


China's technological footprint in Africa: A patent network analysis

**Author:**Juan Vázquez Rojo^{1,2} **Affiliations:**¹Department of Economics, Corporación Universitaria de Asturias, Bogotá, Colombia²Department of Business and Technology, Camilo José Cela University, Madrid, Spain**Corresponding author:**Juan Vázquez Rojo
jvazquez@ucjc.edu**Dates:**

Received: 26 Oct. 2023

Accepted: 13 Mar. 2024

Published: 23 Apr. 2024

How to cite this article:Vázquez Rojo, J. (2024). China's technological footprint in Africa: A patent network analysis. *South African Journal of Business Management*, 55(1), a4331. <https://doi.org/10.4102/sajbm.v55i1.4331>**Copyright:**© 2024. The Author.
Licensee: AOSIS. This work is licensed under the Creative Commons Attribution License.

Purpose: The study aims to examine China's rising technological influence in Africa within the context of Industry 5.0 and how it compares to traditional powers like the European Union (EU) and the United States (US).

Design/methodology/approach: Utilising an innovative patent network analysis methodology, this study draws on data from the World Intellectual Property Organization's (WIPO) Centre for Intellectual Property Statistics from 2001 to 2021.

Findings/results: The analysis reveals China's significant and growing presence in technological diffusion throughout Africa, potentially surpassing regional historical players.

Practical implications: These findings have far-reaching implications for policy formulation and management strategies, particularly in a global landscape where technology standards and patents can significantly influence economic and business dynamics.

Originality/value: This study contributes to the existing literature by offering a nuanced understanding of power dynamics in African value chains and a new context for relations between developed and developing countries. It emphasises the strategic importance of understanding technological centrality in emerging regions.

Keywords: China-Africa relations; technological influence; network analysis; industry 5.0; intellectual property rights.

Introduction

The rapid technological advancements and integration of technologies characteristic of Industry 5.0 are reshaping global economic paradigms and altering geopolitical landscapes (Russel & Berger, 2021; Xu et al., 2021; Vázquez Rojo, 2022). Developed countries have traditionally dominated technological innovation and economic leadership, but the rise of China is changing this dynamic (Rikap & Lundvall, 2021). The relationship between developed and developing nations is central to this change, emphasising China's burgeoning technological influence in African countries.

The extensive literature on China's growing economic and technological influence in Africa encompasses diverse perspectives, delving into institutional quality (Mlambo, 2022), debt dynamics (Jones & Ndofo, 2022), inclusive development (Debongo et al., 2022), small-and medium-sized enterprise (SME) engagement (Chen, 2020; Runde et al., 2021) and the broader impact on local suppliers and industries (Giovannetti & Sanfilippo, 2016; Shen, 2014; Shen & Power, 2016). This body of work also highlights a pivotal shift from China's focus on infrastructure to innovation in applications and services (CIO, 2021; Hruby, 2021), raising critical discussions about dependency and security concerns (Enuka, 2011; Mason, 2017). The technological aspect, a key component in this relationship, reflects both the benefits and challenges of China's engagement (Habyarimana & Opoku, 2018; Munemo, 2013; Tugendhat, 2021) and underscores the historical evolution and potential of technology transfer (Gravett, 2023; Li, 2016). The emergence of Industry 5.0 further accentuates the strategic significance of technological leadership in areas like 5G, artificial intelligence (AI) and clean energy (Rühlig, 2023; Russel & Berger, 2021), demonstrating the critical role of China in shaping Africa's technological and economic landscape.

While there is extensive literature on economic, technological and trade dynamics between these nations, a critical gap exists in understanding the impact and scope of China's growing technological presence in Africa. This gap is significant as it overlooks how these developments are reshaping the global power structure and altering the role and influence of African countries

Note: Special Collection: Managerial Practices.

Read online:

Scan this QR code with your smart phone or mobile device to read online.

in the worldwide market. Addressing this gap is essential to unravel the complexities of the new global order shaped by Industry 5.0, where technology plays a pivotal role in redefining economic and geopolitical boundaries.

China's expanding technological influence in Africa is a critical factor shaping the global economic and political landscape, especially in the context of Industry 5.0. This shift challenges the historical dominance of Western powers and has profound implications for African development and integration into the global economy. Employing an innovative methodological framework, this study utilises patent network analysis to examine China's position in African value chains and assess whether China surpasses the United States (US) and the European Union (EU) as the most central actors within these networks. This exploration is vital to understanding the broader global context. It addresses the identified research gap, focussing on patterns of influence and diffusion that reveal the potential impact of Chinese firms in these regions (Winecoff, 2015, 2020; Yang et al., 2019).

Our research also emphasises the significant role of technology in redefining economic and geopolitical boundaries. The interaction between Global Value Chains (GVCs) and Intellectual Property Rights (IPRs) highlights the emergence of 'Intellectual Monopoly Capitalism' (Pagano, 2014; Rikap, 2021) and its impact on global inequality. This study aims to provide a nuanced understanding of these dynamics, offering insights into how the concentration of capital in intangible assets influences the power relations between countries and throughout firms (Durand & Milberg, 2020; Haskel & Westlake, 2018; Rikap, 2021).

The theoretical contributions of this study are multifaceted. Firstly, it extends the discourse on GVCs and international relations by providing a detailed analysis of technology diffusion dynamics within these networks, mainly focussing on the interaction between China and African nations. This aspect enriches our understanding of how technology power, as a component of GVCs, influences and is influenced by economic international relations. Secondly, the study contributes significantly to the ongoing discussions about the role of IPRs in shaping the economic and geopolitical landscapes. It offers a nuanced examination of how IPRs affect the integration of developing countries into the global market, with a particular focus on African nations.

From a managerial perspective, this research provides critical insights for policymakers and business leaders. In an era marked by China's growing technological influence, comprehending the evolving landscape of technological power, particularly in Africa, is crucial. Our findings guide strategic decision-making for countries at various stages of development, helping them navigate the complexities and leverage the opportunities presented by the current shifts in global technology and power structures.

Methodologically, our study utilises data from the World Intellectual Property Organization's (WIPO) Intellectual

Property Statistics Data Centre (WIPO, 2023). This approach allows for an empirical analysis of China's, the EU's and the US's technological influence across 17 African countries from 2001 to 2021. Such a longitudinal perspective sheds light on the progression of China's role in African technological spheres, offering a more holistic understanding than what is typically provided by conventional economic or trade-focussed analyses.

Our findings indicate a paradigm shift: China is not only strengthening its technological presence in Africa but is also emerging as a predominant technological force, surpassing historical players like the EU and the US. This development carries profound implications for international cooperation, development policy in Africa and the global strategic landscape. It underscores the urgent need to understand technological centrality globally and offers critical insights into the evolving power dynamics within African value chains.

Global Value Chains and Intellectual Property Rights: The geoeconomics of technological dominance and power asymmetry

In the contemporary global economic landscape, GVCs and IPRs play a pivotal role in sculpting the dynamics of capitalist economies and the balance of power between developed and developing nations. Global Value Chains, by facilitating competitive advantages across diverse geographies, have given rise to a fragmented yet globally distributed production system. This system disproportionately benefits core countries, allowing them to accumulate a substantial share of economic surplus and exert significant influence over global economic patterns (Rikap, 2021; Rísquez, 2022). Concurrently, IPRs, as critical intangible assets, enhance this dynamic. They allow core country firms to dominate high-value, knowledge-intensive sectors, perpetuating their economic pre-eminence. This concentration of intangible assets, predominantly in developed countries, engenders stark power asymmetries in global trade, favouring nations with well-established intellectual property frameworks and advanced technological capabilities (Schwartz, 2017; World Trade Organization [WTO], 2021).

