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Global structures of digital dependence and the rise of technopoles

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ABSTRACT

What are the global structures of digital dependency, and to what extent do the US and China dominate them? How can patterns of digital dependency be understood theoretically and measured empirically? These questions are crucial for both policymakers and academics. Our paper contributes to ongoing debates on the implications of increasing asymmetries and power concentrations driven by digital transformation and the rise of platforms. Building on insights from international relations (IR), international political economy (IPE), and scholarship on (infra)structural dependencies and the weaponisation of interdependence, this article draws on a comprehensive dataset from the Digital Dependence Index (DDI) to offer a framework for mapping and theorising the global structures of digital dependency. Across three dimensions – hardware, platforms and patents – we show that high and increasing levels of digital dependence have emerged, and that the US and China can be characterised as technopoles with significant technological autonomy and great potential to weaponise infrastructure and technologies. Such a structural perspective can be used to further explore and conceptualise the nexus between digital infrastructures, dependency and autonomy on the one hand, and the emergence of a new techno-geopolitical world order on the other.

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Dependency; information and communication technology (ICT); technopole; autonomy; infrastructural power

Introduction

US negotiators warned Ukraine during recent negotiations that access to Elon Musk's Starlink satellite internet, essential for its military and communications, could be cut off if a deal on critical minerals was not reached, after President Zelenskiy initially rejected US proposals (Shalal and Roulette 2025). This pertinent example of the weaponisation of digital dependency represents a much larger phenomenon at the heart of contemporary international relations. What is the nature of digital dependencies, and to what extent do the US and China dominate them? Put differently, how can patterns of digital dependence be understood theoretically and measured empirically? This paper contributes to the debate on the implications of increasing power asymmetries driven by digital infrastructure. Building on international political economy (IPE) scholarship on infrastructure and the weaponisation of interdependence (Farrell and Newman 2019, Gehl Sampath 2021, Green and Gruin 2020, Winecoff 2020, Goede and Westermeier 2022), we offer a framework for theorising and mapping structures of global digital dependence.

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Although various dependencies have been analysed for specific sectors such as production and finance, our theoretical and empirical understanding of the global structures of digital dependency that affect entire economies and societies remains vague and incomplete. The notion of 'structures' has long been central to Marxist (Wallerstein 1974), Realist (Waltz 1979) and IPE (Strange 1988) approaches that explain outcomes in world politics in terms of asymmetries and/or structural power shifts at the systemic level. Extending structuralist assumptions (Wight 2006, p. 174) with a socio-technical, relational structural model, we draw on a new dataset to measure three critical dimensions of digital dependency. Our empirical findings suggest not only a highly uneven global dependency structure in the digital domain, but also the rise of two technopoles, the US and, to a lesser extent, China, both of which are significantly more autonomous than any other actor. Combining structural theory with a comprehensive dataset, we explore how digital dual dependency constrains state autonomy and enables the unequal use of 'infrastructural power' that shapes the emerging techno-world order.

In the remainder of this article, we review the relevant literature, develop a conceptual framework of global digital dependency structures, and introduce the Digital Dependency Index (DDI). We then examine the characteristics of the global digital dependency structure along the dimensions of hardware, platforms and intellectual property between 2010 and 2019. After showing that the US and China can be qualified as technopoles, we explore the similarities and differences between the two cases and examine the dual dependence of the remaining countries in the digital periphery. Finally, we discuss the insights and limitations of our approach and conclude with suggestions on how a structural perspective can be used to further theorise and inform policy on the nexus between digital dependency and autonomy.

Towards a framework of digital dependence structures

Literature review

A wide range of scholarship has discussed digital infrastructures and the problem of (inter)dependence as a matter of discourses and practices of statecraft. For example, scholars have explored discourses of digital sovereignty and various new policies in pursuit of 'technological autonomy', as in the case of the EU and China (Mueller 2019, Bellanova *et al.* 2022). Concerns about digital dependency and vulnerability are growing as a result of shock events. In 2014, for example, the debate on 'digital sovereignty' became heated following the Snowden revelations, with China, the EU, and India having their own, partly overlapping, ideas on how to regain sovereignty in times of dominant US platforms. Whether through measures such as 'de-risking' and 'de-coupling', or by promoting industrial and innovation policies, as well as new laws for data and cybersecurity, the main targets are not only the monopolistic practices of (foreign) ICT companies, but also the potential influence of other states (Floridi 2020, Leander *et al.* 2023, Schneider 2023, Blancato 2024).

