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Green growth and innovation in the Global South: a systematic literature review

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ABSTRACT

There has been much interest in green growth and innovation in recent years. The main idea is that domestic green growth policies can provide 'win-wins' to both the environment and the economy. But we still know very little about the impact of such policies, especially in developing countries—the 'Global South.' The literature remains underdeveloped. This is disappointing since the Global South could leverage green growth policies to enhance competitiveness, 'leapfrog' directly to cleaner technologies, and 'catch-up' economically and environmentally through innovation in environmental technologies. The lack of research is also problematic because greenhouse gas emissions from developing countries are growing rapidly. Without green growth and innovation it will be exceedingly difficult to meet the urgent needs of climate change. Against this backdrop, this paper conducts machine-aided citation, bibliometric, and keyword analyses on green growth research with a particular focus on developing countries, innovation, and environmental technologies.

KEYWORDS

Global South; environmental innovation; climate technologies; environmental regulation; green growth; green industrial policy

1. Introduction and background

Green growth policies are back in vogue. They first garnered serious attention in the aftermath of the 2008–2009 global financial crisis, which saw countries around the world roll out green stimulus packages to boost domestic economies (Zysman et al. 2012; Bowen and Hepburn 2014; Georgeson, Maslin, and Poessinouw 2017). Notably, these efforts were not limited to developed countries, with China surpassing the United States in terms of green stimulus spending (Falkner 2013). Green growth policies refer to 'win-win' interventions that benefit both the environment and the economy (Ambec and Lanoie 2008; Machiba 2011). In general, green growth aims to promote 'low carbon, resource-efficient, and socially inclusive' economies and can be 'driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency' (UNEP 2011).

Likewise, there is also growing interest in how environmental regulations impact firms and drive innovation and competitiveness (Meckling and Allan 2020; Meckling 2019;

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Meckling and Hughes 2018). This is sometimes referred to as the environmental policy-induced-innovation hypothesis (Jaffe, Newell, and Stavins 2005). Research on these policies and their heterogeneous effects on economies is particularly important for the Global South since green growth simultaneously addresses developmental, environmental, and economic needs (Goldthau and Hughes 2020; Lema, Rabellotti, and Sampath 2018; Lema, Iizuka, and Walz 2015; Papaioannou 2014). Indeed, the effects of green growth are increasingly seen as underlying technological and economic 'catch-up' in developing countries and have been cited as a primary reason for implementing green industrial policies (Walz et al. 2017; Rodrik 2014; Matsuo and Schmidt 2019; Pegels 2014; Wu and Salzman 2013).

However, a taxonomy of green growth policies and related mechanisms in the Global South remains underdeveloped in the extant literature (Lema, Iizuka, and Walz 2015). This is problematic from the standpoint of meeting domestic green growth imperatives. But it could be even more critical to meeting global climate and environmental objectives since greenhouse gas emissions from developing countries will soon exceed those of developed countries (Maskus 2010; Den Elzen et al. 2013). Against this background, this paper undertakes an extensive systematic literature survey by making use of open-source citation and keyword mapping software (VOS-viewer) (Van Eck and Waltman 2013). The main contribution of this paper is to provide analysis and synthesis of the scant but growing body of research on green growth in the Global South. Through this systematic analysis salient gaps are identified, common keywords are located and discussed, as well as the prominent researchers and their respective conceptual and theoretical contributions.

Furthermore this paper finds that—considering the domestic competitive implications of green growth—a renewed interpretation of domestic green growth with respect to global climate policy is called for. For example, within global climate negotiations there seems to be an anachronistic idea that green technologies must diffuse to the Global South even though developing countries have experienced much green technology innovation in recent years (Bayer, Dolan, and Urpelainen 2013; Mealy and Teytelboym 2020). Indeed, developing countries supply almost one-third of global green exports (Walz et al. 2017). Thus there appears to be a conceptual divide between what domestic green growth means within developing countries and how green growth and sustainable development continue to be imagined within multilateral development agencies such as United Nations Environment Program (UNEP) and climate change treaties such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. Secondly, green growth tends to focus on the domestic economy; indeed benefits to domestic firms and society at large is a central tenet of green growth policy (Luderer et al. 2019). However, multilateral climate and sustainable development policies envision global collaboration and mutual benefits and largely ignore how green growth aims to confer advantages to domestic firms and industries. These conceptual divides are reflected in the extant literature. These differences and dynamics are likely to intensify in the coming years given that green growth and climate change are fast becoming even more pressing policy and political concerns, while concurrently the economies in the Global South fight even harder to climb the ladder in the global economy. Throughout the paper these conflicts are highlighted.

This paper proceeds as follows. In the next section (Section 2), key concepts, themes and definitions that underpin green growth are discussed. These themes will guide the remainder of the paper, including the literature search methods (Section 3) and

discussion, implications, and limitations (Section 4). Section 5 provides a conclusion and suggestions for future research.

2. Extant literature: concepts and definitions

Researchers have identified several different policy tools to drive technological and economic catch up through green growth. Intrinsically, green economic growth and development goals require innovations because innovation provides economic benefits and cleaner technologies (Walz et al. 2017). Green growth is thus partly predicated on green industrial strategies which in turn can create first-mover advantages, innovation-inducement effects, and export prowess, among other benefits to the domestic economy. These concepts help to illuminate how domestic green growth initiatives interact in the global 'green techno-economic paradigm' (Freeman 1996; Acemoglu et al. 2016), which refers to the globally competitive green technological innovation industry that has arisen over the last two decades.

Green growth and sustainable development, rather than a burden on the economy, are now seen as twin pillars of industrialization and economic growth (Schot and Steinmueller 2018; Corbo 2019; Quitzow 2013a; Quitzow et al. 2014; Lema, Iizuka, and Walz 2015). Hence technological innovation and industrial competitiveness are deeply intertwined; they result in 'virtuous cycles' of innovation, learning and technological upgrading (Guerrieri and Meliciani 2005; Ruttan and Hayami 1984). In this sense, environmental regulations can become 'a tool for competitive advantage […] for minimizing ecological impacts of economic production while enhancing the competitiveness of firms' (Shrivastava 1995, 183). Thus, beyond green growth imperatives and related mechanisms lie other crucial economic imperatives for how sustainable development unfolds in the Global South.

Green technological innovation and inducement policies are not confined to the Global North, as had been widely assumed in the past, but are broadly supported by countries in the Global South as well (Walz and Köhler 2014; Köhler, Walz, and Marscheider-Weidemann 2014). Indeed since the early 2000s, in rsponse to such policies, the latter have demonstrated increasing innovative capacities for green innovations (Walz and Marscheider-Weidemann 2011). For instance Walz et al. (2017) find that 'From the early 2000s until 2013, the share of [developing countries] in world green exports rose from 18.7% to almost 31.6%' (472). The question is no longer how to diffuse climate and environmental innovations to the South, as formulated within the earlier UNFCCC policy documents, but how countries in the Global South can drive their economies through the emerging global green economy by becoming more globally competitive, inventing green technologies, and seeking out economic and environmental win-wins. Beyond the positive domestic impacts of developing-country catch-up and technological upgrading, more widespread innovation in and diffusion of environmental technologies can have global public goods effects as well (e.g. helping to avert the global climate crisis) (Maskus 2010).