The hierarchical categorisation of firms within this global framework is predicated mainly on their asset intensity and geographical location. Firms that are intensive in IPR and human capital are typically situated in core countries. In contrast, those focussing on capital-intensive operations are often located in semi-peripheral regions, while labour-intensive firms are more common in peripheral countries. The aggregation of intangible assets in leading companies such as Apple, Google or Qualcomm, predominantly based in core countries, not only exemplifies the asymmetry in global trade but also underscores the economic dominance of these nations. This structure results in an economic power concentration within a select few corporations, exerting substantial influence on the global market (Borja Reis & Pinto, 2022; Rikap & Lundvall, 2021; WTO, 2021).

Furthermore, the situation in emerging economies like South Africa illustrates these nations' multifaceted challenges in the global economic arena. Economic volatility, political instability and constrained access to credit and infrastructure critically shape the landscape for technological innovation and entrepreneurship (Robina-Ramírez & Human, 2020). When viewed with the overarching global dynamics of IPRs and GVCs, these local conditions underscore the complex hurdles emerging economies encounter in their efforts to participate effectively in the worldwide market.

Intellectual property rights safeguard innovation and proprietary knowledge within the global economic framework. These rights facilitate control over essential technologies, designs and brands, thus underscoring their significance in the international economy (Durand & Milberg, 2020; WIPO, 2022). The increasing trend of capitalising knowledge and the growing concentration of capital in intangible assets has led to the emergence of 'Intellectual Monopoly Capitalism'. It highlights a shift in the global economic order, where intangible assets have become more valuable than tangible capital in global trade and production (Durand & Milberg, 2020; Haskel & Westlake, 2018; Rikap, 2021).

Lead firms in GVCs, armed with technical expertise and IPRs, often establish oligopolistic dominance over products and supply chains. This dominance creates situations where suppliers with proprietary or IPR-protected inputs can gain significant bargaining power. However, the concentration of knowledge and power in the hands of a few has far-reaching implications, especially for labour markets in developing countries. Within GVCs, tasks are typically skewed towards lower-knowledge activities in these regions, leading to limited bargaining power for local firms and a cap on potential wage growth and enhancement of employment quality (Nathan, 2020).

Furthermore, intellectual monopolies, represented by large incumbent firms, profoundly impact innovation systems within GVCs (Rikap, 2023). These entities have evolved from temporary beneficiaries of innovation gains to dominant players, perpetuating continuous rent extraction through systematic innovation and reinvestment in research & development (R&D). This path-dependent evolution in knowledge management enables these firms to continuously innovate, capture rents and reinforce their dominant market positions (Rikap, 2023).

This dynamic fosters the expansion of intellectual rents. It widens the gap between these monopolies and other market participants, who often need help to keep pace with rapid innovation and knowledge appropriation strategies. The disparity is further magnified by platform network effects and stringent IPR regimes, consolidating the dominance of these monopolies in critical sectors like pharmaceuticals and information technologies. Consequently, these monopolies have reshaped the landscape of technological innovation and management within GVCs, profoundly influencing

both the trajectory of technological progress and the distribution of economic benefits and power in global networks (Aguar de Medeiros & Trebat, 2017; Borja Reis & Pinto, 2022; Rikap, 2021, 2023).

In this context, the concept of 'weaponised interdependence,' articulated by Farrell and Newman (2019, 2023), underscores how dominant countries leverage their strategic positions within global networks, particularly in patents and intellectual property, to exert geopolitical influence. This tactic is especially apparent in sectors such as semiconductors, where nations like the US have utilised restrictions to impact firms, including Huawei, demonstrating the significant role of strategic network positions in international relations and global trade dynamics.

Additionally, the historical dominance of countries like the US in GVCs and intellectual property has been crucial in global influence, especially in controlling technological standards. This control has significant implications for developing countries that are attempting to ascend the value chain (WTO, 2021). By contrast, emerging economies like China employ parallel strategic approaches to redefine their roles in the global market. Initiatives like 'Made in China 2025' and 'China Standards 2035' illustrate China's ambition to emerge as a leader in future technologies, including AI and 5G, reflecting its intention to shape global technology governance (Petersen & Ueta, 2021).

China's rising influence in Africa: A multifaceted approach to technological diffusion and geopolitical shifts

The dominant influence of the EU and the US has long shaped the geopolitical landscape in Africa. However, this paradigm is being challenged by China's growing influence, which includes a blend of infrastructure and technological investments, trade agreements and diplomatic engagements (Mayer & Zhang, 2020). This pivot in geopolitical dynamics marks a critical juncture that demands a comprehensive analysis to understand its implications and future trajectories (Hillman & Sacks, 2018).

In its quest to expand technological influence on the continent, China has implemented strategic plans like 'Made in China 2025' and 'China Standards 2035' (de Graaff, 2020; Liu & Tsai, 2020; Malkin, 2020; Petersen & Ueta, 2021). These initiatives are emblematic of China's aspiration to evolve into an advanced manufacturing leader and to set global standards in emergent technologies such as AI, 5G and quantum computing (Vlados, 2020; Xuetong, 2020). This ambition is palpable in China's escalating role in establishing technological standards and amassing a substantial patent portfolio. Huawei's advancements in 5G technology exemplify this strategic progression (Alfayad, 2019; Petersen & Ueta, 2021).

Simultaneously, China initiated the Belt and Road Initiative (BRI) in 2013, aiming to augment connectivity and

cooperation across Asia, Africa and Europe (Hillman & Sacks, 2018; Shen, 2014). The BRI extends beyond the construction of physical infrastructure, such as roads and ports, to include the Digital Silk Road (DSR) initiative. The DSR seeks to bolster digital infrastructure, encompassing telecommunications networks and data centres. Collectively, these initiatives represent a significant impulse by China to bridge infrastructural gaps, stimulate economic growth and enhance living standards in Africa, further solidifying its influence in the region.

China's engagement in Africa, however, transcends mere infrastructure development. It is increasingly characterised by scientific and technological collaboration, evidenced by a surge in joint research publications and patents. This trend is particularly notable in African countries with well-established science and technology infrastructures, such as South Africa, Egypt and Morocco (Muchie & Patra, 2020). The escalation in collaborative efforts is in sync with China's active participation in Africa since the early 2000s and the establishment of the BRI and DSR. These international strategies align with China's domestic agenda and act as conduits for internationalising its patents and technology standards, especially in Africa. As a result, China's technological footprint in Africa is witnessing rapid expansion, particularly in digital infrastructure (CIO, 2021). Leading Chinese corporations, such as Huawei and ZTE, have been crucial in developing telecommunications infrastructure throughout the continent. Notably, Huawei is credited with constructing 50% of Africa's 3G and 70% of its 4G networks, predominantly financed through Chinese loans (CIO, 2021).