Moreover, awareness of the power consequences of new innovations such as 5G, advanced semiconductors and artificial intelligence applications has redefined national security concerns and forced major powers to position themselves strategically (Mueller 2017, Rankin 2018). Digital products and services provided by companies headquartered in developed countries further reinforce the dependency and unequal power relations between core and periphery countries (Arewa 2021). Following a similar logic, Western analysts and think tanks believe that China's Belt and Road Initiative (BRI) aims to reshape the global political economy in Beijing's favour (Holslag 2017, Hillman 2021). The Digital Silk Road and the 'Made in China 2025' strategy could help expand China's global influence in data governance, digital infrastructure and connectivity (Shen 2018, Gagliardone 2019, Seoane 2020, Erie and Streinz 2021). As a result, competing geo-economic flagship projects are accelerating the competition between China and the U.S. Observers expect a bipolar fragmentation to emerge in the digital domain, led by the U.S. and China, with both sides eager to reduce dependencies as much as possible (Yan 2020, Schindler *et al.* 2023).

A second strand of literature exploring the co-constitutive effects of digital ecosystems and infrastructures on the techno-political order has raised conceptual questions about the reshaping of the structures of world politics and the state-economy nexus (Herrera 2002, Mayer and Acuto 2015, Bueger *et al.* 2023, Bakonyi and Darwich 2024). In the nineteenth century, as all actors on the global stage became entangled in and dependent on infrastructures such as telegraphs and railways, the question of the autonomy and sovereign status of states became linked to technical infrastructures as well as to international law (Howland 2014, McCarthy 2024). The global rise of information and communication technologies in the twentieth century was no different, reinforcing multiple questions of entangled and coproduced sovereignty and leading to controversies about the loss of national autonomy and its reassertion and reconstitution (Herrera 2002, Lambach 2020).

A third strand of literature pays more attention to growing infrastructural asymmetries. This concern is informed by the observation that big data, smart algorithms and processes of platformisation have reshaped the basic conditions of business, growth, trade and industrial policy worldwide (Helmond 2015, Weber 2017, Kloet *et al.* 2019, Liu 2021). As the dominance of multinational tech giants such as infrastructure platform companies Alphabet, Meta, and Microsoft, and infrastructure providers such as Huawei and Samsung have become the focus of public policy concerns, conceptual interpretations have ranged from the rise of tech companies as new power centres (Lehdonvirta 2022, Vlist *et al.* 2024) to debates about the reconstruction of sovereignty within the multiple digital layers of the global 'stack' (Bratton 2016) and 'digital imperialism' (Kwet 2019, Adu Amoah 2025).

Against this backdrop, we are witnessing a revival of structural approaches, animated by the growing relevance of persistent structural effects and the advancing theoretical elaboration of what Susan Strange (1988) has called global structures (Babones and Aberg 2019, David and Schmidt 2019, Haggart *et al.* 2019, Malkin 2022). Indeed, scholars writing from a structural perspective have noted the endurance of US hegemonic power (Winecoff 2015, Petry 2021). For example, just as US regulatory decisions in the 1990s and 2000s shaped the Internet and its international governance (Carr 2016, Price 2018), US control of the Internet remains closely linked to the rest of the STACK, including submarine cables, IXPs, ASNs, satellites, and cloud data centres (McCarthy 2015, Winseck 2019, Goede and Westermeier 2022, Vlist *et al.* 2024). However, the limitations of capturing structures transformed by trade-based globalisation and the effects of digitalisation are evident in debates ranging from weaponised interdependence to state-platform capitalism, and from digital imperialism to technological sovereignty. While scholars from different theoretical perspectives assume asymmetric global structural constellations as the backdrop against which countries and their economic statecraft must be analysed (Kwet 2019, p. 5, Farrell and Newman 2019, p. 49), few offer a comprehensive data-driven methodology for mapping these structures. Before attempting to measure the actual structural patterns of digital dependence, we therefore set out below the key conceptual terms we use to define the nature of the structure of the global digital economy and its implications.