2.1. Sustainable development and green growth

For developing countries green growth is seen as a subset of the broader policy goals of sustainable development (Borel-Saladin and Turok 2013). Both green growth and

sustainable development policies are woven into environmental and climate policies to a certain extent. But whereas the latter addresses issues such as 'reduced poverty and social inequality, and environmental progress' (Borel-Saladin and Turok 2013, 221), green growth tends to focus on policies such as research and development (R&D), investment, and development of green technologies and infrastructure (Borel-Saladin and Turok 2013). Moreover, green growth relies on green industrial policy, innovation and research policy. In general, green growth harkens back to key evolutionary economics concepts, such as: (1) lead markets, (2) policy-induced innovation and innovation-by-export, (3) first-mover advantages, (4) policy pioneer countries, (5) leap-frogging and catch-up. Each of these features of green growth are unpacked in the subsections below. In addition, each category guides the literature search strategy detailed in Section 3, and mirrors the explication of the literature results provided in Section 4.

2.2. Environmental regulations and the Porter Hypothesis

Much attention has been paid to green growth, innovation, and technological development and diffusion in recent years (Ambec et al. 2013). Domestic-level green growth policies have far-reaching consequences for climate change as well as economic development (Fankhauser et al. 2013; Schmidt and Huenteler 2016). National green growth strategies 'aim at decoupling economic development from adverse environmental impacts [and] have become a new paradigm for policymakers in developing countries' (Schmidt and Huenteler 2016). In the well-known Porter Hypothesis (PH), Porter and van der Linde (1995a, 1995b) made what was at that time a bold claim: environmental regulations can, if properly crafted with flexible mechanisms, drive innovation 'offsets' which will benefit, rather than impede, the domestic economy. They argue persuasively that environmental regulations can, and often do, induce innovative responses in firms—especially firms that are already highly competitive. In turn, these firms will become more globally competitive. Such innovation offsets are likely to outweigh the cost of regulation borne by firms. Indeed, Porter and van der Linde specifically state that 'environmental standards can trigger innovation […] such 'innovation offsets' […] will be common [and] can even lead to absolute advantages over firms in foreign countries not subject to similar regulations' (98). This suggests that carefully constructed environmental regulation can drive innovation and competitiveness. The PH is probably the most well-known and original conceptualisations of green growth.

Drawing on roots within the evolutionary economicse school (Dosi 1982; Freeman 1995), the PH rests on key concepts such as innovation, technological change, and development. It is not a linear model—e.g. that innovation is 'sequential'—but rather it conceptualizes innovation, R&D, and technological development as dynamic processes that result from 'technology push or market pull pressures'; such processes can be catalyzed by government regulations and supported by innovative and technological competencies within a country (Pugh and Chiarini 2018). In order to empirically test the Porter Hypothesis, Jaffe and Palmer (1997) introduce four separate 'interpretations', which make empirical studies much more straightforward (Ambec et al. 2013):

- **The Weak PH:** Properly designed environmental regulation may spur innovation (in some but not all firms)

- **The Strong PH:** Environmental regulation often leads to an increase in firm competitiveness (productivity-enhancing)
- **The Narrow PH:** Flexible regulatory policies give firms greater incentives to innovate and thus are better than prescriptive forms of regulation (innovation-inducing)
- **The Narrowly-Strong PH:** Environmental regulations can enhance a country's competitiveness (Porter and Van der Linde 1991; Ambec et al. 2013). 'In a setting of dynamic international competition […] government can garner dynamic comparative advantage [by] […] inducing early innovation in environmental technology' (Jaffe and Palmer 1997, 610). (competitiveness-enhancing)

The Weak PH aligns closely to the environmental policy-induced innovation literature (Johnstone et al. 2012). The Strong PH resembles more recent literature that tests multi-factor productivity trends against environmental policy stringency (Albrizio et al. 2014; Kozluk and Zipperer 2015; Rubashkina, Galeotti, and Verdolini 2015). The Narrow PH deals with the different types and typologies of environmental policy (Haščič and Johnstone 2011; Johnstone and Haščič 2011; Herman and Shenk 2021). Finally, the Narrowly-Strong PH version—which receives considerably less attention in the literature—seems to embody some of the key 'global competitiveness' concerns that underscore domestic green growth initiatives in developing economies: green industrial policy can create 'first-mover advantages', promote technological and economic 'catch-up', provide 'leap-frogging' opportunities, help to create 'lead markets', and finally, provide positive benefits through 'innovation-by-export'. With an eye on this last version of the PH (the Narrowly-Strong PH), the remainder of this section further unpacks these key cross-border, green growth and development features within a complex globally competitive economy.

2.3. Green industrial policies

Green industrial policies are a key policy tool for domestic green growth. Industrial policies can take many forms including industry promotion, employment generation, direct subsidies, tax credits, and market creation policies (Wu and Salzman 2013; Rodrik 2014; Pegels 2014; Kemp and Never 2017). Industrial policies can, in part, help to determine which technologies gain market dominance (Lund 2009). In terms of green growth, green industrial policy—defined as 'policies that promote industries that produce green technologies' (Harrison, Martin, and Nataraj 2017, 254)—has become a lever for domestic green growth. However it has led to a number of conflicts, evidenced by the dozens of disputes registered under the World Trade Organization (Wu and Salzman 2013; Pegels 2014). These conflicts have permeated through developing and developed countries (Lewis 2014; Vazquez-Brust, Smith, and Sarkis 2014; Mealy and Teytelboym 2020).

The implication for environmental technology innovation is that green industrial policy can act as a drive for green growth (Lewis 2012). But the policy must be carefully articulated, taking into account National Innovation Systems (NIS) dynamics (Lundvall 1988), endogenous comparative advantages (Nelson 1993), as well as an understanding of demand for climate technologies on the global market (Hoffert et al. 2002). As such, in addition to potential domestic impacts of the policy, carefully constructed

green industrial policies may also account for the stringency of foreign environmental policies (Herman and Xiang 2019, 2020; Nykvist and Nilsson 2015). Hence, environmental regulations have become linked directly to domestic green industrial policies but can be at odds with mutli-lateral climate policies (Wade 2012; Neumayer 2001; Perkins and Neumayer 2012). In short, while green industrial policies can provide important 'political signals [to] reduce uncertainty over future policy trajectories by revealing the governments' intentions' (Meckling and Nahm 2019, 471), they should be recognized as domestic policy tools that may conflict with global environmental and policy imperatives. This subject has not been deeply explored in the literature.

