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The scientific system in the Global South in an emerging multipolar world

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Abstract The article analyses the changes and trends in the scientific systems of countries and regions in the Global South shifting the focus away from the BRICS countries. The research is underpinned by the critical scholarship on the globalisation, internationalisation and regionalisation of science and higher education. The empirical analysis is positioned within the broader changes in the international system characterised by multipolarity.

The article first aims to map and identify trends, processes and discourses characterising science in the Global South. Second, it aims to investigate and analyse challenges, changes and developments in the scientific system of countries and regions in the Global South by focusing on publications and regional/international collaborations. While knowledge based theories and discourses are informing science development and changes in countries in the Global South in line with global trends, this is not only done to sustain and increase economic competitiveness. Countries are seeking to reposition themselves in a changing international system by increasing their scientific and technological sovereignty through strategic publications and regional collaborations.

Keywords: science, globalisation, knowledge societies, multipolarity, regionalisation, Global South

The scientific system in the Global South in an emerging multipolar world.

Introduction

On January 27, 2023, 50 delegates from twenty-six countries gathered in Havana with the aim of launching a New International Economic Order (NIEO) [Progressive International 2023].¹ The Havana Congress agreed that central to this envisaged order would be a unilateral and coordinated Global South action on science, innovation and technology with the aim of ensuring technological sovereignty, as well as liberating knowledge and peoples (Progressive International 2023).

Over the past three decades, the importance of science, innovation and technology for economic growth and development has been emphasised by new growth and knowledge-based economy theories (Godin 2006; Godin and Gingras 2000; Leydesdorff 2010; Stiglitz 1999a; WB 2002, UNESCO 2005). During the same period, key trends and processes that have characterised higher education and science worldwide are the global increase in demand and provision of access to higher education (Calderon 2018); the growth, diversification, commercialization and privatisation of higher education institutions (Selenica 2018); the increase in global interaction, interconnectedness, mobility and collaboration (Geuna 2015; Ackers and Gill 2009); the growing use of technology (Bell and Pavitt 1997; Crespi and Dutrénit 2014); as well as processes of regionalisation and globalisation (Robertson 2014; Robertson and Kedzierski 2015; Fawcett 2017).

As part of these processes, higher education and science have undergone profound changes. The research seeks to analyse such changes and trends by focusing on the scientific system of countries and regions in the Global South. I position the empirical analysis within existing scholarship on the globalisation of higher education, the rise of knowledge-based economy theories and the hegemonic consolidation of knowledge-based economies and societies' discourses and imaginaries, as well as growing efforts of governments around the world to improve their domestic capacity in science, technology and innovation (STI). Changes in the scientific system in the Global South are placed within the broader context of an emerging multipolar world order. The research addresses the emergence of multipolarity of the international system from the angle of science in the Global South and is underpinned by the critical scholarship on the globalisation and regionalisation of science (Gomes et al. 2012; Robertson et al. 2012). Most of the research on

¹ Progressive International. (2023). "Havana Congress plans 'unilateral but coordinated action' to secure technological sovereignty for the Global South," 30 January 2023, <https://progressive.international/wire/2023-01-30-havana-congress-plans-unilateral-but-coordinated-action-to-secure-technological-sovereignty-for-the-global-south/en> last accessed 31 January 2023

science in the Global South has been focused on its role for emerging economies such as Brazil, Russia, India, China, and South Africa (BRICS). However, the dominant focus on these countries has led to the marginalisation in scholarship discussions of other countries and regions in Africa, Asia and Latin America. Moreover, most of the research has been informed by economic theories and investigated from economic scholarship and perspectives.

The paper seeks to address these gaps and has two main objectives. First, it aims to map and identify trends, processes and discourses characterising science in the Global South. Second, it aims to investigate and analyse challenges, changes and developments in the scientific system of countries and regions in the Global South by focusing on publications and regional/international collaborations. Overall, the paper aims to locate the above-mentioned scientific processes and trends within a changing world order characterised by multipolarity.

The research is based on primary and secondary sources, including academic and practitioners-related literature as well as databases and policy documents. It combines political economy analysis, in-depth literature review and textual analysis of key documents. The article compares research and development funding, performance and bibliometric data that are included in the statistical reports of international agencies such as UNESCO, World Bank and OECD. More specifically, the paper analyses data from the latest UNICEF Science Report (2021). Initially, the article used the category of 'emerging economies' for its empirical focus to refer to those emerging countries that were marginalised in academic discussions regarding the BRICS countries. The 'emerging economies' category is a contentious one, which is often used politically to reproduce power hierarchies as well as exclude countries such as Iran, Venezuela and Cuba. In this article, it has now been replaced by the 'Global South' category as the latter is a more all-encompassing and inclusive one and better reflects the empirical focus of the research.

The paper is structured as follows. The first three sections focus respectively on (1) knowledge-based economy theories and discourses, (2) globalisation, higher education and science, and (3) multipolarity and regionalisation. Section four analyses national and regional scientific trends, processes and discourses in the Global South. Section five analyses patterns of publications and scientific collaborations. Section six presents some conclusions and identifies questions for further research.

1. The rise of knowledge-based economy/society discourse and imaginary

In its seminal 1998 report, UNESCO argues that the 21st century society is “increasingly knowledge-based, and higher education with its components of learning and research has become crucial for the cultural, socio-economic and political developments of individuals, communities and nations.” (1998, 2) Over the last two decades, higher education and science have been regarded as key drivers underpinning development in low-income and developing countries (Naidoo 2011, 40). This has been supported and promoted by a significant policy shift among the agendas of international organisations such as the World Bank (WB), the Organisation for Economic Co-operation and Development (OECD), the European Union (EU), and UNESCO, following decades of under-investment in tertiary education influenced by the low rates of social and economic return WB theories (WB 2002; TFHES 2000).

The change in approach resulted from the recognition that the gap between developed and developing countries depended to a large extent on knowledge disparity rather than capital scarcity (Stiglitz 1999b, 588). The view that knowledge and innovation can be mobilised and used for economic development by developing countries, thus leapfrogging traditional developmental stages, is an assumption common to a range of knowledge-based economic set of theories (Bell 1968; Carayannis and Campbell 2011; Foray 2004; Stehr, Adolf and Mast 2020; WB 1998). The role of universities for the upgrading of less developed countries and for their technological and economic growth has been recognized by a range of studies within the knowledge-based economy debate (Mowery and Rosenberg 1999; Murmann 2003; Brundenius et al. 2011; Conceição and Heitor 1999; Deiacio et al. 2012). This contribution, the scholarship argues, is either realised through university-industry linkages (De Fuentes and Dutrenit 2012), spinoffs (Benneworth and Charles 2005; Chen and Kenney 2007; Kroll and Liefner 2008) or through the creation of a skilled workforce (Bell and Pavitt 1997).

More specifically, the debate about the role of science, innovation and higher education for developing countries has been dominated by studies investigating the contribution and relevance of science in the rise of emerging economies such as the BRICS countries. These countries have developed their national innovation system through substantial investment of R&D expenditure and personnel, patents and high-tech (Sesay et al. 2008; Daniels et al. 2017). Their rapid economic growth has relied on strategies that connect science with business, incentivising innovative activities, and combining the import of technology with internal R&D efforts (Sesay et al. 2018). Several studies have analysed the relationship between development, catch up processes and science (Nguyen and Choung 2020). Scholars have used R&D expenditure as an indicator to map

and confirm catching up dynamics and trends and as a way to analyse the level of development of countries (Furman and Hayes 2004; Mazzoleni and Nelson 2007). The Chinese scientific development has been underpinned by a focus on intensively building domestic capacities over the last three decades. By contrast, other developing countries such as India, Iraq and Pakistan that have relied on the best practices and scientific growth of advanced countries have not achieved similar scientific and developmental advantages as China (Goldember 1998).