Core concepts

The notion of structure advanced here builds on insights from earlier IPE scholarship on the relational and structural dimensions of power (Strange 1988, May 1996, Mueller 2010). The 'neo-structuralist' literature examines different structures and how their often self-reinforcing nature affects foreign policy, the distribution of power, and change/continuity in international relations. Recent work has developed Strange's four structures, emphasising 'network centrality' (Schindler *et al.* 2023), with a focus on statecraft and geopolitical competition. Digital innovation – and in particular the diffusion of general-purpose technologies (Ding 2024) – has a major impact on security, production, finance and knowledge structures. Platformisation and the diffusion of digital currencies and AI applications have arguably made digital infrastructures, and their hardware and software components, an essential power structure (Plantin *et al.* 2018, Huang and Mayer 2022). As the foundation of other infrastructures, digital infrastructure – and its dependencies and asymmetrical power dynamics – is thus consequential for all other areas (see Sandvig 2013, Bueger *et al.* 2023).

There are four key aspects to our account of digital dependency structures. First, such structures are the result of socio-technical processes that create digital dependencies, defined as ‘the extent to which actors in a particular country have to rely on foreign-controlled digital technologies to perform digital activities’ (Mayer and Lu 2023, p. 5). Such dependencies arise from the invention, production, supply and use of digital technologies through the agency of states, firms and other users. The structural position of a state, in turn, is the cumulative result of such multifaceted processes. Its form is relational, referring to the sum of bilateral digital dependencies between host states and foreign ICT firms. This understanding is consistent with the relational thinking of complex interdependence theory and contrasts with the morphological approach to structures typical of neorealist IR theories that focus on capabilities (see Wight 2006). The structural effects of digital dependencies on actors are not only about shaping ‘what actors can or cannot do’ (Farrell and Newman 2019, p. 49), but also about the potential costs for dependent states seeking to reduce asymmetries and increase their autonomy. In short, digital dependency relations are emerging structures that create opportunities to influence outcomes (e.g. actors’ behaviours or choices), but also impose constraints on actors (e.g. vulnerabilities and risks).

Second, the broad notion of a global digital interdependence structure provides an ontological way of understanding the entanglement of each state’s autonomy within global technological constellations. In particular, it is ‘asymmetric network structures’ (Farrell and Newman 2019, p. 45) that lead to the potential for the weaponisation of interdependence. This coercive/compulsory type of power (see Barnett and Duvall 2005) is referred to here as infrastructural power: the potential to deny states and firms access to or use of ICTs and digital infrastructure through control of key nodes, choke points and central hubs of networks, ecosystems or platforms, or through regulatory control over firms that provide hardware, data and communication services on which other societies and economies rely. A greater number of bilateral asymmetric dependencies leads to the accumulation of infrastructural power. It enables a state to influence other dependent states by altering their available options or by imposing sanctions. If a state is unable to weaponise digital dependencies, it does not have infrastructural power. In an asymmetrically interdependent digital world, very few states have the ability to control critical choke points to exert influence (see Drezner *et al.* 2021, Pearson *et al.* 2022). In contrast, large tech companies like GAFAM have immense infrastructural power over most countries and other non-state actors (Lehdonvirta 2022).

The flipside of these structural effects of digital dependence is the autonomy of states, firms and other actors. Accordingly, a state’s degree of autonomy can be conceptualised as varying degrees of vulnerability to foreign ICT supplies and dependence on digital infrastructures. We conceptualise the degree of autonomy as the total digital dependence of a state relative to the rest of the world, thus making autonomy quantifiable and comparable. Increasing digital autonomy means reducing vulnerability, which is not the same as having infrastructural power. In particular, such a structural account of autonomy complements the notion of infrastructural power because a state can still be vulnerable despite the potential to weaponise interdependencies. Increasing autonomy can be the result of deliberate decisions to opt for the ‘exit option’ (Hirschman 1970) by restricting technology imports or the use of foreign platform services, accompanied by growing ‘indigenous’ technological innovation and digital capabilities of domestic firms through investment, regulations and industrial policy (Staab *et al.* 2025, Pearson *et al.* 2022).