Huawei's strategic alliances in Africa, notably with MTN in South Africa for 5G deployment in coal mines and Debswana in Botswana for a pioneering diamond mine project, illustrate its expanding technological clout (Huawei, 2023). These initiatives, enhancing safety and efficiency, signify the reach of core firms into peripheral markets. They reflect the structural dynamics discussed by Rikap and Lundvall (2021) and Schwartz (2017), evidencing the transfer of advanced technologies from central to peripheral areas, underscoring Huawei's pivotal role in redefining industrial standards and influencing technological advancement across the continent.

Additionally, China is making inroads in software and services, with Chinese venture capital increasingly investing in African logistics and financial technology startups. This shift from infrastructure to application innovation signifies strengthening China's influence over Africa's digital landscape (Hruby, 2021). However, this multifaceted approach has sparked debates about dependence and the implications for local suppliers. While Chinese investments have expedited mobile broadband deployment, concerns about dependency and security risks for local businesses are emerging (CIO, 2021).

In this context, the burgeoning economic presence of China in Africa has catalysed extensive academic discourse. Mlambo (2022) scrutinises the sustainability of China's African investment model, focussing on institutional quality. Jones and Ndofor (2022) highlight the growing concern of African indebtedness linked to Chinese investments. Debongo et al. (2022) present an optimistic view, emphasising the positive impacts of Chinese foreign direct investment on African economic development. However, they also underscore the need for sound policy implementation to maximise these benefits.

Chen (2020) and Runde et al. (2021) provide further insights into the complexity of China-Africa relations. Runde et al. discuss China's limited engagement with African SMEs. Chen examines the dual nature of China's policies in Africa, oscillating between long-term state interests and short-term goals of non-state actors. Mason (2017) and Enuka (2011) explore these dynamics from an international relations perspective. Mason contends that China offers limited alternatives to existing post-colonial structures, whereas Enuka advocates for the role of the Forum on China-Africa Cooperation (FOCAC) in strengthening economic and humanitarian ties between the regions.

The technological aspect of China-Africa relations elicits mixed responses in the literature. Giovannetti and Sanfilippo (2016) argue that Chinese influence has displaced local African producers. In contrast, Shen (2014) and Shen and Power (2016) acknowledge the beneficial effects of Chinese investments in infrastructure and renewable energy development in Africa. Habyarimana and Opoku (2018) and Munemo (2013) provide a nuanced view of the economic impact of China-Africa relations from a technological standpoint, acknowledging both benefits and challenges. Tugendhat (2021) offers an in-depth analysis of Huawei's training centres in Kenya and Nigeria, revealing limitations in knowledge transfer processes.

Li (2016) delves into the historical aspects of technology transfer in China-Africa relations, suggesting that despite a long technological collaboration dating back to 1964, there remains significant potential for expanding and deepening these ties. Gravett (2023) examines the reliance of a substantial portion of the African population on Chinese companies for telecommunications and digital services, highlighting China's growing digital footprint in Africa.

This body of literature underscores the multifaceted nature of China's economic and technological influence in Africa. As China's role and influence in Africa continue to grow, it presents crucial questions for this study to investigate. We aim to explore China's integration into African value chains through technological diffusion and assess its influence compared to other global players.

Our research methodology will play a crucial role in accomplishing this. While previous studies have shed light on various aspects of China's presence in Africa, they often

overlook the importance of technological diffusion in the region. This gap in the literature highlights the need for a more comprehensive approach, which this study aims to provide by examining the regional patent network in Africa. Through this analysis, we hope to offer a more nuanced understanding of China's technological impact on the continent.

Methodology and data

This study employs social network analysis (SNA) to explore the dynamics of technological diffusion in African value chains. Initially conceived in fields such as sociology and computer science, SNA has been applied in multiple disciplines to study relationships at different scales: interpersonal, inter-firm or interstate (Froehlich, 2022; Laat et al., 2007; Martínez et al., 2003; Nunes & Abreu, 2020).

The choice of SNA for this study is grounded in its unique ability to map and analyse the complex and multifaceted relationships inherent in technological diffusion across African value chains. Unlike other methodologies focussing on one-dimensional analyses or isolated aspects of technological transfer, SNA provides a holistic framework that visualises the structure and dynamics of interactions among various actors over time. This methodology is well suited for exploring how patents and collaborations spread and evolve networks, revealing critical patterns and flows of influence fundamental to understanding the systemic nature of technological diffusion (Borgatti et al., 2009). Additionally, SNA facilitates the examination of centrality and periphery within these networks, which is crucial for assessing power distribution and access to technology in the African context. This analysis is essential for identifying both innovation hubs and areas that may be marginalised or underrepresented in the global flow of technology. In summary, SNA provides a powerful and tailored analytical lens for unravelling the complexities of technological diffusion in Africa, offering insights that more traditional methods might not fully capture (Provan et al., 2007).

In a network, nodes represent entities, individuals, organisations or countries. Edges denote the relationships between these entities (Froehlich, 2022). In this study, the relationships involve technology patent transfer (Feczko et al., 2015), as SNA has previously been applied in studying technology diffusion globally (Winecoff, 2015, 2020; Yang et al., 2019). This approach allows a deeper understanding of how information and influence flow through networks (Hoppe & Reinelt, 2010; Scott & Carrington, 2014).

We analyse data from the Intellectual Property Statistics Data Center of the World Intellectual Property Organization (WIPO, 2023). The information includes all the patents filed by foreign companies in every country. The study period spans from 2001 to 2021 and focusses specifically on an African sub-network, where only connections where the recipient of the technology is an African country are considered. The sample includes 131 countries, 17 of which

are African: Algeria, Egypt, Gambia, Ghana, Kenya, Madagascar, Malawi, Mauritius, Morocco, Rwanda, Seychelles, South Africa, Sudan, Tunisia, Uganda, Zambia and Zimbabwe. We adopt the methodology of Winecoff (2015, 2020) and Yang et al. (2019) to ensure adequate representation of technology diffusion. Specifically, we select the dataset 'Foreign-oriented patent family by origin and destination office' excludes regional offices and focuses on registered patents with a transnational scope.

When companies apply for a transnational patent, they have invested significant money in registering their invention in foreign countries. These patents are usually for high-quality and commercially relevant inventions. This shows that the company intends to implement their technology in the local market, making it a more accurate and reliable indicator of global technological diffusion (Yang et al., 2019). Nonetheless, handling patent information carefully is crucial as the quality and innovative value may vary. Not all patents are equally influential or have equal potential for prosperity (Yang et al., 2019).

We construct a weighted directed network to investigate technology diffusion in the African patent network. The nodes represent countries, and a directed edge from node i to node j represents the recognition of patents from i in j . The network is represented as a graph $G = (V, E, W)$, where V is the set of nodes, E is the set of edges and W is a matrix of weights. In this matrix, $W = (W_{ij})^{N \times N}$, W_{ij} denotes the number of patent applications from country i to country j .

In this framework, centrality measures quantitatively identify the most influential nodes. In technology diffusion, these metrics reveal the strategic position of countries. We use weighted outdegree and indegree centrality to highlight key technology actors and recipients.

The weighted outdegree centrality of a node i is calculated as:

$$C_{out}(i) = \frac{\sum_{j \in N} \omega_{ij}}{W} \quad [\text{Eqn 1}]$$

Where $\sum_{j \in N} \omega_{ij}$ is the sum of the weights of the outgoing edges of node i , and W is the total sum of the weights for all outgoing edges in the network. This metric indicates a country's influence on technology transfer to Africa. A high value suggests that the country is a crucial technology sender.