2.4. Lead markets, first mover advantages, and innovation-by-export

Lead markets are defined as countries where a globally successful innovation first originates (Beise and Rennings 2005). Incubating lead-markets requires policy timing, design, and stability (Jaffe, Newell, and Stavins 2005; Quitzow et al. 2014). From a policy perspective the focus tends to be on how to induce technological innovation and development in the lead market country (Quitzow et al. 2014; Walz and Köhler 2014). Further, lead markets can 'create durable competitive advantages for domestic companies that develop clean technologies for export to late adopters' (Meckling 2015, 588). While 'green' lead markets are often assumed to be markets located in high-income countries, the electrical vehicle and energy storage technology revolution that has unfolded in China suggests otherwise (Walz and Köhler 2014). What this also shows is that developing economies can, indeed, become lead markets, create first mover advantages, and simultaneously support their export sectors. The latter is a particularly salient topic for emerging low-carbon technologies and, as shown in the following sections, has garnered much attention in the literature as of late.

A closely related concept, innovation-by-export, first popularized in evolutionary economics literature, is now undergoing a revival in environmental technology and innovation literature (Bayer, Dolan, and Urpelainen 2013; Van de Graaf and Colgan 2016; Van Leeuwen and Mohnen 2017). Researchers find compelling evidence that firms from a variety of developing countries innovate through export of green technologies (Algieri, Aquino, and Succurro 2011; Peters et al. 2012; Groba and Cao 2015; Costantini and Mazzanti 2012). How might a country maintain environmental technology export prowess? Innovation competencies are built up through technological knowledge, national innovation systems (NIS), and enhanced by locational advantages which can imbue countries with first-mover advantages. Knowledge serves as a key driver of innovation-by-export—which is one reason there should be a concerted focus on NIS and inward knowledge transfer because knowledge competencies can help to maintain export advantages (Andersson and Ejermo 2008).

2.5. Policy pioneer countries, catch-up and national innovation systems

Environmental policy pioneer is a concept that denotes the country with the first or most stringent environmental regulation. It was popularized by Jänicke and Jacob (2004) to refer to the risk-reward intrinsic to introducing green growth policies ahead of other countries. The policy pioneer country differs from the lead market country in two

fundamental ways. First, a policy pioneer country has the most stringent policy which is likely to induce inward technology and knowledge flows (Huber 2008); on the other hand, lead markets can arise from endogenous factors such as absorptive capacity, an attractive market, or lower wages—factors which have little relation to environmental policies. In principle, environmental pioneer policy countries can take advantage of inward knowledge, technology, and innovation spillovers (Huber 2008; Quitzow et al. 2014). Expanding on these conceptualisations, policy pioneers also underpins the theoretical foundations of country-level 'catch-up' (Acemoglu et al. 2016). Catch-up itself relies on 'technological capabilities for technological learning from other countries' (Fagerberg 2011, 287). Finally, to confer advantages to domestic firms and industries, policy pioneers should already have a well-developed national innovation system in place. This helps to ensure that inward knowledge and technology spillovers enhance rather than crowd out domestic green competitiveness.

In sum, the above mechanisms and policy levers help to explain how green growth functions within a globally competitive economy. Importantly green growth is supported through development of environmental and low-carbon technologies (Walz et al. 2017), which are fascinating from a global political economy perspective. First, environmental innovations require some form of government support to stimulate demand as well as provide subsidy since they remain costly. Second, a growing number of countries exhibit innovative capacities to develop new environmental technologies, which means that there is much competition within and across countries for policy support. Third, these technologies are considered critical to meet the goals of climate change at the global level—(e.g. many country-level 'nationally determined contributions' under the Paris Climate Agreement demand more renewable energy, electrical energy storage, and electrical vehicles), therefore it is critical to understand how different policy experiments have impacted the rate and direction of environmental and climate technology innovation (Popp 2011).

In the next section, the systematic literature search method is described. Each of the categories discussed in this section are used to specify the literature searches. The individual search results are then amalgamated to create a full corpus. In order to demonstrate the gap in developing country research on green growth, two corpuses are built: one for total articles and the second for developing country-focused articles. Detailed analysis is only conducted on the latter. The results of the systematic literature search are reported, synthesized and discussed in Section 4.

3. Method and data

Systematic literature reviews have been gaining traction in recent years, in part thanks to new software tools. A systematic review should be easily replicable, transparent and consistent, which has the effect of limiting human errors and biases (Cook, Mulrow, and Haynes 1997). It should, moreover, include a theoretical study supported through examination of bibliographic information to analyze specific topics and themes. Machine-aided tools such as VOS-viewer—which is used here—can provide comprehensive and detailed reviews of academic literature without requiring manual content analysis. They can quickly deliver insight into key themes, topics, keywords, as well as quantitative

statistics (Cook, Mulrow, and Haynes 1997; Tranfield, Denyer, and Smart 2003; Bricker 1989).

Consistent with related systematic literature review research (Gaur and Kumar 2018; Sequeira and Santos 2018) VOSviewer, an open-source software tool, is deployed in this paper. In a recent and related article, for example, Sequeira and Santos (2018) also use VOSviewer to analyse co-citations among authors and countries for renewable energy policies and politics. The main benefit is that it can digest raw data from a variety of online article sources to display clusters, link analyses, textual and keyword analyses, and graphical results. Clusters can then be constructed according to non-negative weights which indicates a certain degree of importance of a node or link. Higher weighted items feature more prominently in the display (Van Eck and Waltman 2013). In short, VOSviewer provides a comprehensive and relatively unbiased snapshot of the extant literature.

3.1. Methodological approach

The literature search is conducted with Scopus Advanced search, which competes with WoS (World of Science) for literature databases with the largest bibliographic coverage. However, the Scopus database has at least 20% more coverage than Web of Science and is better at delivering keyword and citation data (Falagas et al. 2008). Secondly, it is more geared towards social sciences, which indeed is the focus here (Falagas et al. 2008). One major drawback, however, is that Scopus Advanced search requires a subscription; as such, the methods deployed in this paper are not entirely replicable, which is one requirement for a truly systematic literature review (Bricker 1989). This is one among many limitations to this paper, however, which are discussed in the final section of this paper.

To find thematic similarities in the extant literature, two bibliometric techniques are depoloyed here: (1) bibliograhic coupling and (2) co-citation analysis. The former is better at clustering more recent atricles (because they have not been yet widely cited), while the latter is better at identyfing historical trends in the literature (Boyack and Klavans 2010). Morevoer, co-citation analysis reveals similarities among related articles whilst bibliographic coupling links articles based on the references that they have cited (Boyack and Klavans 2010; Kovacs, Van Looy, and Cassiman 2015). Both techniques, importantly, reduce human error and bias. While the corpus-building step requires research choices, the analyses do not require prerequistite knowledge or research preferences (Bricker 1989). Therefore, it is a partially automated and systematic method (Boyack and Klavans 2010). Finally, in line with Firoozeh et al. (2020), an automated keyword extraction is deployed to round out the systematic literature search and review. This shows the common keywords found throughout the abstracts and titles of the corpus, and how they connect and relate with one another, which ideally will help to guide future research.