Another WB Report *Accelerating Catch-up: Tertiary Education for Growth in Sub-Saharan Africa*, further reiterates the link between higher education, science, knowledge and catch-up processes (WB 2009). It proposes to address some of the difficulties in balancing the market for tertiary-level education and skills through the regionalisation of private higher education provision (WB 2009). According to Susan Robertson, WB's new role has been part of a new multilateral agenda in higher education in developing countries, which inaugurated and legitimated a period of international and transnational interventionism and agenda-setting in national education systems (Robertson 2009). More specifically, the concept of knowledge economy or knowledge-based society "not only legitimates the Bank's policy reversal on the value of higher education, but it has enabled an articulation with capacity discourses and projects that provide a platform for trade agendas to be prioritised." (Robertson 2009, 120)

2. Globalisation, higher education and science

In the report *Constructing Knowledge Societies*, the WB introduced new concepts such as globalisation and the knowledge economy, putting them at the core of development strategies (WB 2002). As a matter of fact, over the last three decades, higher education has undergone profound processes of globalisation and regionalisation. As the imaginary of knowledge-based economy and society has gained traction, economic advantage and competitiveness are increasingly based on the consumption and production of knowledge (Selenica 2018). The discourse of knowledge economy and the process of globalisation have underpinned the transformation and internationalisation of science and higher education at the national, regional and global level (OECD 2014).

For this article, I rely upon the literature known as the 'globally structured agenda for education', which has focused on the global nature of higher education agenda-setting and policy-making/implementation and has extensively and critically investigated these processes (Dale 2000; Verger et al. 2012; Verger et al. 2016). Such scholarship has analysed the factors, causes, and agents behind the globalisation of higher education policy by focusing in particular on the role of

international organisations and donor agencies. Central to this literature is the idea that “processes of globalization have drastically altered the education landscape across the world and, more particularly, in the context of developing countries.” (Verger et al. 2012, 4) For this scholarship, economic globalisation is the driving force behind the transformations occurring in higher education (Dale 2000).

The current globalisation of higher education and science is global in reach and pervasiveness as a result of the accelerated diffusion of innovation and technology and it is based on the assumption that science and research are crucial for the production of knowledge in an era where knowledge-based economy is central to the development and expansion of globalisation. Globalised higher education and science has undergone significant changes and has been characterised by a series of policy issues and topics such as international academic mobility and interdependence, institutionalised global competences transposed through policy tools and governance instruments operating at global, regional and national scales (Robertson and Komljenovic 2016; Robertson 2014). Several scholars have critically scrutinised the global dynamics of higher education and science particularly focusing on market-mechanisms like competition and choice to generate greater efficiency, as well as the proliferation and penetration of private-for-profit actors in and across higher education and science (Robertson et al. 2012; Robertson and Kedzierski 2015; Verger et al. 2016). Higher education and science are at the heart of neoliberal globalisation, as knowledge-producing areas in an era dominated by the discourse and practice of knowledge-based economy and society (Jessop et al. 2008).

Scholars have shown that both the transformation of science and higher education as a result of discourses such as knowledge-based economy and processes such as globalisation on the one hand, and the role played by states, international organisations, and other social forces and factors (i.e., global market competition) on the other, differ across countries and regions. In the Global North, the transformation of higher education has entailed the introduction of audit and market mechanisms (Naidoo 2011, 43). By contrast, in China and other emerging Asian economies, states have tied the expansion of science and higher education to national development strategies, as well as to increasing national competitiveness at the global level (Vidovich et al. 2007). The globalisation of knowledge and the growth and diffusion of new technologies have furthered inequalities in marginalised regions and peripheries. I use the globalising lens in this article, which I complement and juxtapose to recent developments in the scientific systems in countries in the Global South.

3. Multipolarity and regionalisation in a changing world order

Multipolarity has emerged as a category framing and explaining a number of geopolitical challenges and changes of the last fifteen years. Processes and events such as the rise of China, the Arab springs and the national and regional reconfigurations of the Middle East and North Africa, the emerging BRICS, the decline of the United States, and the Russia-Ukraine war have led to discussions and academic debates on the international configuration of power. Whether the world is transitioning from liberal US-led unipolarism towards a post-liberal multipolarism is a puzzle addressed by many analysts and International Relations scholars.

While the concept is not new and has been used at least since the aftermath of World War II, in its current phase it refers to an international system characterised by multiple poles of power, polarity referring both to nation-states as well as regional and international entities and organisations, all competing or collaborating for influence. The first BRICS Summit in June 2009 called for a more democratic and just multipolar world order. Other BRICS communiqués have also reiterated this call. Similarly, the UN Secretary-General Ban Ki-moon declared in 2013 at Stanford University that we are moving increasingly and irreversibly to a multipolar world (Ban Ki-moon 2013).

The assumption of a world order characterised by tectonic shifts does not refer only to the rise of nation-states such as the BRICS but also to the proliferation of regional organisations and the acceleration of processes of regionalism since the end of the Cold War (Fawcett and Hurrell 1995; Fawcett 2004; Fawcett 2010). Processes of regionalisation and the rise of a range of regional projects and dynamics have also been analysed in relation to the higher education sector and student mobility (Robertson 2014; Robertson et al. 2012; Robertson and Kedzierski 2015). Asia is at the heart of regional projects related to students' and researchers' mobility (Robertson and Kedzierski 2015). Other overlooked regions such as Latin America and Africa have also engaged in fostering student mobility through a number of region building projects and initiatives funded by the European Commission (Robertson 2014). By investigating patterns of regional scientific collaborations, often as a result of crises such as COVID 19 or other structural challenges that have a regional dimension, this article aims to contribute to the above mentioned scholarship.

4. National and regional trends in the scientific system of countries in the Global South

The section aims to identify national and regional trends in particular by focusing on discourses, challenges and priorities that are shaping science in the Global South. Science is reconfigured across countries and regions and it is closely linked to economic and socio-political processes and structures. An analysis of national and regional trends shed light on simultaneous processes of competition and collaboration/convergence within and among countries in the Global South, as well as topics and discourses underpinning such processes. Lastly, it unravels a number of challenges that are both reflected in and addressed by science.

4.1. *Artificial intelligence and space in a multipolar world order*

China, the Russian Federation and the USA are competing for global leadership in the field of Artificial Intelligence (AI). However, a number of countries in the Global South are also repositioning themselves in this global competition. Among Gulf States, Saudi Arabia and the United Arab Emirates have adopted national AI strategies, while Arab states such as Algeria, Egypt and Tunisia are planning to do so (Alesia et al. 2021). In Sub-Saharan Africa, Cameroon has the highest number of publications per million inhabitants on AI and robotics and on energy-related fields, with a publication intensity four times higher than that of South Africa in the above-mentioned areas (Kingiri and Onana 2021).² Ecuador's research output on artificial intelligence (AI) and robotics has been growing by a rate of 9%, one of the highest in the world: between 2012 and 2015 scientists published 248 articles on the topic while between 2016 and 2019 they produced 2208 publications.³

Another field where patterns of collaboration and competition intertwine is the aerospace industry. The exports of aerospace products progressed by 14% per year between 2010 and 2016 in Mexico.⁴ The African Space Strategy based upon earth observation, navigation and positioning systems, satellite communications and space science and technology aims to create an African Space Agency to be based in Egypt (Schneegans et al. 2021, 51). In this regard, the signing of a cooperation agreement between the African Union and the EU's Copernicus programme in 2018 underpinned the launch of the African Outer Space Programme in 2019.⁵