Similarly, the weighted indegree centrality of a node i is defined in a similar way:

$$C_{in}(i) = \frac{\sum_{j \in N} \omega_{ji}}{W} \quad [\text{Eqn 2}]$$

Where $\sum_{j \in N} \omega_{ji}$ is the sum of the weights of the incoming edges to the node i . This metric is handy for identifying primary African technology recipients. A high degree of value for an African country suggests a strategic position in technology value chains.

With the methodological and mathematical framework in place, we are ready to address the central objectives of this study. We will use these approaches to dissect the structure and dynamics of the African regional patent network and to assess the relative influence of China, the US and the EU on technology transfer to Africa. The results of the study will then be presented, organised into three main components that reflect our objectives:

Firstly, through Figure 1, we will provide an overview of the African regional patent network, weighted by its outdegree. This will provide a first impression of the dominant actors and the primary recipients in technology transfer.

Secondly, Figure 2 examines the leading African patent destinations of the three major technological powers, highlighting centre-periphery dynamics and differences in technology diffusion between developed and developing countries.

Finally, through Figure 3 and Figure 4, the analysis will focus on the evolution of weighted outdegree and indegree centrality, respectively, from 2001 to 2021. This will allow an assessment of strategic shifts and fluctuations in the technological influence of key players.

These results will provide the basis for a rich discussion connected to the existing literature, culminating in the study's conclusions.

Ethical considerations

Ethical clearance to conduct this study was obtained from the Asturias Corporación Universitaria Ethics and Bioethics Committee.

Results

In this section, we present a detailed analysis of the African regional patent network, highlighting the dynamics of technological diffusion and the role of global players. Our focus is on how these dynamics reflect and reinforce existing power structures within GVC.

The African regional patent network has grown significantly over the past two decades, as shown in Figure 1. From 2001 to 2021, the number of patents increased from 473 to 7288, reaching 75024. This indicates the increasing importance of patents on the African continent.

The network's structure reveals a distinct centre-periphery dynamic, with countries like the US, the EU, India, the United Kingdom (UK), China, Japan, Korea, Switzerland, Canada and Australia leading technology diffusers. On the other hand, South Africa is the primary recipient of patents, followed by Morocco, Egypt, Algeria and Madagascar. This pattern suggests that technology flows mainly in one direction, from these technology centres to African nations, highlighting the critical role of these countries in technology diffusion to Africa.

This upward trend in patent numbers reflects increasing innovative activity and underscores Africa's growing importance as a critical destination for global technological transfer. These figures indicate a shift in the focus of technological powers towards the African continent.

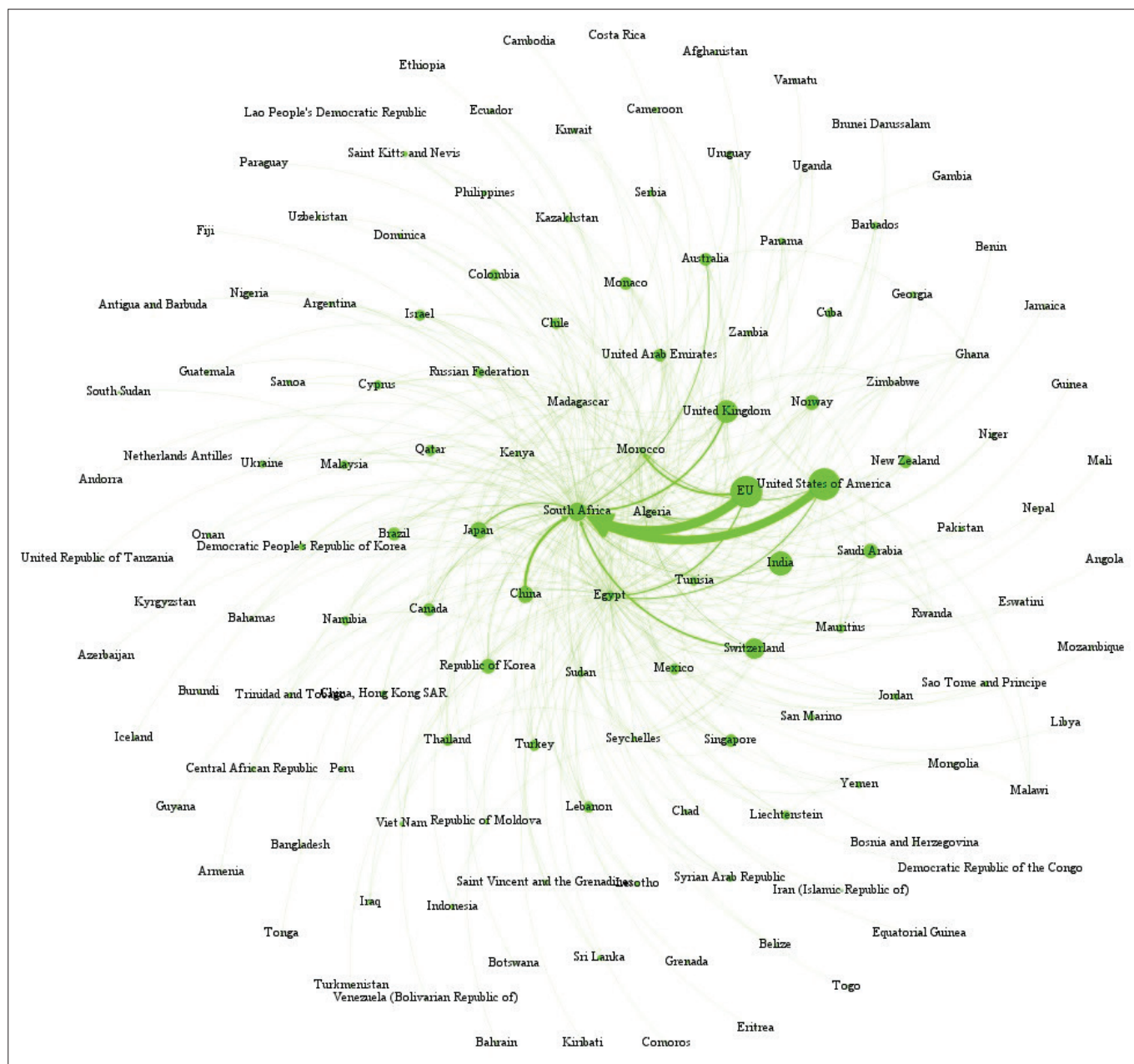
A closer examination of the geographical distribution of these patents reveals a distinct centre-periphery dynamic in technology transfer. The data unveil a clear pattern of technological flow predominantly from developed countries to African nations, underscoring the central role of these countries in technology diffusion to Africa. The data presented in Figure 2 highlights the top five African countries that receive the most patents from the US, China and the EU. South Africa is the predominant partner for all three. However, there are differences in secondary relationships. Morocco, Egypt and Algeria complete the picture for the EU, while Egypt precedes Morocco for the US. China shows a similar pattern to the US but has a higher activity concentration in South Africa. This indicates that China's growing presence in the African patent network is heavily influenced by its relationship with South Africa. This trend could suggest a more focussed strategy on China's part to expand its technology in Africa.