3.2. Overview of the corpus search results

The systematic search strategy was conduced on January 5, 2021. It was subsequently re-verified on March 2, 2021. In the appendices, the precise search terms that were inputted into Scopus Advanced search toolbar are listed (Appendix 1 and 2). Below, only the main

category of each search string is displayed, which compares all research output (corpus 1) with those that have a developing economy focus (corpus 2) (see Figure 1 and Table 1). Only published, peer-revied articles are selected. Also excluded are conference papers and books.

While temporal trends are not shown in Figure 1, they are dicussed in the results section. As shown, across all categories, no more than 10% of the literature focuses on developing economies. The most evident gap is, interestingly, found in the four different versions of the Porter Hypothesis (weak, strong, narrow, and narrowly-strong). Innovation-and-export has the highest representation in the literature at 9.8%. This is likely due to the prowess of the Chinese renewable energy export experience. In short, the literature gained momentum following the 2009 financial crisis; while developing country-focused literature has gained much traction since 2018. However, despite this recent uptick in interest, there remains a marked lack of research focusing on developing countries or the Global South across all search themes.

The dearth of research on green growth in developing countries is problematic. These are especially critical concerns for policymakers in developing and middle-income countries because they are fast becoming the largest greenhouse gas emitters. As such, the lack of research might also have negative consequences for meeting the pledges made under the Paris Climate Agreement. Indeed, there is also a high risk that, should developing countries not upgrade through green growth, they will become 'locked-in' to fossil fuels (Unruh 2002; Rip and Kemp 1998). That will preclude 'leapfrogging' and 'catch-up' opportunities via green growth and competitiveness (Hansen and Lema 2019; Gosens and Lu 2013). This has obvious negative implications for both their domestic economies as well for the global climate and

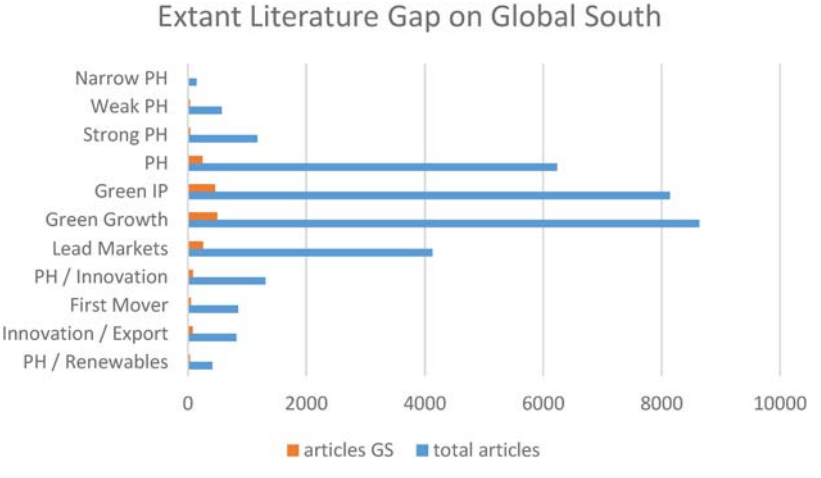

Figure 1. Comparison of research on green growth, innovation, and policy.

Note: The blue bars show the number of articles focused on any country, while the orange bars show the articles with a Global South country focus. 'Narrow', 'weak', and 'strong' are the interpretations of the Porter Hypothesis. 'Green IP' is Green Industrial Policy; 'PH/Innovation' means Porter Hypothesis and innovation effects; 'PH/Renewables' means Porter Hypothesis and renewable energy.

Table 1. Corpus 1 and Corpus 2 (developing countries) literature data.

Search Theme	Corpus 1 (all)[a]	Corpus 2 (developing countries)	% Developing Countries
Green Growth	8635	495[3]	5.7%
Green Industrial Policy	8140	457	5.6%
Lead Markets	4127	256	6.2%
First-Mover	851	49	5.8%
Innovation-and-export	820	80	9.8%
Porter Hypothesis	6236	245	3.9%
PH (W,N,S,N-S) [2]	1898	76	4%
PH /renewable energy	32	32	7.7%
PH /Innovation	1309	80	6.5%
—	—	—	—
Total	**32048**	**1770**	**5.5%**

[a] This table shows the number of articles for each search theme and corpus, followed by the percent of articles represented by a Global South research focus. All duplicates were removed in the final merged sample. [2]Weak, narrow, strong and narrowly-strong versions searched separately, then combined. [3]Green Growth is removed from the final Corpus 2 aggregated sample because it largely overlaps with green industrial strategy/policy.

environment. Therefore, the research gap needs to be systematically and urgently addressed.

4. Results and discussion

The complete results for each specific theme are supplied in the appendices. Here the results are presented for the merged developing-country corpus containing all themes. The results are divided according to: 1) co-citation analysis; 2) bibliometric coupling; 3) text and keywords. Finally, a synthesis is provided to demonstrate the predominant gaps that remain and the implications for future research.

4.1. Results: co-citation analysis

According to the automated co-citation analysis, with respect to literature on developing countries, there are five overarching research pillars: 1) catch-up, 2) renewable energy innovation, 3) technological and national innovation systems, 4) green industrial policy, 5) the Porter Hypothesis. It is important to note, however, that these results are not representative of the entire extant literature because the Scopus searches directly specified some of these themes. Nevertheless, it is interesting that catch-up, technological innovation systems, leapfrogging, and spillovers are each generously represented throughout the corpus as these categories were not specified in the Scopus search. This indicates that these themes are, as expected and discussed in Section 2, closely related to the categories in the searches Figure 2.

4.2. Results: bibliographic coupling

Bibliographic coupling, in contrast to co-citation analysis, provides a more detailed picture of recent literature (Figures 5 and 6). Therefore, the results for bibliographic coupling show abundantly more papers, with a noticeable growth in the literature since 2018. This demonstrates, importantly, that the extant literature on green growth

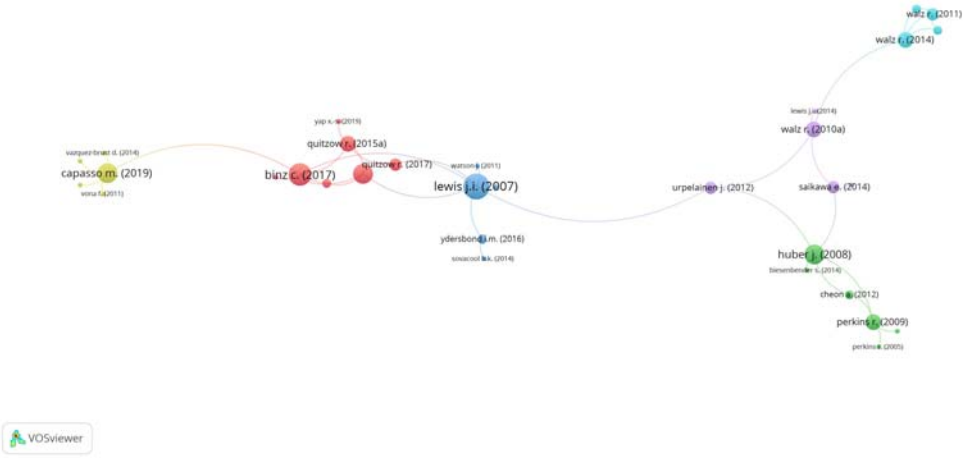

Figure 2. Corpus 2 Developing countries co-citation analysis.