4.2. *Science, innovation, digital economy and indigenous development*

² <https://www.nature.com/nature-index/country-outputs/Cameroon>, last accessed 24 January 2023

³ <https://www.nature.com/nature-index/country-outputs/Ecuador>, last accessed 24 January 2023

⁴ <https://www.trade.gov/country-commercial-guides/mexico-aerospace>, last accessed 24 January 2023

⁵ United Nations. (2018). "African Union signs Cooperation Agreement with EU Copernicus Programme", 8 February 2018 <https://www.un-spider.org/news-and-events/news/african-union-signs-cooperation-arrangement-eu-copernicus-programme> last accessed 20 January 2023

The identification of innovation and digital economy as engines of growth is a key topic and discourse that is shaping the configuration of science in regions across the Global South. This is expressed through innovation funds and initiatives across the Black Sea countries, such as the single Republican Centralised Innovation Fund (Belarus) and the Innovation Agency (Azerbaijan). In Central Asia, Uzbekistan has placed innovation-based development at the top of the political agenda. Cambodia, Indonesia and Thailand are focusing on the development of economic zones that could attract investment and foster innovation (Suleimenov 2021). Similarly, the Cuban National Plan for Economic and Social Development, has made innovation a key priority (Ministry of Economy and Planning 2019). In this regard, the Mexican government has shifted to a form of innovation that decreases the role played by the business sector. This has entailed in practice that the National Council of Science and Technology (CONACYT) is not funding private business ventures while still engaging in PPP such as the Querétaro Aerospace Cluster.⁶ The government is focusing on promoting basic science through the establishment of a new programme Frontier Science, co-ordinated by CONACYT. Moreover, it has centralised the governance systems of science, technology, innovation, academia under CONACYT.

Science and innovation are also used by countries to decrease reliance on foreign expertise and boost national development. Bangladesh aims to produce the main chemical components of drugs by itself with the launch of the Active Pharmaceutical Ingredients Industrial Park in Munshiganj, expected to be operational by 2023, (Khan 2020).⁷ Similarly, Sri Lanka has launched a new pharmaceutical manufacturing plant in 2020 in the framework of a public private-partnership. In Latin America, countries are experimenting with policies that integrate indigenous and local knowledge systems stressing social innovation for sustainable development. In Paraguay, science and sustainable development seem to be linked as it is suggested by the effort to implement a national reform transforming the country into a carbon-neutral economy by 2050. Approximately, 75% of the funding stemming from science and innovation policy instruments target applied research. Moreover, one-third of research expenditure targets natural sciences, engineering and technology, while more than half targets agriculture, health and environmental sciences (Dutrénit et al. 2021).

⁶ The Querétaro Aerospace Cluster is a successful case in point in Mexico's recent developmental approach to science. The government has played a key role to its success by supporting innovation through public policies, subsidies and infrastructure development.

⁷ Khan, S. (2020). "API Park to boost export of medicines." The Financial Express, 11 July 2020

<https://www.thefinancialexpress.com.bd/views/api-park-to-boost-export-of-medicines-1594485666> last accessed 20 January 2023

4.3. ***Knowledge, technological hubs and centres of excellence in countries and regions in the Global South***

Knowledge-driven development is another key discourse shaping countries' economic strategies. This has informed the development of knowledge, research and technological hubs across countries and regions. Iran has seen a substantial growth in knowledge-based firms and starts-ups, as a result of both internal demand and the creation of technology incubators and innovation accelerators (Schneegans, Lewis and Straza 2021, 66). By 2020, 49 innovation accelerators have been set up with private equity while 113 innovation centres have been established between science parks and universities in Iran (Schneegans, Lewis and Straza 2021). The number of tech hubs in West Africa has been growing with the respective countries hosting several of them: Burkina Faso (10), Cameroon (28), Ghana (36), Côte d'Ivoire (30), Nigeria (101), Mali (11), Senegal (22) and Togo (21) [Essegbey et al. 2021].⁸ Supported by a World Bank project, Ethiopia, Kenya and Uganda have established centres of excellence focusing on climate-smart agriculture, agro-ecology, biodiversity protection, medicine and water management (Shneegans, Lewis and Straza 2021, 68). Ethiopia, which hosts the Africa Centres for Disease Control and Prevention, is focusing on innovative drug development and the development of a pharmaceutical industry. Rwanda hosts several centres of excellence, one supported by the World Bank and focusing on energy research, mathematics, the Internet of Things and data science, and another one—the East African Institute for Fundamental Research—established in a joint project with the UNESCO Abdus Salam International Centre for Theoretical Physics that focuses on AI-related fields (Kingiri and Onana 2021). In 2020, 12 Central and East African countries hosted 166 active tech hubs with 42% of them located in Kenya (Kingiri and Onana 2021).

4.4. ***Structural challenges and the reconfiguration of scientific priorities***

Countries in the Global South are dealing with a number of global and structural environmental challenges and this has been translated into a re-configuration of their scientific systems and priorities. Arab States are addressing water scarcity, soil erosion and environmental degradation by focusing on science-based solutions, in particular indoor vertical farming, desalination and large-scale solar plants (Aleisa et al. 2021).

⁸ Financial stability remains a challenge for the majority of the 844 African start-ups and technological hubs, which rely on funding sources from development partners and international donors. Nigeria has 101 tech hubs and 80% of their investment comes from offshore sources.

Renewable energies have emerged as a key priority across regions and countries in the Global South. While the mining sector represents the bedrock of Central Asian economies, governments are investing in renewable energy programmes such as the ‘solar auctions’ in Kazakhstan and Uzbekistan. Renewable energy has also become a key sector in Iran (Sadreghazi 2021). In Central and East Africa, Kenya and Ethiopia are also focusing on renewable energy: in Kenya geothermal power reaches 35% of households, while Ethiopia has almost completed the Grand Ethiopian Renaissance Dam (Kingiri and Onana 2021). West African countries are restructuring their economies and their scientific systems to tackle climate challenges. Senegal is using state oil and gas revenues to support SMEs focusing on solar energy, agriculture and health. In partnerships with the African Development Bank and the World Bank, countries are expanding and investing in different energy projects and increasing the share of renewables in the region. Next to hydropower projects, countries are exploring other sources and forms of energy policies such as nuclear energy. As a result of climate-change related drought and flooding, several countries in Africa are prioritising climate-smart agriculture practices and policies such as the Zambia’s Climate-Smart Agriculture Investment Plan (2019) [Kraemer-Mbula et al. 2021] In Bolivia, the National Science, Technology and Innovation Plan (2013) has envisaged the incorporation and intertwinement of indigenous and local knowledge with modern science for the solution of systemic crises, such as climate change. Science is playing a key role as part of Ecuador’s *National Development Plan 2017-2021: Toda una Vida*, envisaging among others the inclusion of ancestral knowledge alongside scientific and technological knowledge (Dutrénit et al. 2021, 223). In line with a regional trend among other Latin American countries, over the last decade Ecuador has been prioritising energy infrastructure and supporting the transition from thermal to renewable energy sources, as it is shown by the strong growth in scientific publications on smart-grid technology (152%).

5. Towards a multipolar geography of science? Knowledge output and scientific collaborations

Over the past five years, developing countries are diversifying their economies by making them more knowledge-intensive, making science increasingly synonymous with economic competitiveness (Naidoo 2011; Jessop et al. 2008). In this regard, countries are using different strategies such as doubling the research intensity, increasing the number of full-time equivalent researchers, or increasing the share of publications in fields such as physics and astronomy through

international collaborations. Overall research investment has outpaced global economic growth. Patterns and trends of international and regional collaborations in the Global South are analysed in the following two subsections focusing, on the one hand, on publications and intra-regional scientific collaborations in terms of co-authorships and, on the other, on regional research initiatives and partnerships.