The temporal evolution of patent network centrality in Africa sheds light on how the influence of different global actors has changed over time. This analysis is key to understanding the shifting dynamics of power and control in technology transfer. Figure 3 shows how the outdegree centrality of China, the EU and the US has changed over time from 2001 to 2021. During this period, the EU and the US have remained active players in technology diffusion in Africa, though their centrality has slightly decreased. This means that China has successfully managed to internationalise its technology and has emerged as a new alternative to the EU and the US.

China's outdegree centrality has grown significantly, from being non-existent in 2001 to surpassing the US in 2021 with a value of 0.27. This suggests a shift in the African patent network, where China has gained influence and is positioning itself as a central player in technology diffusion to Africa. This increase in China's influence is mainly reflected in its relationship with South Africa, as shown in Figure 2.

These findings show that the US and the EU are still essential players but are losing ground to China, particularly in South Africa. This is likely because of China's expansionist policies on the continent and its consolidation of its position in African regional value chains.

The growing centrality of China in the African patent network signifies a significant shift in technological power dynamics. This rise suggests an increase in China's influence in technology transfer to Africa, potentially altering the existing structures of power and control in GVCs.



Source: World Intellectual Property Organization. (WIPO). (2023). *WIPO IP statistics data*. Retrieved from <https://www3.wipo.int/ipstats/>

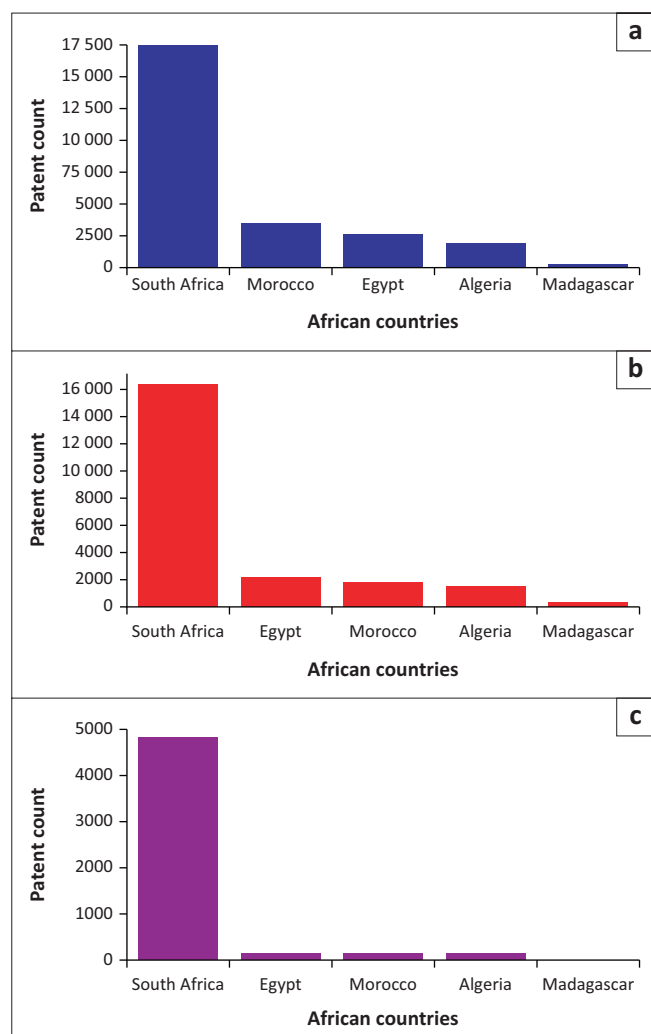
FIGURE 1: Regional African patent network (2001–2021).

To further understand how different African countries are integrated into this network, we analyse the centrality of technology reception within the patent network. This approach allows us to identify critical nodes through which technology diffuses across the continent. Figure 4 shows the evolution of weighted indegree centrality in the network over this period. The results indicate that technology reception varies among countries, with South Africa, Morocco, Algeria and Egypt initially acting as central nodes. These nodes can serve as the main entry points for technology diffusion in Africa, which has significant implications for the structure of regional value chains.

From 2010 onwards, South Africa became the dominant receiving node, reaching a weighted indegree centrality of 0.75 in 2021. This finding is essential for understanding the

strategies of external actors such as China, the EU and the US. These findings underscore the strategic role of South Africa, and to a lesser extent, other African countries, as central nodes in technology reception. These nodes can significantly influence the structure and operation of the regional value chain.

Based on the results, the study suggests a network structure of centre-periphery in Africa's technology transfer and intellectual property. Major players such as the US, the EU and China are central nodes, having a highly weighted outdegree centrality. This observation aligns with existing theories on the concentration of economic power and the role of IPRs in GVCs (Durand & Milberg, 2020; Rikap, 2021; Schwartz, 2017; WTO, 2021).



Source: World Intellectual Property Organization. (WIPO). (2023). *WIPO IP statistics data*. Retrieved from <https://www3.wipo.int/ipstats/>

EU, European Union; US, United States.

FIGURE 2: Top 5 African patent destinations of US, China and EU (2001–2021). (a) Top African destinations for EU patents; (b) Top African destinations for US patents; (c) Top African destinations for China patents.

On the other hand, African countries mainly act as peripheral nodes, receiving technology and intellectual property instead of generating or distributing it. This confirms that technology diffusion is mainly unidirectional, from core countries to the periphery (Mason, 2017). In the context of weaponised interdependence, China's increasing centrality in Africa's technological landscape is significant. As Farrell and Newman (2019, 2023) express, countries that control critical nodes in global networks can exercise considerable geopolitical influence. By consolidating its position in key sectors, China gains the ability to influence economic and political outcomes in the region. This influence extends beyond mere technology diffusion, allowing China to dictate terms in broader international relations, including trade policies and diplomatic alliances. Such a position could enable China to manage global interdependencies to its advantage, reinforcing existing power asymmetries and creating new ones.

The increasing involvement of China in the network can be seen as a reflection of its economic strategies and geopolitical

ambitions. The 'Made in China 2025' and 'China Standards 2035' initiatives are being promoted through the BRI or DSR, which is suggested by Malkin (2020) or Rühlig (2023). The focus on South Africa highlights the strategic role it might be playing for China, possibly in line with broader schemes such as the BRI or their growing partnership as BRICS (Brazil, Russia, India, China and South Africa) members (Hillman & Sacks, 2018).

However, it is essential to note that these findings should not be interpreted as conclusive. Political stability or institutional development influences the observed structure, and the data are limited to 17 African countries. Future research could expand on this study by examining social network analysis in other types of networks, including commercial, financial or foreign direct investment.

Overall, this study provides an empirical viewpoint that contributes to a more detailed comprehension of power dynamics in African value chains. While these conclusions are preliminary, they have implications for academic theory and policymaking, highlighting the need for further research to delve into these issues more deeply.

