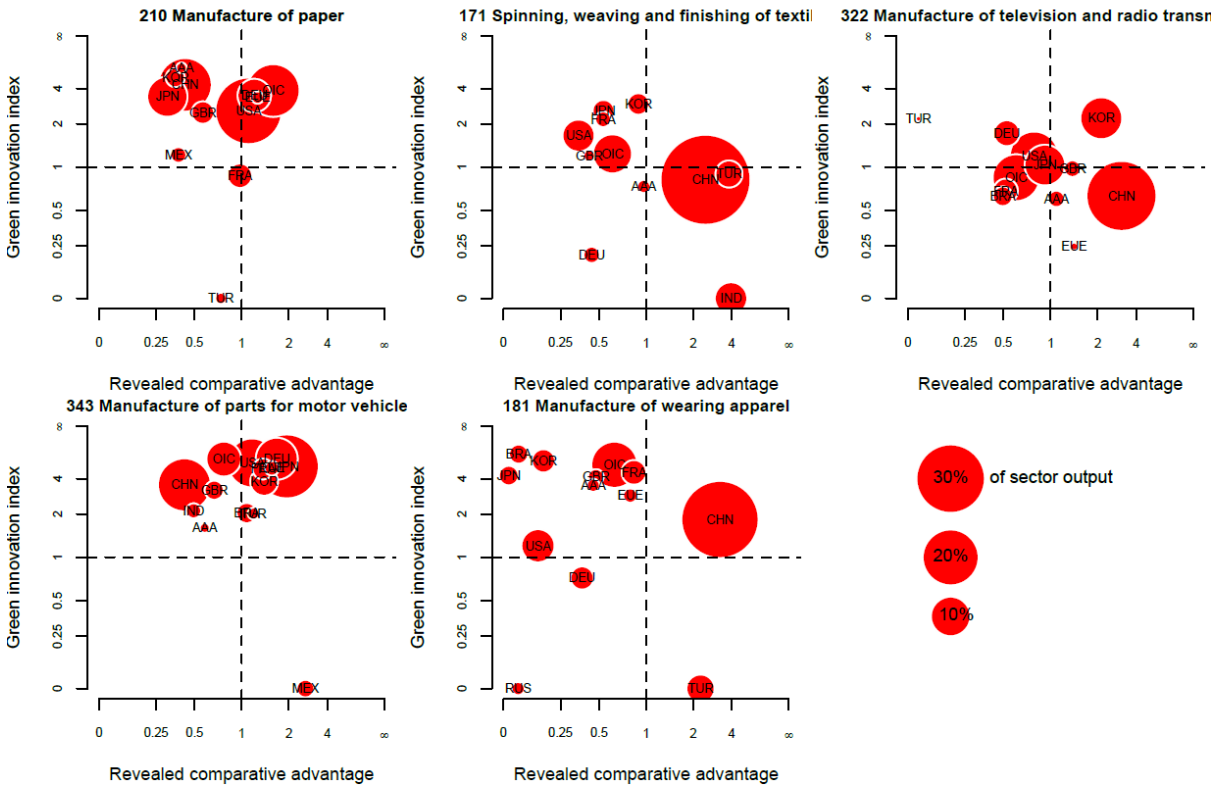




Note: Each bubble indicates the location of a country-sector on the GII-RCA plane. The size of the bubble indicates the size of the country sector, using output data from UNIDO.

Figure 3: A low-carbon SWOT – Sector Analysis





Note: See Figure 2 for further explanations.