5.1. ***Patterns of scientific output and co-authorships in the Global South***

Open science is considered as a key factor for achieving the UN Sustainable Development Goals by 2030 and “a powerful tool to bridge the science divide between and within countries” (Persic et al. 2021, 16). However, large inequalities persist, given that more than 70% of publications remain inaccessible to the majority of the world’s scientists (UNESCO 2021). According to a study by Gui et al., “[s]cience is happening in more countries, although the spread is geographically uneven. The geography of global science is evolving from a bipolar world to a tripolar pattern, and there are shifts in relative terms from the West (Europe and the USA) towards the East (Asia-Pacific), and from the Global North (established economies) to the Global South (emerging economies),” as figure 1 below illustrates (2019, 1615). In 2000, the global science output, based on the number of publications that are visually represented in the map as affecting the size of each country, was geographically dominated by North America and Europe forming a bipolar world. Fifteen years later, the geography of science has substantially changed with the rise of the Asia-Pacific region and the shifts from a bipolar science world to a tripolar one. The global scientific output is now driven by Europe, North America and Asia-Pacific, with China becoming the second largest science superpower (Gui et al 2019, 1616). The Asia-Pacific region hosts six countries in the world top 20 for science production. Moreover, countries from other regions such as Brazil (South America), South Africa and Egypt (Africa), Turkey, Iran and Saudi Arabia (West Asia) are also rising in the global scientific output, confirming the shift towards a more multi-polar world science-wise.

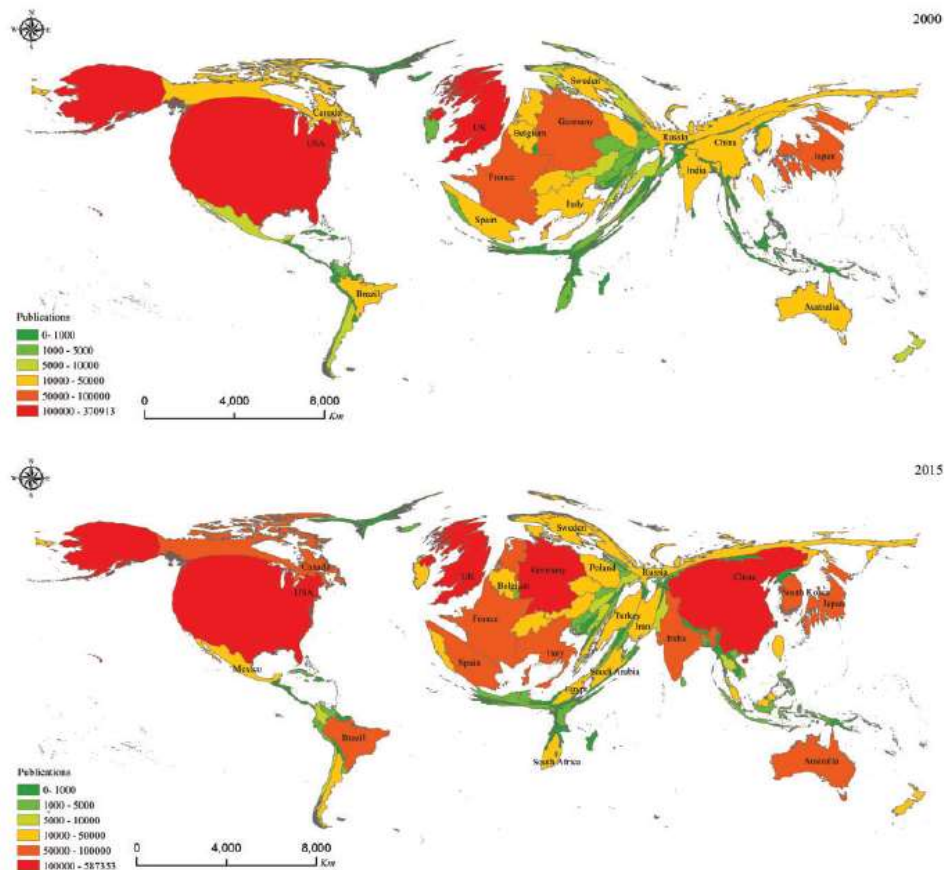


Figure 1. Spatial patterns for global science by country or region (2000-2015). Source: Gui et al. 2019: 1616

According to Straza and Schneegans, “the relationship between publication output and development pathway is neither direct, nor a one-way street. Although trends in publication output can reflect government prioritization trickling down through research funding, scientific publications alone are not causative of societal change.” (Straza and Schneegans 2021, 83) In Central Asia, there is a clear relationship between national priorities and trends in research outputs, given the specialisation of the respective countries in transboundary water management.

While in 2019, the EU (28.6%), China (24.5%) and the USA (20.5%) combined accounted for three-quarters of the global scientific production, thirteen countries contributed further for 1% or more of publications: India (6.1%), the Russian Federation (3.7%), Brazil (2.8%), Iran (2.3%), Turkey (1.6%), Indonesia (1.4%), Malaysia (1%) and Saudi Arabia (1%) [Schneegans et al. 2021, 55]. Indonesia and Saudi Arabia experienced substantial rises in the shares of global scientific outputs between 2011 and 2015.

For low-income countries, overall scientific output grew by 71% and surged by 170% for cross-cutting technologies (Schneegans et al. 2021, 55). During 2015-2019, the four fastest growing fields in countries in the Global South were AI and robotics, energy, materials science and nanoscience. More specifically, the shares of developing countries in the global scientific output on AI and robotics surged. In 2019, Cameroon had the highest publication intensity in AI and robotics in the subcontinent.⁹ Ecuador's scientific output showed the fastest growth rate in Latin America (152%): between the periods 2011-2015 and 2016-2019, the scientific output of Ecuador on robotics and AI grew ninefold, representing one of the highest rates in the world.¹⁰

The second-fastest growing field is energy, which is the top field for Egypt, Saudi Arabia and South Africa. Materials science ranked first for Indonesia. Sustainability topics account for greater shares of national output by developing science systems, in particular in Indonesia, Ecuador and Iraq during 2016-2019 (Schneegans, Lewis and Straza 2021, 43). Over the last decade, the global share of publications on photovoltaics in lower-income countries and low-income countries have increased respectively from 7.6% to 21.6% and from 0.2% to 1.4% (Schneegans, Lewis and Straza 2021, 43).

According to UNESCO, "developing countries showed strong specialization in research related to the Sustainable Development Goals," with a particular focus on floating plastic debris in the ocean (UNESCO 2021, 78). At the global and national levels and across both developed and developing countries, the great majority of scientific publications focus on health research (in Ghana 49% and USA 48%). Sustainability research has been reactive rather than proactive, in particular research on new or re-emerging viruses. Liberia, Sierra Leone and the Democratic Republic of Congo have experienced a growth in the scientific output related to new or re-emerging viruses that can infect humans. Liberia's publications on this topic grew from 33% between 2012-2015 to 133% between 2016 and 2019, a research intensity that is 144 higher than the global average (Straza and Schneegans 2021, 80). Between 2011 and 2019, Liberia, Guinea and Sierra Leone had the strongest specialisation in the world on emerging viruses. Much of the publications were the result of international collaborations, accounting for 70% of scientific publications in low-income countries (Straza and Schneegans 2021, 80). The top ten countries for growth in scientific publishing on new or re-emerging viruses between 2011 and 2019 were Brazil, Colombia, Pakistan, Sierra Leone, DRC, Guinea, Lebanon, Liberia and Cameroon. Iraq is emerging on many SDG-related topics, in particular

⁹ <https://www.nature.com/nature-index/country-outputs/Cameroon>, last accessed 24 January 2023

¹⁰ <https://www.nature.com/nature-index/country-outputs/Ecuador>, last accessed 24 January 2023

in areas where it has had a pre-existing specialisation such as health, desalinisation, wastewater treatment and solar photovoltaics (Strazza and Schneegans 2021). Indonesia is the other country that has tripled its scientific output between 2011 and 2019 for 40 SDG-related topics. This is related to the national policy of linking publication of research in indexed journals to the scientists' career performance (Scott-Kemmis et al. 2021).