Note: The articles displayed are from the co-citation analysis with developing country research focus (Corpus 2). Minimum 10 citations per article threshold. Lewis (2007), Binz et al. (2017), and Huber (2008) demonstrate the greatest centrality in the network.

and developing economies is gaining some momentum in recent years. This is a positive development although large gaps remain.

Below, the results of the bibliographic coupling analysis provide a broad overview of the thematic areas in the literature, or research trends, contained within each cluster. In addition, as shown in the 'yearly' cross sectional results (Figure 5), it is evident that the literature has experienced much growth since 2018, which is promising. Much of the recent research focuses on China, but also Pakistan, Saudi Arabia, 'MINT' (Mexico, Indonesia, Nigeria, and Turkey) countries, and the 'BRICS' (Brazil, Russia, India, China, and South Africa) countries. It is also notable that 'carbon emissions intensity' and 'artificial neural networks' are an emerging as a very novel research area. The latest research, from a geographical perspective, have clustered around China and other East Asian economies, likely because they have successfully deployed green growth policies to boost their economies and create first-mover advantages in key climate and environmental technologies, and by overlapping with information and communication technologies (ICT) industries. The green cluster is very recent and centres on China, CO_2 emissions, and economic growth. The red cluster, meanwhile, exhibits many of the same articles from the co-citation analysis. The blue cluster, also quite recent, focuses on firm-level (rather than country-level) research questions. The purple cluster, which is not as new, focuses on global value chains and governance Figure 3.

4.3. Results: keyword analysis

Finally, a keyword analysis is conducted. The clustering and connectiveness among keywords also shows interesting results. 'China', 'sustainable development', 'industrialization', 'environmental economics', and 'carbon emissions' are well represented across the corpus. Shown prominently in the purple cluster are: 'China', 'energy efficiency', 'manufacturing', 'regression analysis' and 'urbanization'. In the red cluster: 'commerce',

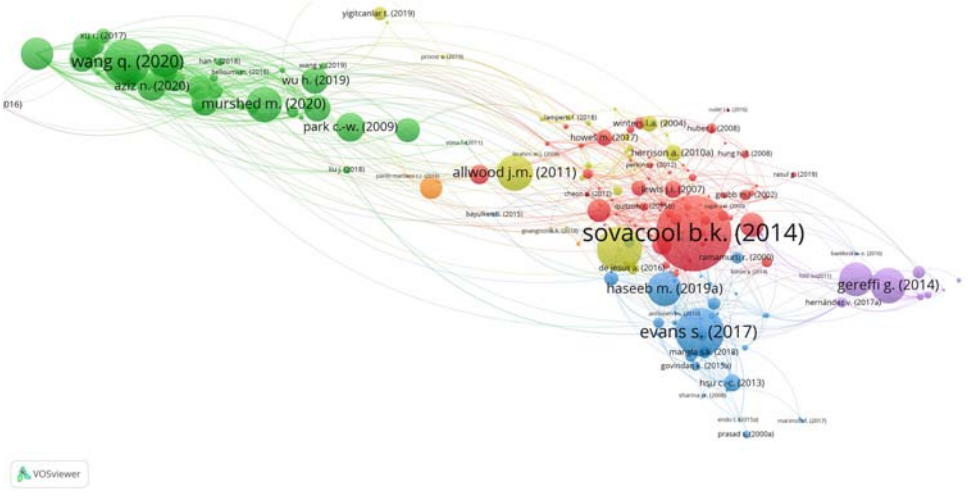

Figure 3. Corpus 2 Developing countries bibliographic coupling, clustering display.

Note: The articles displayed are from the bibliographic coupling analysis with developing country research focus (Corpus 2). Minimum 10 citations per article threshold, link analysis.

'productivity', 'research and development' and 'knowledge management'. In the blue cluster: 'carbon dioxide', 'carbon emissions', 'CO_2 emissions' and 'Kuznets curve'. In the yellow cluster: 'developing world', 'sustainability', 'global value chains', 'European Union' and 'political economy'. In the green cluster: 'energy policy', 'global warming' and 'energy utilization'. In the light blue cluster: 'industrialization', 'agriculture', 'technology' 'and statistical analysis'. Finally, other regions and countries that feature in the results are: 'Malaysia', 'sub-Saharan Africa', 'Africa', 'Brazil', 'Indonesia', 'India' and the 'United States'.

4.4. Discussion

In this subsection, the results of the co-citation, bibliometric, and keyword analyses are discussed with respect to the key features of mechanisms that underlie green growth, as articulated in Section 2 (green growth, the Porter Hypothesis, green industrial policies, lead markets, innovation-by-export, first-mover advantages). The literature search results are leveraged to provide a more comprehensive review of the extant literature of green growth in the Global South. Furthermore, key remaining gaps are discussed. Finally, Section 4.5 offers a synthesis.

4.4.1. Green growth

Green growth is a new imperative in the twenty-first century as the climate crisis and other environmental crises become more pronounced and accelerate. The state plays an important role in this respect by helping industries and firms develop technological competencies and by helping to induce much-needed environmental innovations (Meckling and Nahm 2019; Walz and Eichhammer 2012; Lanoie et al. 2011; Walz 2010). As the systematic search results reveal, several recent papers have brought the issue of green growth in developing economies to the fore. Capasso et al. (2019) is a

prominent example: the paper offers an important synthesis of the green growth literature. Consistent with the findings here, they demonstrate that the Global North continues to receive much of the attention, despite the fact that the Global South has seen much green growth activity in recent years. As the 'green growth' search term is discarded in the final corpus, we do not expand more on this subject unless it deals with the key mechanisms and tools that undergird green growth (e.g. first-mover, lead markets, policy pioneers, etc.).

4.4.2. Environmental regulations and the Porter Hypothesis

Green technology innovations rely on environmental policy to create demand (Rennings 2000). In the absence of environmental regulation, the demand for clean technologies will be significantly lower, which will delay important low-carbon transitions (Rennings 2000). By stimulating innovations, environmental regulations can actually enhance competitiveness (Porter and Van der Linde 1995). This is the 'political rationale' for the Porter Hypothesis (Huber 2008; Lewis and Wiser 2007; Saikawa and Urpelainen 2014). Therefore the demand for environmental technologies 'depends very much on the extent by which regulation leads to a correction of the market failures […] Without such regulation, the demand will be much lower, and the various demand effects are less likely to be strong' (Walz and Köhler 2014, 24). In this manner, researchers tend to agree that environmental regulations induce innovation in environmental technologies, which are essential to meet climate policy goals. How does this play out in the Global South?