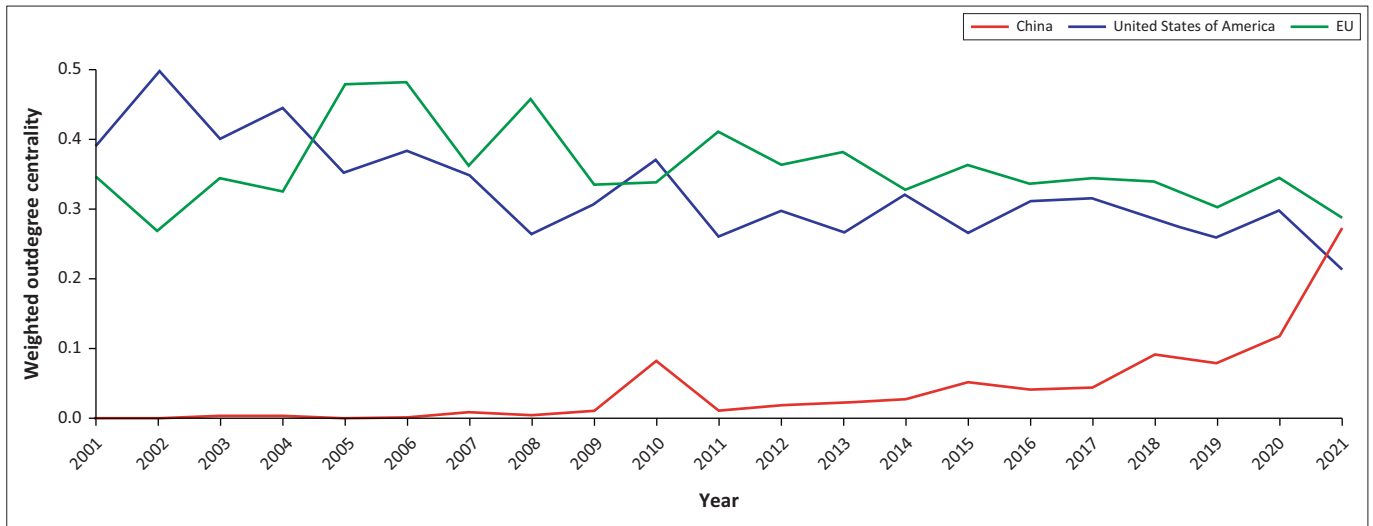
Conclusions

This paper sheds light on China's increasing technological influence in Africa as part of the dynamics between developed and developing nations within the context of Industry 5.0. Using the African patent network and SNA, this research reveals crucial insights into China's growing regional impact. This shift represents a departure from the traditional dominance of the US and the EU.

As intangible assets continue to increase in value and capital becomes increasingly concentrated, a new phenomenon known as 'Intellectual Monopoly Capitalism' has emerged, creating further disadvantages for developing nations. In this context, IPRs protect innovation and knowledge, allowing companies to gain an edge in GVCs. Patents have long been recognised as a measure of a country's technological prowess, and in the era of Industry 5.0, their significance is even greater. Countries that effectively disseminate technology are better positioned to shape the 'rules of the game' for emerging technologies essential to the global economy in the years ahead. For example, China proactively influences these technological norms through strategic initiatives such as 'China Standards 2035', the BRI and the DSR.

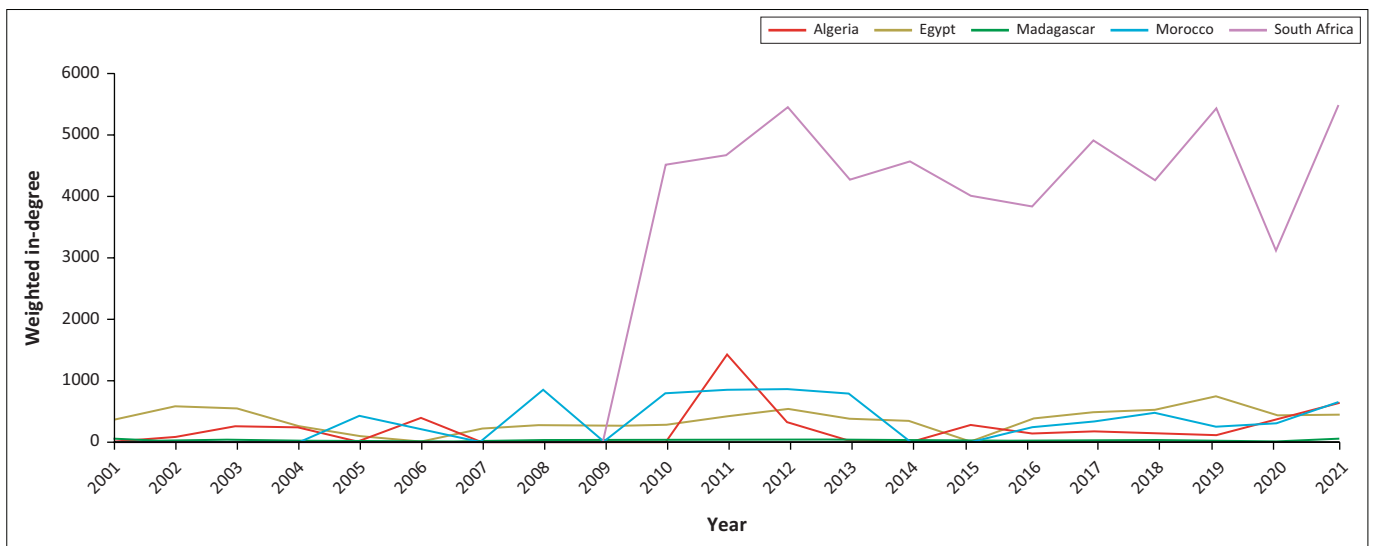
By examining patent data using SNA, the study analyses the impact of the technology transfer of China, the US and the EU in the African value chain. Our research has revealed a centre-periphery configuration within Africa's technology transfer landscape.

Specifically, the study analyses patent data from WIPO spanning 2001–2021, focussing on a sub-network of 131 African countries, including 17 nations. Using weighted



Source: World Intellectual Property Organization. (WIPO). (2023). *WIPO IP statistics data*. Retrieved from <https://www3.wipo.int/ipstats/>

FIGURE 3: Evolution of weighted outdegree centrality (2001–2021).



Source: World Intellectual Property Organization. (WIPO). (2023). *WIPO IP statistics data*. Retrieved from <https://www3.wipo.int/ipstats/>

FIGURE 4: Evolution of weighted indegree centrality (2001–2021).

directed network models, the study measures technology diffusion by assessing centrality measures that highlight the influence of crucial technology players.

The nodes at the centre of this structure consist of the US, the EU and China, thus confirming pre-existing theories about the concentration of economic power and the importance of IPRs in GVCs. In contrast, African nations primarily serve as peripheral nodes, receiving technology rather than originating or disseminating it. This approach enables a comprehensive exploration of the intricate layers of influence and power within the technology landscape of the African continent, uncovering patterns that may need to be discernible through traditional economic analyses.

The increasing importance of China in the current global landscape has significant geopolitical implications, particularly in Africa. Their strategic plans, such as 'China Standards 2035', BRI and DSR, have successfully consolidated

their position in key sectors, giving them more significant influence over regional business and politics. This has enabled China to dictate terms in broader international relations and has given them more power over African firms. The focus on South Africa highlights its strategic importance for China, which is likely to be aligned with their broader schemes, such as the BRI, or their growing partnership as a member of the BRICS.

The study's insights are highly relevant for managers in developed and developing countries. Specifically, firms must remain aware of the ever-evolving dynamics of technology diffusion, especially with China's growing influence. Managers in developed countries should reassess their strategies with the rise of China's technological power. This could involve exploring partnerships that leverage this shift to provide access to new markets and technological capabilities. In contrast, managers and policymakers in developing countries, particularly in Africa, should prioritise

policies and business strategies that promote technological capacity building and innovation to ensure they are not just passive recipients but active participants in the global technology landscape. Furthermore, they could use China's presence in Africa to gain bargaining power, as there is an alternative to the US and the EU. Understanding these trends is essential for businesses in developing countries, especially Africa to establish strategic alliances and capitalise on new technological advancements.