Sustainable alternatives to plastics have been the second fastest growing research topic for Sub-Saharan Africa between 2012-2019. On the same topic, the scientific output of Indonesia, Malaysia and Thailand has increased five times the global average intensity in 2019 (Strazza and Schneegans 2021, 89). Other countries that have seen their scientific output on this topic growing are Brazil, India, Iran and Nigeria. Tropical communicable diseases and HIV research are among the top five topics for Sub-Saharan countries (Strazza and Schneegans 2021, 89). Research output on the impact of soil, freshwater and air pollution on human health has been doubling in Sub-Saharan Africa (from 523 during 2012-2015 to 1085 during 2016-2019). In Central and Southeast Asia, freshwater management represents a growing research focus in terms of scientific output. In Sub-Saharan Africa, there is an increasing research focus on the impact of climate hazards on local communities, the topic showing the tenth-fastest growth rate in the region. Climate-ready crops are another fast-growing research topic in Sub-Saharan Africa. Other developing countries whose scientific output on climate-ready crops have been growing are Mexico, Ethiopia, Ghana, India, Kenya, Mali, Mozambique and Senegal.

The scientific output on renewable energy has been particularly growing in lower middle-income countries. Ethiopia, Nigeria and South Africa are leading publications on battery efficiency in Sub-Saharan Africa. E-waste research is growing in Africa with Ghana, Nigeria and South Africa leading the field (Maphosa and Maphosa 2020). Other African countries whose output on this topic is growing are Ethiopia (9.3% growth rate), Mauritius, Cameroon, Mozambique, Uganda and Zimbabwe (Strazza and Schneegans 2021, 100).

Sustainability science has become a key focus of policy-making and research in Latin America (Aguirre-Bastos et al. 2019). Researchers in Latin America publish a higher proportion of papers than the global average on topics such as smallholder producers, traditional knowledge and biodiversity management (Dutrénit et al. 2021, 213). In Latin America, scientific output in scientific journals increased by 25% between 2015-2019, with Ecuador (171%), the Dominican Republic (98%), Honduras (97%) and Peru (85%) having experienced significant growth rates in terms of publications. The significant growth in scientific output in Ecuador is related to an improvement of

postgraduate education and policies that have been designed and successfully achieved to attract foreign researchers to Ecuadorian universities. Paraguay's scientific output grew by 72% in the period 2015-2019. Over the last decade, Cuba and Venezuela have experienced a drop in the volume of scientific publications. While Spain and the United States stand as key international partners in co-authorships, there exists a level of intra-regional co-authorship; in this regard, Brazil is a partner for 13 countries, Mexico for 10 and Colombia for 4. As a general trend, the largest countries in Latin America tend to author more with the United States and Europe.

International co-authorships have been growing, with a trend of intra-regional scientific collaboration among scientists in developing countries as shown by figure 2 below. Large diasporas are also boosting co-authorships and international scientific collaboration as is the case of Pakistani scientists that are based in Saudi Arabia (Osama et al. 2021). In Latin America, Brazil and Peru are among Colombia's top five scientific partners. During the period 2017-2019, Ghana was among the top five scientific partners for Burkina Faso, Liberia and Sierra Leone; Uganda was among top five scientific collaborators for eight sub-Saharan countries while South Africa was among top five scientific collaborators for 23 African countries (Schneegans, Lewis and Straza 2021, 59).

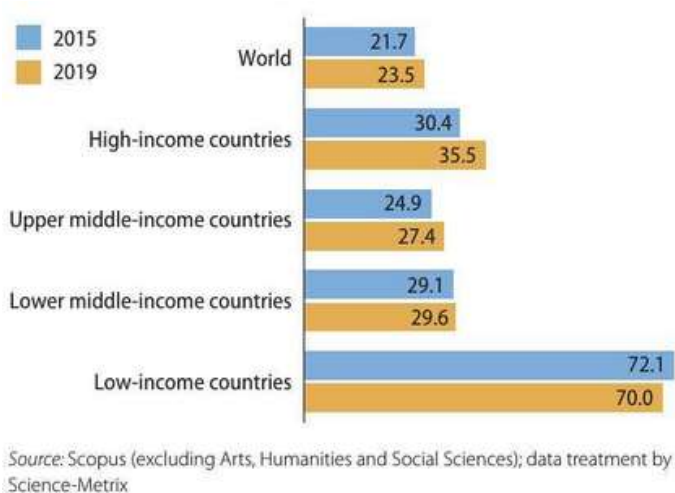


Figure 2. Share of publications involving co-authors from two or more countries in 2015 and 2019 (%). Source: Persic et al. 2021, 12

Between 2015-2019, the level of international scientific collaborations in low-income countries remained high, respectively 72% in 2015 and 70% in 2019 (Schneegans, Lewis and Straza 2021). Region-wise, South and South East Asia have the lowest levels of scientific collaboration with less than 25% (Schneegans, Lewis and Straza 2021). In 2019, Malaysia (44%), Pakistan (56%) and Singapore (71%) had some of the highest ratios of international scientific collaborations in Asia. In

Iran, the ratio of international co-authored publications during the period 2015-2019 increased from 21% to 28% (Shneegans, Lewis and Straza 2021, 58). In South East Asia, the recent publishing record reflects stronger bilateral ties among ASEAN scientific communities, with research intensity improving in Malaysia, Thailand and Viet Nam.

5.2. ***International and regional scientific collaborations in the Global South***

The participation of countries in broader regional and international research and technological initiatives and partnerships is a key trend characterising the development of science across countries and regions. Turkey's geothermal industry is growing due to the participation of Turkish geothermal power companies in the EU's Horizon programme in research consortia; the number of geothermal power plants increased from 3 to 49 in the period between 2009-2019 (Schneegans, Lewis and Straza 2021). West African countries are addressing weather patterns and food insecurity through the development of expertise on climate science (Essegbey et al. 2021). In this regard, the Economic Community of West African States (ECOWAS) and the German government are collaborating to create the *West African Science Service Centre on Climate Change and Adapted Land Use*, which is envisaged to include a Climate Research Programme and a Graduate Studies Programme.

The outbreak of the COVID-19 pandemic has stimulated several bottom-up initiatives and created new models of regional cooperation in Latin America. One of them is the Solidarity Call to Action, a voluntary patent pool launched by Costa Rica and WHO on 29 May 2020, serving as a platform for vaccines, medicines or other tools needed to cope with COVID-19 and that could be manufactured in signatory countries¹¹ (Dutrénit et al. 2021, 201). Mercosur launched a similar initiative making available US\$ 16 million supporting a coordinated approach to the pandemic through research and funding.