Third, the combination of autonomy and infrastructural power brings us to the definition of a technopole. In general, technopoles (see Castells and Hall 1994) have emerged from ‘regional ‘hubs’ of innovation’ that have their origins in significant ‘economies of scale in access to training data, computing power and the talent base [that] privilege the large over the small’ (Schmid *et al.* 2025, p. 7). The term technopole here refers to states that control key technological (and military) capabilities and have regulatory authority over large, innovative technology/platform companies and their infrastructure architecture (Plantin and Seta 2019, Munn 2023). But the core aspect of technopoles is their global structural position, which includes (1) a high degree of digital autonomy and (2) significant infrastructural power.

Fourth, the relationship between technopoles and the rest of the world can be described as an ongoing process of ‘peripheralisation’ (see Saredidine 2024). On the one hand, technopoles seek to further increase their own autonomy, for example through the restructuring of supply chains or industrial policy (Schindler and Rolf 2024), and to foster the growing digital dependency of the rest of the world. On the other hand, most states in the periphery have to adapt to structural pressures and accept rent extraction.

Methodology

Data from the Digital Dependency Index (DDI) are used to quantitatively explore the global shape of the digital dependency structure. Based on Mayer and Lu (2023), this index allows for an examination of the degree of dependence of 23 individual countries on foreign information and communication technologies (ICTs). Using aggregate macro data, the DDI quantifies the share of foreign ICT products needed to satisfy domestic demand. The score ranges from zero, indicating a state of autarky, to one, indicating absolute dependence.¹ The aggregated DDI consists of three main dimensions (hardware, platforms and patents), each of which is measured by a set of different sub-indicators (see appendix). For the sake of simplicity, the three dimensions are treated analytically as distinct and measurable, even though they are linked in complex ways.

The concept of autonomy is operationalised through the aggregation of DDI values, which are categorised into four different levels, following the terminology proposed by Keohane and Nye (2011). States in the sensitivity range (DDI between 0 and 0.5) can be considered ‘autonomous actors’. Conversely, states in the vulnerability range (DDI between 0.5 and 1.0) are susceptible to weaponisation activities or other types of disruption (see Table 1). In addition, we operationalise the concept of infrastructural power by measuring bilateral dependency ratios in the digital sphere. The greater the asymmetry in the bilateral dependency ratio between particular states, the greater the infrastructural power of one side. Technopoles are characterised by a significant degree of aggregate digital dependency and a preponderance of asymmetric bilateral dependencies.

Table 1. Digital Dependence framework.

Digital Dependence Framework		
Degrees of Dependency	DDI score	Ratio between domestic demand and foreign supply of digital technologies
Absolute independence	DDI = 0	Autarky
Low sensitivity	$0 < \text{DDI} \leq 0.25$	Autonomy very high. Domestic digital technology is in a dominant position
High sensitivity	$0.25 < \text{DDI} < 0.5$	Domestic supply delivers majority of digital tech. Considerable level of resilience
Low vulnerability	$0.5 < \text{DDI} \leq 0.75$	Global markets supply majority of digital tech
High vulnerability	$0.75 < \text{DDI} < 1$	Autonomy very low. Foreign digital technology is in a dominant position
Absolute dependence	DDI = 1	Foreign digital technologies fully cover domestic demand

Source Mayer and Lu (2023)

The three dimensions of the global digital dependence structure

The disaggregated DDI data reveal an uneven digital dependency structure (see Table 2). Platform dependency is particularly high, with an average of 0.89; hardware dependency is relatively low, with an average of 0.72; and patent dependency is more evenly distributed, but still very high, with an average of 0.96. The three substructures take different forms. For example, hardware dependencies are the least asymmetric. The leading group of three autonomous countries (average 0.44) is followed by ten countries with low vulnerability (average 0.63), while the remaining ten countries have high vulnerability (average 0.90). This suggests that there are significant differences in the ability of countries to control the operation of ICT goods and services and innovation in the ICT sector. In contrast, patent dependencies show a structure without autonomous actors. Even the

Table 2. Three dimensions of dependence structure.