As some articles seem to home in on—in line with the PH—domestic environmental regulations can play a key role in creating competitive advantage for domestic firms in developing countries (Groba and Cao 2015; Algieri, Aquino, and Succurro 2011; Fankhauser et al. 2013). To that end, Stadelmann and Castro (2014) undertake what is perhaps the largest study of developing countries and renewable energy support policies. In their analysis of policy development across 112 developing countries from 1998–2009, including four different types of clean energy support policies, they find that international factors significantly influence the adoption of such policies (e.g. policy diffusion). This suggests that developing countries are increasingly more likely to absorb inward policy spillovers and recognize the benefits of domestic green growth. A related body of the literature has sought to explain competitiveness and green growth through global value chains. For instance, Silvestre (2015) and Hsu et al. (2013) examine sustainable supply chains and future trajectories in emerging economies. Green supply chains are also examined by Wiebe and Yamano (2016) and Koźluk and Timiliotis (2016). Meanwhile, somewhat differently, Patriarca and Vona (2013) investigate income inequalities with respect to environmental technology development. Finally, a major contribution that stems directly from Global South research is frugal innovations which, in light of depleting world resources, envisions innovations much differently than traditional, R&D and financially intensive technological innovations (Gandenberger, Kroll, and Walz 2020).

4.4.3. Green industrial policies and renewable energy

Green industrial policies are cited as increasingly more prevalent throughout the Global South (Biesenbender and Tosun 2014; Quitzow, Huenteler, and Asmussen 2017; Lewis

2014; Mealy and Teytelboym 2020). But such policies can have important political consequences because they typically favour domestic economies (Biesenbender and Tosun 2014). Surprisingly, the term 'green industrial policies' does not feature very prominently in the keyword results (Figure 4), although green industrial policies are the subject of three prominent papers in the co-citation analysis (Yap and Truffer 2019; Lewis 2014; Biesenbender and Tosun 2014) Figure 5.

A number of papers have focused on the BICs economies (Brazil, India and China), which are now home to some of the world's most competitive renewable energy technology companies, due in large part to green industrial policies (Yu et al. 2016; Kim and Kim 2015; Lema and Lema 2012; Lema, Berger, and Schmitz 2013; Tiwari and Herstatt 2012). The prowess of green industrial policies in developing countries is seen as 'intensifying industrial policy competition' (Mealy and Teytelboym 2020, 472), a subject that certainly warrants much consideration in future research. There remain, however, important challenges ahead for implementing green industrial policies in developing countries (Harrison, Martin, and Nataraj 2017). Indeed, in an earlier analysis Lewis (2014) identified industrial policy competition as an emerging feature in global green growth paradigms, specifically with respect to electric vehicle subsidies; this claim is seconded by Nykvist and Nilsson (2015). Wind energy has also been a common focus in BICs. Both China and India have begun to dominate the global wind energy industry by inducing domestic demand whilst at the same time supplying foreign markets—an evident focus on industrial and trade, as well as innovation, policies (Lewis 2011; Ru et al. 2012; Camillo 2013; Walz and Delgado 2012). Likewise, Furtado and Perrot (2015) empirically demonstrate how wind energy innovation systems perform in Brazil and South Africa, noting that path dependence and carbon lock-in have precluded their wind industries from developing like China and India. Indeed, South Africa is an important example, being 'locked-in' to coal-fired energy because of institutional inertia and path dependency (Furtado and Perrot 2015). Along similar lines, Rennkamp and Perrot (2016) examine the National Innovation Systems of Brazil, Africa, and India with respect to the wind energy sector.

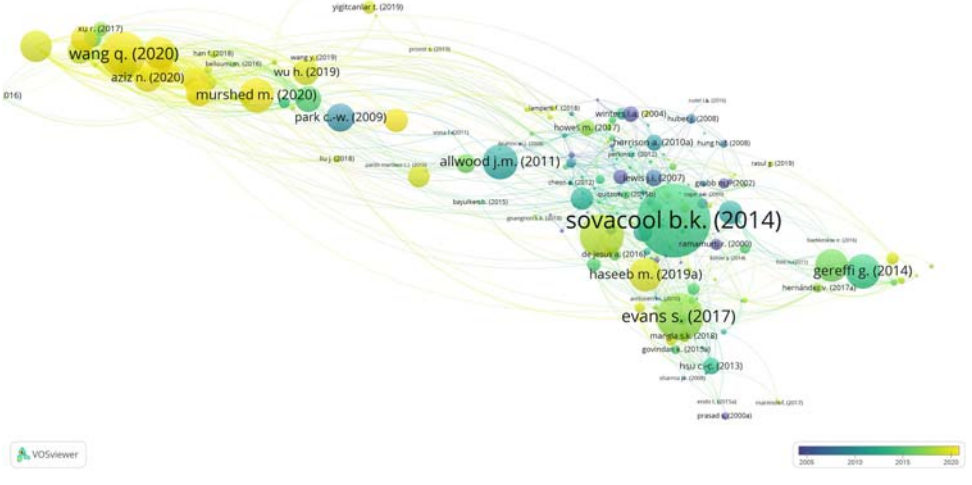

Figure 4. Corpus 2 Developing countries bibliographic coupling, overlay (yearly) display.

Note: This image mirrors Figure 3, but shows the temporal trends (prior to 2010 is blue, 2010/2015 teal and 2019/2020 yellow).