Latin America is at the forefront in terms of collaboration and integration processes such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership. In 2015, the EU and ECLAC blocs adopted an action plan for scientific cooperation and researcher mobility with the aim of expanding it towards the creation of a common research area. Under the Horizon 2020 programme 27 joint project proposals were selected for evaluation with topics ranging from personalised medicine, to bioeconomy and the "establishment of an international network of

¹¹ Chile was the first to enter the pool followed by Argentina, Belize, Brazil, Dominican Republic, Ecuador, El Salvador, Honduras, Mexico, Panama, Paraguay, Peru and Uruguay

research centres in social science.” (Dutrénit et al. 2021, 204) SICA has also actively supported scientific cooperation through an agreement with Canada’s International Development Research Centre to strengthen the policy-making capacities of the national research and innovations centres of SICA’s states. While the region has been characterised by geopolitical heterogeneity and disunity, regional scientific bodies such as the Open Science Forum for Latin America and the Caribbean and ECLAC have promoted scientific collaboration through meetings and conferences. Other initiatives that have boosted multilateral cooperation in science are the Association for Aeronautics and Space (ACAE) developed by a Costa Rican team and the Argentine-Brazilian Center for Biotechnology (CABBIO). Lastly, the Ibero-American Programme of Science and Technology for Development (CYTED) is another bottom-up initiative that aims to increase multilateral scientific collaboration in Latin America by facilitating the interaction and flow of knowledge among research networks.

South Africa has contributed to increasing collaborative research among African countries through the South African National Research Foundation’s participation as one of the three sponsors of the Science Granting Councils Initiative, which was launched in 2016 together with the Canadian International Development Research Centre and the UK Department for International Development.¹² Other regional initiatives that have stimulated scientific outputs are the *Southern African Development Community’s Regional Climate Change Programme* (Kraemmer-Mbula et al. 2021) and the *West African Science Service Centre on Climate Change and Adapted Land Use* (Essegbey et al. 2021). In West Africa, climate-related research has been growing supported by regional initiatives such as the *Africa Higher Education Centers of Excellence* programme, in particular the *West Africa Centre for Crop Improvement at the University of Ghana*. Another initiative supported by a \$ 50 million German grant is the *West African Science Service Centre on Climate Change and Adapted Land Use* that includes doctoral programmes at universities at the regional level (Essegbey et al. 2021). The World Bank has supported the *Centres of Excellence Programme in East Africa*, more specifically one centre specialising in climate-smart agriculture at Haramaya University in Kenya and one specialised in agro-ecology and livelihood systems at the Uganda Martyrs University (Kingiri and Onana 2021).

An example of multilateral regional collaboration is the *Central American Integration System* (SICA) aiming to build resilience to climate change. Other regional, bottom up initiatives have been focusing on biotechnology, space science and open science (Schneegans, Lewis and Straza 2021, 63). International collaboration with foreign research groups has played an important role in

¹² <https://sgciafrica.org/> last accessed 22 January 2023

astronomy-related research in Latin America. The European Southern Observatory (ESO) in Chile is supported by 16 European countries. ESO has been constructing the largest telescope on earth, the 39-metre Extremely Large Telescope (ELT) at Cerro Armazones expected to be completed in 2025 and whereby many cutting-edge European companies are contributing to its construction. Similarly, 500 researchers from 17 countries are involved in the Pierre Auger Cosmic Ray Observatory in Argentina, a joint observatory initially launched by Argentina, Brazil, Bolivia and Mexico, with more than 17 countries and 500 researchers currently collaborating in the project (Dutrénit et al. 2021, 213). Other cutting-edge projects include the Mexico Marge Millimeter Telescope jointly designed by Mexico's National Institute of Astrophysics, Optics and Electronics (INAOE) and US' University of Massachusetts. The Telescope is part of the Event Horizon Telescope (EHT), itself a collaboration of 347 scientists from 60 institutions located in 20 countries.

6. Conclusions

Scientific changes and developments in the Global South confirm previous studies from the critical scholarship on the globalisation and regionalisation of science and higher education concerning the persistence of the hegemonic discourse of knowledge economy/society underpinning national scientific and policy developments as well as the rise of regional and international collaborations occurring at different scales and taking different forms. However, the paper also revisits some of the assumptions of this literature as far as the role of international organisations and global templates are concerned. In line with the scholarship investigating the relationship between science, innovation and development in the BRICS countries, this article shows that national governments in the Global South are playing a more active role in their national scientific systems and therefore using science and knowledge to: first, reposition themselves at the regional and international levels and increase their sovereignty in the economic and political international order; second, tackle structural and developmental national and regional challenges.

This double imperative and pressure in the way science is used by countries in the Global South illuminates some of the contradictions that are at the heart of neoliberal global discourses, theories, policies and practices—advocated and promoted by a range of international organisations—which have shaped developmental and higher education strategies in the Global South. What can be argued to be in continuity with KBE theories and discourses is the underlying understanding and expectation that knowledge (outputs), innovation, and technology will not just

boost national development and growth, but also help countries in the Global South to leapfrog developmental stages, ultimately addressing huge structural asymmetries between developed and developing countries in the global political economy. What, by contrast, can be seen as being in discontinuity with such theories and discourses and perhaps representing an emancipatory potential for the role of science in the Global South, is that science is often linked to the local and contextual needs of addressing challenges affecting these countries, rather than just as a tool of increasing or maintaining competitiveness at the regional and international level.

As the research has shown, countries in the Global South are dealing with a number of structural challenges which are reconfiguring scientific priorities, such as the climate crisis, the transition to renewable energies, water management, and environmental degradation. Several Latin American countries are at the forefront of combining ancestral and indigenous knowledge with scientific knowledge. The imperative that science must integrate different systems of knowledge emerges from the national development policies of several countries. Countries such as Bangladesh, Sri Lanka, Nicaragua, Paraguay, Peru, Mexico are using sustainable science and innovation to boost indigenous development and reduce reliance on foreign expertise and technology.

However, the analysis of publications suggests that countries in the Global South are also using science to boost and sustain economic competitiveness. One of such strategies is the increase in the share of publications in fields such as physics and astronomy through international collaborations. In terms of knowledge output and publications, the current world is a tripolar one, undergoing shifts from the West to the East and from the Global North to the Global South. While science is happening in more countries, the spread is geographically, financially and materially uneven.

In terms of regional and national scientific trends, the data analysed has shown simultaneous processes and patterns of competition and collaboration within and among countries in the Global South. Science is a contested field that reflects and furthers multipolar competition while at the same time is underpinned by collaborative patterns. Artificial Intelligence, quantum technologies and aerospace have emerged as key fields of competition and collaboration. Beside China, the US and the Russian Federation, other countries that are competing on AI comprise several Gulf States, Arab States such as Algeria, Egypt and in Tunisia, Cameroon in Sub-Saharan Africa, as well as Ecuador in Latin America. In Africa, a number of regional initiatives in the aerospace industry reflect the potential for international and intra-African scientific collaborations.

Scientific innovation as a growth engine remains a key discourse shaping the configuration of science through national and regional initiatives in the Black Sea, Central and Southeast Asia and Latin America. Knowledge-driven development is another key discourse, often intertwining and overlapping with innovation, shaping countries' economic and scientific strategies. This is reflected in the proliferation of research and technological national and regional hubs in Iran, on the one hand, and in West, Central and East Africa regions, on the other hand. The extent to which these tech hubs are supporting national development is a key question that needs further investigation in future research.