	Hardware dependence 2019	Platform dependence 2019	Patent dependence 2019
Korea, Rep.	0.36	0.81	0.87
Singapore	0.46	0.98	1
China	0.5	0.58	0.76
Mexico	0.51	0.97	1
Estonia	0.52	0.98	1
Israel	0.54	0.99	0.99
Germany	0.59	0.98	0.97
Japan	0.61	0.95	0.8
France	0.65	0.98	0.98
Italy	0.69	0.98	1
United States	0.70	0.07	0.72
United Kingdom	0.74	0.98	0.99
Indonesia	0.75	0.95	1
Canada	0.79	0.98	0.99
Turky	0.8	0.95	1
India	0.87	0.95	1
Australia	0.89	0.99	1
South Africa	0.9	0.96	1
Russian Federation	0.91	0.82	0.99
Brazil	0.95	0.98	1
Kenya	0.96	0.90	1
Argentina	0.99	0.97	1
Saudi Arabia	1	0.98	1
Average	0.72	0.89	0.96

Calculated based on DDI data. Source: <https://digitaldependence.eu/en/>.

US (with a score of 0.72) is in the low vulnerability column. The rest fall into the high vulnerability category (average score 0.97).

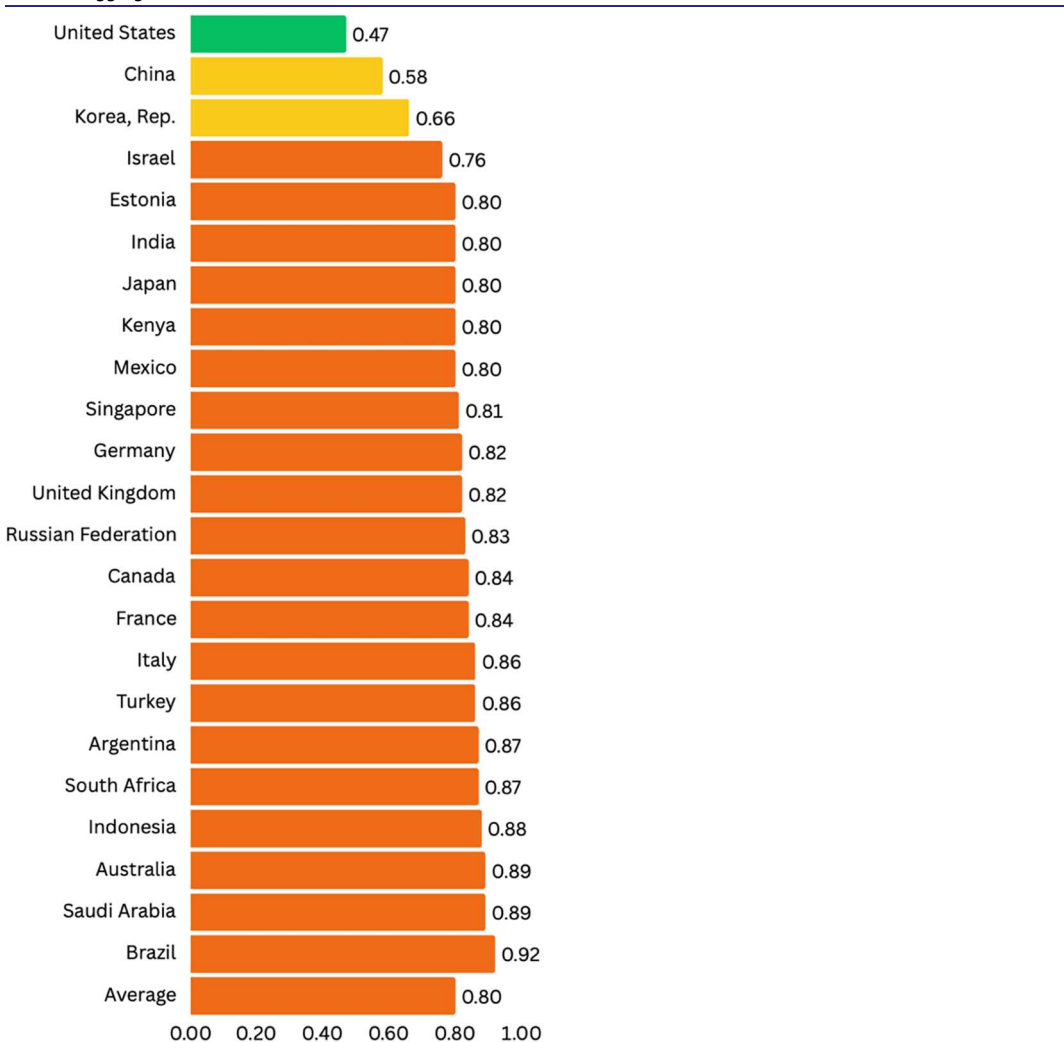
The substructure of platform dependence is the most uneven. The US is the only autonomous actor (score 0.07), with a large gap to all other countries, which, with the exception of China (score 0.58), are all in the high vulnerability category (average score 0.95). China appears to be on its way to becoming the second autonomous actor in this dimension.