However, it is essential to note that relying solely on patent data from WIPO may not provide a complete picture of technology diffusion dynamics. Informal knowledge transfer and non-patentable innovations should also be considered vital factors. Additionally, African countries' political stability and institutional development can significantly impact the observed patterns. To gain a more comprehensive understanding, it is crucial to include qualitative analyses, policy impact studies and in-depth case studies.

Future studies should include the analysis of trademarks alongside patents within GVCs. This approach aims to enhance our understanding of intellectual property's strategic impact on technology diffusion and competitive positioning, providing valuable perspectives for strategic decision-making in international markets.

Overall, this study contributes to the academic discussion on GVCs and technology diffusion while providing practical guidance for managerial decision-making in the era of Industry 5.0. It calls on policymakers and business leaders to adapt to changing global interdependencies and technological shifts, especially with the rise of China as a global power.

Acknowledgements

Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Authors' contributions

J.V.R is the sole author of this research article.

Funding information

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability

The data supporting the findings of this study are publicly available through the World Intellectual Property Organization.

Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. It

does not necessarily reflect the official policy or position of any affiliated institution, funder, agency, or that of the publisher. The authors are responsible for this article's results, findings, and content.

References

- Aguiar de Medeiros, C., & Trebat, N. (2017). Inequality and income distribution in global value chains. *Journal of Economic Issues*, 51(2), 401–408. <https://doi.org/10.1080/00213624.2017.1320916>
- Alfayad, F. (2019). Huawei and The Gulf region: Market opportunities despite the ongoing US-China Trade War. *International Review of Management and Marketing*, 4(9), 47–53. <https://doi.org/10.32479/irmm.8206>
- Borgatti, S.P., Mehra, A., Brass, D.J., & Labianca, G. (2009). Network analysis in the social sciences. *Science*, 323(5916), 892–895. <https://doi.org/10.1126/science.1165821>
- Borja Reis, C.F.D., & Pinto, J.P.G. (2022). Centre–periphery relationships of pharmaceutical value chains: A critical analysis based on goods and knowledge Trade flows. *Review of Political Economy*, 34(1), 124–145. <https://doi.org/10.1080/09538259.2021.1882192>
- Chen, C.K. (2020). China in Africa: A threat to African countries?. *Strategic Review for Southern Africa*, 38(2), 100–122. <https://doi.org/10.35293/srsa.v38i2.250>
- CIO. (2021). *Africa's reliance on Chinese ICT backbone sparks debate*. Retrieved from <https://www.cio.com/article/193170/made-in-china-africas-ict-infrastructure-backbone.html>
- Debongo, D.D.Y.S., Wu, H.Q., Chang, H.R., Diane, L.K., Nzabana, V., Djossouvi, A.C.D., Osei-Kusi, F., Nguéfio, P.N., Traore, F., & Awadji, F.B. (2022). The impact of China's foreign direct investment on Africa's inclusive development. *Social Sciences & Humanities Open*, 6(1), 100276. <https://doi.org/10.1016/j.ssaho.2022.100276>
- de Graaff, H.N. (2020). China Inc. goes global. Transnational and national networks of China's globalizing business elite. *Review of International Political Economy*, 27(2), 208–233. <https://doi.org/10.1080/09692290.2019.1675741>
- Durand, C., & Milberg, W. (2020). Intellectual monopoly in global value chains. *Review of International Political Economy*, 27(2), 404–429. <https://doi.org/10.1080/09692290.2019.1660703>
- Enuca, C. (2011). The forum on China-Africa Cooperation (FOCAC): A framework for China's re-engagement with Africa in the 21st Century. *Sustainability & Economics Journal*, 6(2), 190–201.
- Farrell, H., & Newman, A. (2023). *Underground empire: How America Weaponized the World Economy*. Penguin.
- Farrell, H., & Newman, A.L. (2019). Weaponized Interdependence: How global economic networks shape state coercion. *International Security*, 44(1), 42–79. https://doi.org/10.1162/isec_a_00351
- Feczko, E., Mitchell, T., Walum, H., Brooks, J., Heitz, T., Young, L., & Parr, L. (2015). Establishing the reliability of rhesus macaque social network assessment from video observations. *Animal Behaviour*, 107, 115–123. <https://doi.org/10.1016/j.anbehav.2015.05.014>
- Froehlich, D. (2022). *Social network analysis: Methods and applications*. Sage Knowledge.
- Giovannetti, G., & Sanfilippo, M. (2016). Do Chinese exports crowd-out African goods? An econometric analysis by country and sector. In S. Henson & F. Yap (Eds.), *The power of the Chinese dragon* (pp. 10–41). Palgrave Macmillan.
- Gravett, W. (2023). Digital neo-colonialism: The Chinese model of internet sovereignty in Africa. *African Human Rights Law Journal*, 22(2), 1–22. <https://doi.org/10.17159/1996-2096/2020/v20n1a5>
- Habyarimana, J., & Opoku, E. (2018). Technological progress, worker efficiency, and growth in Africa: Does China's economy matter? *China Economic Review*, 52, 151–164. <https://doi.org/10.1016/j.chieco.2018.07.004>
- Haskel, J., & Westlake, S. (2018). *Capitalism without capital: The rise of the intangible economy*. Princeton University Press.
- Hillman, J.E., & Sacks, D.A. (2018). How should the United States compete with China's belt and road initiative? *CFR*. Retrieved from <https://www.cfr.org/blog/how-should-unitedstates-compete-chinas-belt-and-road-initiative>
- Hoppe, B., & Reinelt, C. (2010). Social network analysis and the evaluation of leadership networks. *The Leadership Quarterly*, 21(4), 600–619. <https://doi.org/10.1016/j.leaqua.2010.06.004>
- Hruby, A. (2021). The digital infrastructure imperative in African markets. *Atlantic Council*. Retrieved from <https://www.atlanticcouncil.org/blogs/africasource/the-digital-infrastructure-imperative-in-african-markets/>
- Huawei. (2023). *MWC 2023: 5G-oriented smart mine*. Retrieved from <https://www.huawei.com/en/news/2023/3/mwc2023-5g-oriented-smart-mine>
- Jones, C.D., & Ndofo, H.A. (2022). Chinese economic engagement in Africa. *Foreign Policy Research Institute*. Retrieved from <https://www.fpri.org/article/2022/01/chinese-economic-engagement-in-africa/>
- Laat, M., Lally, V., Lipponen, L., & Simons, R. (2007). Investigating patterns of interaction in networked learning and computer-supported collaborative learning: A role for social network analysis. *International Journal of Computer-Supported Collaborative Learning*, 2(1), 87–103. <https://doi.org/10.1007/s11412-007-9006-4>
- Li, A. (2016). Technology transfer in China–Africa relation: Myth or reality. *Transnational Corporations Review*, 8(3), 183–195. <https://doi.org/10.1080/19186444.2016.1233718>