The participation of countries in broader regional and international research and technological initiatives and partnerships is a key trend characterising the development of science across countries and regions in the Global South and further confirms the multipolar nature of science development. Latin America is at the forefront in terms of collaboration and regionalisation processes and this trend further corroborates previous scholarship on the regionalisation and globalisation processes affecting higher education both globally and in specific regions such as Latin America (Robertson 2014; Robertson et al. 2012). In Latin America, the outbreak of the COVID-19 pandemic has stimulated several bottom-up initiatives and created new models of regional cooperation based on open science and solidarity. A similar proliferation of regional scientific initiatives is also observed in several African regions such as East and West Africa. More research is needed to understand how critical junctures and crises, such as the COVID-19 pandemic or international conflicts, may redefine governmental priorities, boost regional collaborations and underpin new processes and practices of national, regional and international collaborations in the field of science. How this can both reflect and underpin the ways in which countries reposition and realign themselves in the emerging multipolar world is a question this article has sought to partially address and answer.

References

Ackers, Louise, and Bryony Gill. 2009. *Moving People and Knowledge: Scientific Mobility in an Enlarging European Union*. Cheltenham: Edward Elgar Publishing.

Aguirre-Bastos, Carlos, Juliana Chaves-Chaparro, Osamu Saito, and Kazuhiko Takeuchi. 2019. "Sustainability science: where and how?" In: Aguirre-Bastos, Carlos, Juliana Chaves-Chaparro, and Salvatore Aricò.(eds) *Codesigning Science in Africa: First Steps in Assessing the Sustainability Science Approach on the Ground*. UNESCO: Paris.

Aleisa, Esra Eisa, Abdelkader Djeflat, and Moneef Zou'bi. 2021. "The Arab States," In. UNESCO 2021. *UNESCO Science Report*: 423-465, UNESCO: Paris

Ban-Ki-moon, UN Secretary-General. 2013. *Remarks at Stanford University*, Stanford, 17 January.

Bell, Daniel. 1968. "The measurement of knowledge and technology. In Sheldon, Eleanor Bernert, and Wilbert E. Moore. (Eds.), *Indicators of Social Change. Concepts and Measurements*. Hartford, CN: Russell Sage Foundation: 145-246

Bell, Martin, and Keith Pavitt. 1997. "Technological accumulation and industrial growth: contrasts between developed and developing countries." In: Archibugi, Daniele, and Jonathan Michie. (Eds.), *Technology, Globalisation and Economic Performance*. Cambridge University Press, Cambridge, pp. 83–137.

Benneworth, Paul, and David Charles. 2005. "University spin-off policies and economic development in less successful regions: learning from two decades of policy practice." *European Planning Studies* 13 (4): 537–557.

Brundenius, Claes, Bengt-Åke Lundvall, Judith Sutz. 2011. "The role of universities in innovation systems in developing countries: developmental university systems – empirical, analytical and normative perspectives," In: Lundvall, Bengt-Åke, K.J. Joseph, Cristina Chaminade, Jan Vang. (Eds.), *Handbook of Innovation Systems and Developing Countries: Building Domestic Capabilities in a Global Setting*. Edward Elgar, Cheltenham: 311–336.

Calderon, Angel. 2018. "Massification of higher education revisited." RMIT University. Melbourne, Australia, June 2018.

Carayannis, Elias,. and David F.J. Campbell. 2011. "Open innovation diplomacy and 21st century fractal research, education and innovation (FREIE) ecosystem: building on the quadruple and quintuple helix innovation concepts and the 'mode 3' knowledge production system." *Journal of Knowledge Economics* 2: 327-72

Chen, Kun and Martin Kenney. 2007. "Universities/research institutes and regional innovation systems: the cases of Beijing and Shenzhen," *World Development* 35 (6): 1056–1074. <http://dx.doi.org/10.1016/j.worlddev.2006.05.013>

Conceição, Pedro, Manuel V. Heitor. 1999. "On the role of the university in the knowledge economy." *Science and Public Policy* 26 (1): 37–51.

Crespi, Gustavo A., and Gabriela Dutrénit. (eds) [2014]. *Science, Technology and Innovation Policies for Development: The Latin American Experience*. Springer: Berlin.

Dale, Roger. 2000. "Globalisation and Education: Demonstrating a 'common world educational culture' or locating a 'globally structured educational agenda'?" *Educational Theory* 50 (4): 427-48

Deiaco, Enrico, Alan Hughes, and Maureen McKelvey. 2012. "Universities as strategic actors in the knowledge economy," *Cambridge Journal of Economics* 36 (3): 525–541.

- De Fuentes, Claudia, and Gabriela Dutrenit. 2012. "Best channels of academia-industry interaction for long-term benefit," *Research Policy* 41 (9): 1666–1682.
- Dutrénit, Gabriela, Carlos Aguirre-Bastos, Martin Puchet, and Mònica Salazar. 2021. "Latin America," In. UNESCO. 2021. *UNESCO Science Report: 201-233*, UNESCO: Paris
- Essegbey, George, Almamy Konté, Natewinde Sawadogo, and Willie Siyanbola. 2021. "West Africa," In. UNESCO. 2021. *UNESCO Science Report: 467-495*, UNESCO: Paris
- Fawcett, Louise. 2004. "Exploring regional domains: a comparative history of regionalism." *International Affairs* 80(3): 429-446.
- Fawcett, Louise. 2010. "Regionalism in Africa and the Middle East: Implications of EU studies." *European Integration* 32(6): 617-636.
- Fawcett, Louise. 2017. "Regions and Regionalism." In Beeson, Mark and Nick Bisley. (Eds.). *Issues in 21st century International Politics*. Palgrave
- Fawcett, Louise, and Andrew Hurrell. (Eds.). 1995. *Regionalism in World Politics*. Oxford University Press.
- Foray, Dominique. 2004. *The Economics of Knowledge*. The MIT Press
- Furman, Jeffrey L., and Richard Hayes. 2004. "Catching up or standing still? National innovative productivity among 'follower' countries, 1978–1999." *Research Policy* 33(9): 1329–1354. <https://doi.org/10.1016/j.respol.2004.09.006>.
- Geuna, Aldo. (ed.) 2015. *Global Mobility of Research Scientists. The Economics of Who Goes Where and Why*. Elsevier: Amsterdam, Netherlands.
- Glänzel, Wolfgang, Koenraad Debackere, and Martin Meyer. 2007. "'Triad' or 'tetrad'? On global changes in a dynamic world." *Scientometrics* 74(1): 71–88.
- Godin, Benoit. 2006. "The Knowledge-Based Economy: Conceptual Framework or Buzzword?" *Journal of Technology Transfer* 31(1): 17-30.
- Godin, Benoit, and Yves Gingras. 2000. "The place of universities in the system of knowledge production." *Research Policy* 29(2): 273-278.
- Gomes, Alfredo M., Susan L. Robertson, and Roger Dale. 2012. "The social condition of higher education: globalisation and (beyond) and regionalisation in Latin America," *Globalisation, Societies and Education* 10(2): 221-245
- Gui, Qinchang, Chengliang Liu, Debin Du, and Dezhong Duan. 2019. "The changing geography of global science," *Environment and Planning: Economy and Space* 51(8): 1615-1617 <https://doi.org/10.1177/0308518X18816694>
- Jessop, Bob, Norman Fairclough, and Ruth Wodak. (Eds.). 2008. *Education and the Knowledge-Based*

Economy in Europe. Rotterdam: Sense Publications

Horta, Horta. 2010. "The role of the state in the internationalization of universities in catching-up countries: an analysis of the Portuguese higher education system." *Higher Education Policy* 23 (1): 63–81.