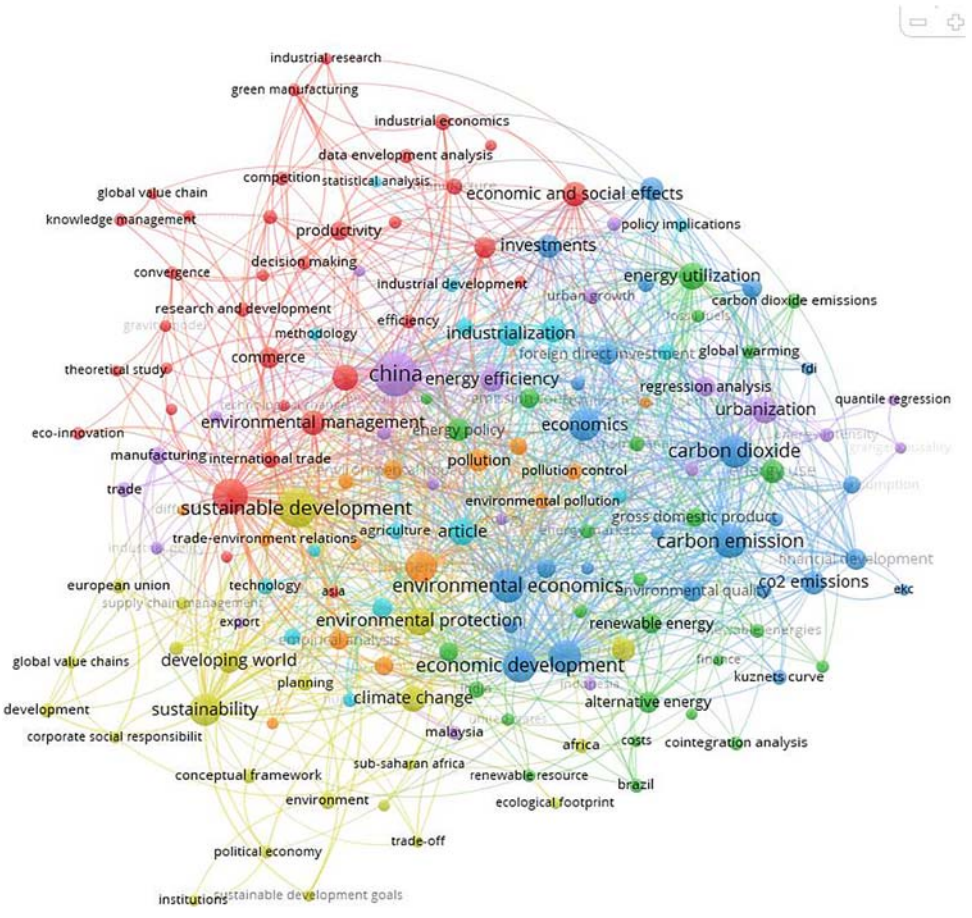

Figure 5. Automated keyword analysis across Corpus 2.
Note: Automated keyword analysis the developing country Corpus 2.

Finally, apart from the BICs which represent the majority of the research here, a recent analysis by Murshed (2020) incorporates trade openness and ICT capacities to understand local renewable energy innovation in a panel of South Asian emerging economies, while Wang and Zhang (2020) recently look at how R&D investment might lead to decoupling emissions from economic growth in BRICS economies. Along similar lines, Nathaniel et al. (2021) examine Africa's carbon emissions trajectories and Simon (2013) explores the interesting question of greening Africa's cities. In sum, green industrial policy competition and the impacts of industrial policy on countries beyond the BICs countries are two key areas for future research.

4.4.4. Lead markets and first mover advantages

In order to create 'lead-markets' policy-makers must recognize the importance of timing, design, and efficacy of environmental regulations, coupled with innovation and technology policies (Jaffe, Newell, and Stavins 2005). Such endeavours are therefore not so easy for developing countries because of resource constraints and weaker institutional

capacities. The seminal paper on lead markets and developing economies, Walz and Köhler (2014), suggests that lead markets can ensure 'economic growth and new employment' (2014, 21). Similarly, Quitzow (2013b) ask what role policy may have had in developing the lead market. Along the same line of inquiry, Cleff and Rennings (2012) introduce the idea that environmental policies can incubate lead markets by raising demand for cleaner technologies. Such policies also aim to create first-mover advantages for domestic firms. In this manner, green growth policies are an important tool to help create lead markets. This has the effect of increasing the propensity for local innovation, technology, and knowledge spillovers into the lead market country. Strong evidence suggests that, for instance, Germany and Denmark became lead markets for wind energy technology while, as remarked elsewhere, China is fast-becoming the lead market for electric vehicles (EVs) and electrical energy storage (Nykvist and Nilsson 2015; Meckling and Nahm 2019).

The related concept 'first-mover' advantages works in tandem to lead markets because the latter tends to confer first mover advantages to domestic firms (Cleff and Rennings 2016). Indeed, stringent environmental regulations can also create first-mover advantages which can, in turn, deliver national competitive advantages to green industries (Jänicke and Jacob 2005; Quitzow et al. 2014; Lacerda and Van den Bergh 2014). However, the 'first movers' in technological development can also be foreign competitors, which seems to be at odds with domestic green growth imperative (Brunel 2019; Herman and Xiang 2019). Initially proposed by Vogel (1997)—and referred to as the 'California Effect' because stringent automobile emissions' policies in California induced technological innovation in foreign rather than domestic firms—the phenomena of foreign innovation inducement from domestic environmental regulation has important implications for green growth policies. If foreign rather than domestic firms reap the benefits of green growth policy, this could be construed as a policy failure. It is this effect which should be looked at more closely for emerging economies, as the BRICS and BICs countries have shown that they have indeed innovated and exported to countries with more stringent environmental policies (Herman and Xiang 2019), consequently taking advantage of foreign-country green growth policies. If first mover advantages are secured by foreign rather than domestic firms, the advantages of incubating lead markets are largely lost. Therefore, the tensions between domestic green growth imperatives and the need to collectively confront climate change and other environmental challenges, are on full display here.

4.4.5. Environmental technology export competitiveness

Countries can gain advantages in technology innovation by leveraging price and export advantages (Beise and Rennings 2005). China has done so with solar and wind technology, India for wind and Brazil with biofuels. Innovation and export are thus key concerns for research on lead markets, first-mover advantages and global competitiveness concerns (Walz 2010). Indeed, because environmental technology innovations already demonstrate high levels of relative export advantage, based on measurement of export share (Fankhauser et al. 2013; Walz et al. 2017), this 'gives them a higher weight in the political economy shaped debate' (Walz and Köhler 2014, 32). As such, successful green growth policies, which may engender export competitiveness in environmental and climate technologies, can be an important tool for developing countries catching

up to the technology and policy frontier (Walz and Köhler 2014). For these reasons, national innovation systems and pioneer environmental policy countries have become a key focus for researchers (Section 2). Indeed, in a recent empirical analysis, Mealy and Teytelboym (2020) provide a ranking of countrie's green growth—many of which are from the Global South—which demonstrates the notable upward movement in a handful of developing countries. Their comprehensive analysis of the productive capabilities shows that a handful of developing countries have significantly improved their global competitiveness in recent years, including China, Malaysia, Uganda and Vietnam.

4.4.6. Policy pioneer countries and national innovation systems

Globally competitive environmental technology firms, which are partly driven by the demand created by policy pioneer countries—but not necessarily domestic firms—can export innovative, environmental technologies as demand grows in foreign markets (Jänicke and Jacob 2004). As discussed in Section 2, innovation and exports closely relate to policy pioneer and national innovation systems. In a seminal article, Huber (2008) explains how policy pioneers accelerate environmental technology diffusion worldwide. Indeed, as early as 1996 Lanjouw and Mody provided ample evidence that demand for environmental technologies can arise from aggregate demand *vis a vis* countries that have 'passed early environmental legislation.' The policy pioneer effects are supported empirically by two recent papers (Brunel 2019; Ogura 2020). As such, policy pioneer countries can create 'durable competitive advantages for domestic companies that develop clean technologies for export to late adopters', which leads to environmental policy competition (Meckling and Hughes 2018). This is a particularly salient point for low-carbon technologies (Lema, Iizuka, and Walz 2015). Policy pioneer country policies are likewise seen as driving diffusion of clean technologies due in large part to spillovers and productivity (Rubashkina, Galeotti, and Verdolini 2015; Albrizio et al. 2014). Similarly, firms that respond to demand induced by stringent policy, whether the policy is at home or abroad, tend to increase their total factor productivity, which in turn contributes to their competitiveness in foreign markets (Albrizio, Kozluk, and Zipperer 2017).