- Liu, M., & Tsai, K.S. (2020). Structural power, hegemony, and state capitalism: Limits to China's global economic power. *Politics & Society*, 49(2), 235–267. <https://doi.org/10.1177/0032329220950234>
- Malkin, A. (2020). The made-in-China challenge to US structural power: Industrial policy, intellectual Property and multinational Corporations. *Review of International Political Economy*, 29(2), 538–570. <https://doi.org/10.1080/09692290.2020.1824930>
- Martínez, A., Dimitriadis, Y., Rubia, B., Gómez, E., & Fuente, P. (2003). Combining qualitative evaluation and social network analysis for the study of classroom social interactions. *Computers & Education*, 41(4), 353–368. <https://doi.org/10.1016/j.compedu.2003.06.001>
- Mason, R. (2017). China's impact on the landscape of African international relations: Implications for dependency theory. *Third World Quarterly*, 38(1), 84–96. <https://doi.org/10.1080/01436597.2015.1135731>
- Mayer, M., & Zhang, X. (2020). Theorizing China-world integration: Sociospatial reconfigurations and the modern silk roads. *Review of International Political Economy*, 28(4), 974–1003. <https://doi.org/10.1080/09692290.2020.1741424>
- Mlambo, C. (2022). China in Africa: An examination of the impact of China's loans on growth in selected African states. *Economies*, 10(7), 154. <https://doi.org/10.3390/economies10070154>
- Muchie, M., & Patra, S.K. (2020) China–Africa science and technology collaboration: Evidence from collaborative research papers and patents. *Journal of Chinese Economic and Business Studies*, 18(1), 1–27. <https://doi.org/10.1080/14765284.2019.1647004>
- Munemo, J. (2013). Examining imports of capital goods from China as a channel for technology transfer and growth in Sub-Saharan Africa. *Journal of African Business*, 14, 106–116. <https://doi.org/10.1080/15228916.2013.804370>
- Nathan, D. (2020). Knowledge, oligopoly and labour in global value chains. *Global Labour Journal*, 11(2), 134–151. <https://doi.org/10.15173/glj.v11i2.3815>
- Nunes, M., & Abreu, A. (2020). Applying social network analysis to identify project critical success factors. *Sustainability*, 12(4), 1503. <https://doi.org/10.3390/su12041503>
- Pagano, U. (2014). The crisis of intellectual monopoly capitalism. *Cambridge Journal of Economics*, 38(6), 1409–1429. <https://doi.org/10.1093/cje/beu025>
- Petersen, B., & Ueta, T. (2021). *Techno-Nationalism and the (Digital Silk) road to state-driven standards-setting: Implications for European firms*. Paper presented at the 47th EIBA Annual Conference, Madrid.
- Provan, K.G., Fish, A., & Sydow, J. (2007). Interorganizational networks at the network level: A review of the empirical literature on whole networks. *Journal of Management*, 33(3), 479–516. <https://doi.org/10.1177/0149206307302554>
- Rikap, C. (2021). *Capitalism, power and innovation: Intellectual monopoly capitalism uncovered*. Routledge.
- Rikap, C. (2023). Intellectual monopolies as a new pattern of innovation and technological regime. *Industrial and Corporate Change*, dtad077. <https://doi.org/10.1093/icc/dtad077>
- Rikap, C., & Lundvall, B. (2021). *The digital innovation race*. Palgrave Macmillan.
- Risquez, M. (2022). *Competitividad en las cadenas globales de producción de la industria automotriz: un estudio de caso del Grupo PSA y su planta ensambladora en Vigo (2005-2019)*. Doctoral dissertation, Universidad Complutense de Madrid. Retrieved from <https://eprints.ucm.es/id/eprint/75530/>
- Robina-Ramírez, R., & Human, G. (2020). How macro level foundations influence emerging micro entrepreneurial activities: The case of South Africa. *Entrepreneurship and Sustainability Issues*, 7(4), 3078–3100. [https://doi.org/10.9770/jesi.2020.7.4\(34\)](https://doi.org/10.9770/jesi.2020.7.4(34))
- Runde, D.F., Savoy, C.M., & Staguhn, J. (2021). China and SMEs in Sub-Saharan Africa: A window of opportunity for the United States. *Center for Strategic and International Studies*. Retrieved from <https://www.csis.org/analysis/china-and-smes-sub-saharan-africa-window-opportunity-united-states>
- Russel, D.R., & Berger, B.H. (2021). Stacking the Deck: China's influence in International Technology standards setting. *Asia Society Policy Institute*. Retrieved from https://asiasociety.org/sites/default/files/2021-11/ASPI_StacktheDeckreport_final.pdf
- Rühlig, T. (2023). Chinese influence through technical standardization power. *Journal of Contemporary China*, 32(139), 54–72. <https://doi.org/10.1080/10670564.2022.2052439>
- Schwartz, H.M. (2017). Club goods, intellectual property rights, and profitability in the information economy. *Business and Politics*, 19(2), 191–214. <https://doi.org/10.1017/bap.2016.11>
- Scott, J., & Carrington, P. (2014). *The sage handbook of social network analysis*. Sage.
- Shen, W., & Power, M. (2016). Africa and the export of China's clean energy revolution. *Third World Quarterly*, 38(3), 678–697. <https://doi.org/10.1080/01436597.2016.1199262>
- Shen, X. (2014). Private Chinese investment in Africa: Myths and realities. *Development Policy Review*, 33(1), 83–106. <https://doi.org/10.1111/dpr.12093>
- Tugendhat, H. (2021). Connection issues: A study on the limitations of knowledge transfer in Huawei's African training centres. *Journal of Chinese Economic and Business Studies*, 19, 359–385. <https://doi.org/10.1080/14765284.2021.1943194>
- Vázquez Rojo, J. (2022). Fortalezas y límites de la economía china en su inserción en el orden internacional. *Sociología Histórica*, 11(2), 107–132. <https://doi.org/10.6018/sh.485891>
- Vlados, C. (2020). The dynamics of the current global restructuring and contemporary framework of the US–China trade war. *Global Journal of Emerging Market Economies*, 12(1), 4–23. <https://doi.org/10.1177/0974910119896636>
- Winecoff, K.W. (2015). Structural power and the global financial crisis: A network analytical approach. *Business and Politics*, 17(03), 495–525. <https://doi.org/10.1515/bap-2014-0050>
- Winecoff, K.W. (2020). The persistent myth of lost hegemony, revisited: Structural power as a complex network Phenomenon. *European Journal of International Relations*, 26(1), 209–252. <https://doi.org/10.1177/1354066120952876>
- World Intellectual Property Organization. (2022). What is Intellectual Property? Retrieved from <https://www.wipo.int/about-ip/en/>
- World Intellectual Property Organization. (WIPO). (2023). *WIPO IP statistics data*. Retrieved from <https://www3.wipo.int/ipstats/>
- World Trade Organization (WTO). (2021). *Global value chain development report*.
- Xu, X., Lu, Y., Vogel-Heuser, B., & Wang, L. (2021). Industry 4.0 and Industry 5.0 – Inception, conception and perception. *Journal of Manufacturing Systems*, 61, 530–535. <https://doi.org/10.1016/j.jmsy.2021.10.006>
- Xuetong, Y. (2020). Bipolar rivalry in the early digital age. *The Chinese Journal of International Politics*, 13(3), 313–341. <https://doi.org/10.1093/cjip/poaa007>
- Yang, W., Yu, X., Zhang, B., & Huang, Z. (2019). Mapping the landscape of international technology diffusion (1994–2017): Network analysis of transnational patents. *Journal of Technology Transfer*, 46(1), 138–171. <https://doi.org/10.1007/s10961-019-09762-9>