Kingiri, Anne Njoki, and Charles Awono Onana. 2021. "Central and East Africa," In. UNESCO 2021. *UNESCO Science Report*: 497-533, UNESCO: Paris

Khan, S. 2020. "API Park to boost export of medicines." The Financial Express, 11 July 2020 <https://www.thefinancialexpress.com.bd/views/api-park-to-boost-export-of-medicines-1594485666> last accessed 20 January 2023

Kraemer-Mbula, Erika, Gussai Sheikheldin, and Rungano Karimanzira. 2021. "Southern Africa," In. UNESCO. 2021. *UNESCO Science Report*: 535-573, UNESCO: Paris

Kroll, Henning, and Ingo Liefner. 2008. "Spin-off enterprises as a means of technology commercialisation in a transforming economy: evidence from three universities in China." *Technovation* 28 (5): 298–313.

Leydesdorff, Loet. 2010. "The Knowledge-Based Economy and the Triple Helix Model." *Annual Review of Information Science and Technology* 44: 367-417.

Maphosa, Vusumuzi, and Mfowabo Maphosa. 2020. "E-waste management in sub-Saharan Africa: A systematic literature review." *Cogent Business and Management* 7(1), DOI: 10.1080/23311975.2020.1814503

Mazzoleni, Roberto, and Richard R. Nelson. 2007. "Public research institutions and economic catch-up," *Research Policy* 36(10), 1512–1528. <https://doi.org/10.1016/j.respol.2007.06.007>.

Ministry of Economy and Planning. 2019. *Plan Nacional de Desarrollo Económico y Social 2030*. Havana, Cuba.

Mowery, David C., and Nathan Rosenberg. 1999. *Paths of Innovation: Technological Change in 20th-Century America*. Cambridge University Press.

Murmann, Johann Peter. 2003. *Knowledge and Competitive Advantage: The Coevolution of Firms, Technology, and National Institutions*. Cambridge University Press, Cambridge.

Naidoo, Rajani. 2011. "Rethinking development: higher education and the new imperialism." In King, Roger, Simon Marginson, and Rajani Naidoo. (Eds.). *A Handbook on Globalization and Higher Education*. Cheltenham: Edward Elgar: 40-58.

Navarro, Juan Carlos, José Miguel Benavente, and Gustavo Crespi. 2016. *The New Imperative of Innovation: Policy Perspectives for Latin America and the Caribbean*. Inter-American Development Bank: Washington, DC.

Nguyen, Chi Mai, and Jae-Yong Choung, 2020. "Scientific knowledge production in China: a comparative analysis." *Scientometrics* 124: 1279-1303

OECD. 2014. *Does Income Inequality Hurt Economic Growth?* Paris: OECD.

Osama, Athar, Sohan P. Sha, and Seetha I. Wickremasingha. 2021. "South Asia," In. UNESCO 2021. *UNESCO Science Report*: 575-603, UNESCO: Paris

Persic, Ana, Fernanda Beigel, Simon Hodson, and Peggy Oti-Boateng. 2021. "The time for open science is now," In UNESCO. 2021. *UNESCO Science Report*: 12-16, UNESCO: Paris

Progressive International. 2023. "Havana Congress plans 'unilateral but coordinated action' to secure technological sovereignty for the Global South," 30 January 2023, <https://progressive.international/wire/2023-01-30-havana-congress-plans-unilateral-but-coordinated-action-to-secure-technological-sovereignty-for-the-global-south/en> last accessed 31 January 2023

Radosevic, Slavo, and Esin Yoruk. 2014. "Are there global shifts in the world science base? Analysing the catching up and falling behind of world regions." *Scientometrics* 101(3): 1897–1924.

Robertson, Susan L. 2009. "Market multilateralism, the World Bank group, and the asymmetries of globalizing higher education: toward a critical political economy analysis." In Bassett Roberta Malee and Alma Maldonado-Maldonado (Eds.). *International Organizations and Higher Education Policy: Thinking Globally, Acting Locally?*, New York: Routledge: 113–31.

Robertson, Susan L. 2014. "Higher Education Regionalising Projects in a Globalising World: a 'Variegated Regionalism' Account." A paper presented to the European Consortium for Political Research, Glasgow – 3-6th September, 2014.

Robertson, Susan L., Roger Dale, Stavros Moutsios, Gritt Nielsen, Cris Shore, and Susan Wright. 2012. "Globalisation and Regionalism in Higher Education: Toward a New Conceptual Framework", In Wright, Susan. (ed) *Working papers on University Reform, Working Paper 20*, EPOKE, Department of Education, Aarhus University.

Robertson, Susan L., and Matt Kedzierski. 2015 . "On the Move: Globalising Higher Education in Europe and Beyond." In Special Issue edited by Block, David, Joseph Maria Cots and Enric Llurda, *Language Teaching Journal*: 1-26.

Robertson, Susan L. and Janja Komljenovic. 2016. "Unbundling the university and making higher education markets." in Verger, Anton, Christopher Lubienski, and Gita Steiner-Khamsi. (eds). *The Global Education Industry, World Yearbook 2016*, London and New York: Routledge.

Stehr, Nico, Marian Adolf, and Jason J. Mast. 2020. "Knowledge Society, Knowledge-Based Economy, and Innovation." In Carayannis, Elias G. *Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship*. Springer Cham: Switzerland: 1536-1541

Sadreghazi, Shuan. 2021. "Iran," In. UNESCO (2021). *UNESCO Science Report*: 395-407, UNESCO: Paris

- Selenica, Ervjola. 2018. *Universities between the state and the market. Development policy, commercialization, and liberalization of higher education*. SAIH report. Oslo: 1-78
- Sesay, Brima, Zhao Yulin, and Fang Wang. 2018. "Does the national innovations spur economic growth in Brazil, Russia, India, China and South Africa economies? Evidence from panel data." *South African Journal of Economic and Management Sciences* 21(1): 1-12
- Stiglitz, Joseph E. 1999a. "Knowledge as a Global Public Good:" In Kaul, Inge, Isabelle Grunberg, and Marc Stern. (Eds.). *Global Public Goods*. Oxford University Press: New York
- Stiglitz, Joseph E. 1999b. "The World Bank at the millennium." *The Economic Journal* 109 (November): 577-97
- Suleimenov, Yerbol. 2021. "Central Asia," In. UNESCO 2021. *UNESCO Science Report*: 367-393, UNESCO: Paris
- TFHES (Task Force on Higher Education and Society). 2000. *Higher Education in Developing Countries: Peril and Promise*. Washington, DC: World Bank. <http://www.tfhe.net/report/overview.htm>, last accessed 24 January 2023.
- UNESCO. 1998. *Summary of the World Declaration on Higher Education*. <http://www.unesco.org/education/educprog/wche/summary.htm>, last accessed 24 January 2023
- UNESCO. 2005. *Towards Knowledge Societies*, Paris: UNESCO.
- UNESCO. 2021. *UNESCO Science Report*. UNESCO: Paris
- Verger, Antoni, Mario Novelli, and Hulya K. Altinyelken. (eds.) 2012. *Global education policy and international development: new agendas, issues and policies*. London: Bloomsbury
- Verger, Antoni, Clara Fontdevila, and Adrian Zancajo. 2016. *The Privatization of Education. A Political Economy of Global Education Reform*. New York and London: Teachers College Press
- Vidovich, Lesley, Rui Yang, and Jan Currie. 2007. "Changing accountabilities in higher education as China 'opens up' to globalisation." *Globalisation, Societies and Education* 5(1): 89-107
- World Bank. 1998. *Knowledge for Development*. World Development Report. Oxford University Press
- World Bank. 2002. *Constructing Knowledge Societies: New Challenges for Tertiary Education*, Washington, DC: World Bank.
- World Bank. 2009. *Accelerating Catch-up: Tertiary Education for Growth in Sub-Saharan Africa*, Washington, DC: World Bank.