Technological innovationin developing countries is dependent on absorptive capacity and other key competencies that have been defined in evolutionary economics (Fagerberg and Godinho 2004; Malerba and Mani 2009). With respect to green growth in developing countries, NIS have begun to receive some attention (Walz and Marscheider-Weidemann 2011; Walz et al. 2017; Lema, Quadros, and Schmitz 2015; Lewis 2014; Quitzow 2015a, 2015b; Quitzow, Huenteler, and Asmussen 2017). Both NIS and Technological Innovation Systems (TIS) theoretical approaches can help show the mix of competencies required for technological development and upgrading for climate technology research (Hekkert et al. 2007; Wieczorek 2018; Huang et al. 2016; Gandenberger and Strauch 2018). Developed by evolutionary economists (Nelson 1993), TIS expands NIS concepts to allow for innovations to occur simultaneously in many places at once (Bergek et al. 2008). Because climate change technologies experience widespread and nearly global demand, TIS might be better equipped to examine innovation systems for environmental and climate technology development (Gosens and Lu 2013; Gandenberger and Strauch 2018).

4.4.7. Knowledge and technology flows (Transfers)

Finally, although not part of the initial search strategy, we briefly touch on knowledge and technology transfers, as the search results demonstrate that these are prominent foci in the literature. Technology transfer ideas long formed part of the bedrock of global climate policy. It is enshrined in the UNFCCC's founding documents (Article 4.1 of the convention, in addition to the Kyoto Protocol's article 4.2; see Philibert 2004). This might have had some impact on the literature because the CDM (Clean Development Mechanism), a key instrument established by the Kyoto Protocol, has dominated the literature on the Global South and technology transfer, in contrast to technology development (Karakosta, Doukas, and Psarras 2010). Nevertheless, Neumayer and Perkins (2005) discuss the importance of environmental technology diffusion irrespective of the CDM. Hansen and Lema (2019) look at how learning and domestic knowledge competencies have helped some emerging economies scale up local industry. These ideas are empirically tested by Wang et al. (2020) who contrast the Global South and OECD countries CO_2 mitigation efforts.

4.5. Synthesis and summary of the results

Throughout the literature uncovered in this systematic review, apart from the evident gaps, a more positive conclusion is that green growth can be a tool for economic growth not only in the Global North, but in the Global South as well. Indeed, once policy tools are effectively deployed, the Global South could experience even greater technological, environmental, and economic benefits in comparison to the North, which has largely already reaped these rewards. As Walz et al. (2017) show, developing economies are playing an increasingly more central role in global green innovation and technology exports, rising to over 30% by 2012, and growing further since. In developing countries that have successfully embarked on green growth, shown empirically by in a recent analysis by Mealy and Teytelboym (2020), 'win-wins' for the economy and the environment are commonplace. These trends are important from several perspectives. For one, developing countries can leapfrog and catch up through green growth and green industrial policy (Hansen and Lema 2019; Gosens and Lu 2013; Binz et al. 2017). Second, as developing countries catch up through green growth they tend to experience more inward investment, knowledge and technologies flows, which in turn leads to a number of local environmental and technological benefits (Saikawa and Urpelainen 2014). Analysis of these policy mechanisms, empirical evidence of their beneficial effects on economies and the environment, as well as lessons learned is critical for developing economies (Walz and Köhler 2014; Tiwari and Herstatt 2012). Thus this area is, indeed, ripe for future research.

In this section, the results of the systematic review of the literature were discussed. Key research themes and thematic constructs were identified. The co-citation analysis has shown a tight-knit—albeit small—group of papers that provide robust analyses on developing countries, green growth, innovation and development. Widening the search, the bibliographic coupling analysis demonstrated that, even though major gaps continue to exist, in recent years there has been an uptick in research in this area, particularly for lead markets and innovation-by-export, as well as papers that seek to explain the remarkable growth in renewable energy technologies supplied by

countries located in the Global South. These developments are welcome. Yet the literature continues to be dominated by research on (and by) the Global North research. Certainly much more research on developing economies is needed, especially considering the alarming growth in greenhouse gas emissions in developing countries. Finally, the keyword analysis provides important overviews of the key themes and keywords throughout the entire corpus. It demonstrates that China, not surprisingly, has become a major focus for research in this area, which is expected because of its prowess in environmental and clean technologies, consequent with its overt green growth strategies since 2010.

5. Limitations and conclusion

5.1. Limitations

There are some important and major limitations of this study. First, because these themes involve rapidly expanding topics—sustainable development, green growth, and green industrial policy—it is very difficult to cover all topics and give due consideration to their nuances. As best as possible, an attempt was made to draw-in the most important and salient topics for developing countries and the Global South. Yet, undoubtedly, important themes and research have been overlooked. In addition the literature search strategy, like the literature itself, remains tethered to concepts that were largely developed to explain how the Global North—rather than the Global South—has developed environmental policy and industrial policy to stimulate environmental innovation and diffusion. Thus, key mechanisms and definitions drawn upon in this paper are may not be particularly well-suited to deal with the much different economic, political and policy realities facing developing economies. As pointed out by Papaioannou (2014), innovations in the Global South behave much differently than the Global North. For example frugal innovations, which are not at all explored in the Global North research, demonstrate that other ideas, beyond cutting edge clean technology development, are indeed important (Gandenberger, Kroll, and Walz 2020). In addition justice concerns are frequently overlooked, even though these are very important concerns in the South. Finally, a more systematic literature review could provide quantative analysis of the clusters throughout each of the three analysis (co-citation, bibliometric, and keyword) as well as incorporate the hundreds of other articles that have recently been published. This might have the effect of demonstrating to researchers the centrality of seminal articles, themes, and keywords. However, to partly mitigate against these many limitations, a relatively unbiased machine-aided software package was deployed. The main benefit of this method is that it is fully reproducible and consistent with other systematic literature reviews.

5.2. Conclusion

In this systematic literature review paper, key green growth concepts were explored from the perspective of the Global South. A literature review was conducted based on these concepts followed by a discussion and synthesis. The policy needs for climate change and environmental destruction are multipronged. It is expected that the literature will

be both dense and fragmented. Likewise, there is much variation in policies, how firms react to such policies, and of course variation across the many countries throughout the world. Hence it is quite difficult to present a holistic overview of this literature without imparting some biases.

Nevertheless, this review has provided some much-needed analysis and synthesis of the key concepts, themes and, most importantly, the gaps that remain in the extant literature on green growth in the Global South. It is hoped that this paper will provide empirical and theoretical grounding to catalyse future researchers, especially researchers from the developing world, to undertake the important research tasks related to (1) how domestic green growth interacts with global climate and environmental policy imperatives; (2) how the Global South can 'catch-up' and 'leapfrog' with green growth and environmental innovation; (3) and finally how a special combination of all of these industrial policies and national innovation system competencies can enable the developing world to scale up their economies and transition to low-carbon trajectories. There is a growing imperative to explain how green growth can or does occur in the Global South, especially considering the alarming rate of emissions growth there. Indeed, if green growth is muted in the Global South, the likelihood of meeting the goals of the Paris Climate Agreement will be significantly diminished.

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