Rise of the technopoles

Combining the three dimensions of the DDI into overall DDI scores illustrates the consolidation of the position of the US and China as technopoles. Both technopoles have significantly increased not only their autonomy but also their infrastructural power vis-à-vis the rest of the world.

The overall DDI scores (see Table 3) show that most countries fall into the high vulnerability category. There are three exceptions: the United States, China and the Republic of Korea. Based on the

Table 3. Aggregated DDI score 2019.



Data Source: <https://digitaldependence.eu/en/>

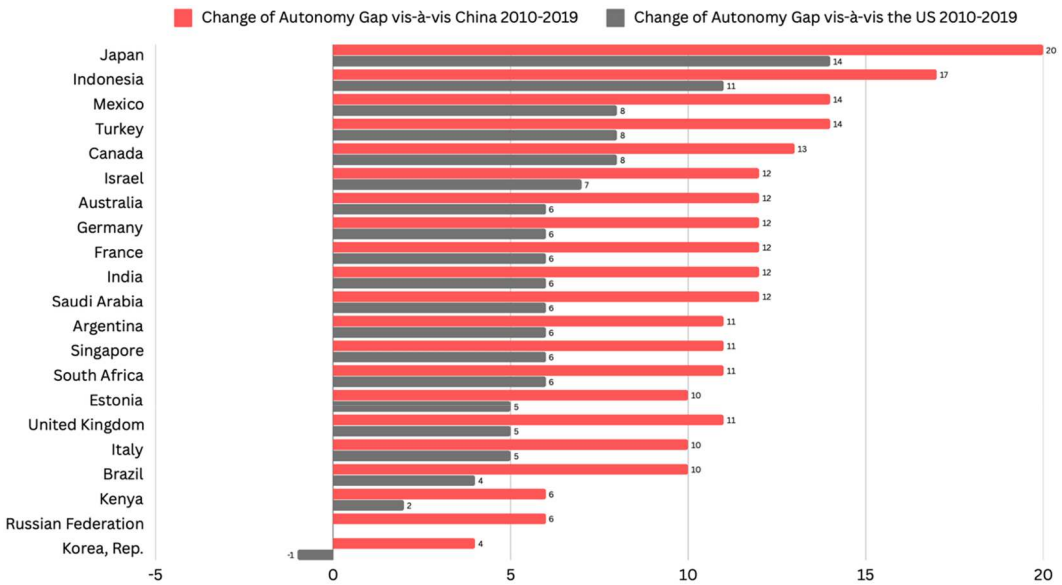


Figure 1. Growth of the autonomy gap with China and the USA 2010–2019 (selected countries, in percentage points). Data source: <https://digitaldependence.eu/en/>.

trend in digital dependency and the changes in the autonomy gap, only China and the US can be considered technopoles. The data in Figure 1 show that between 2010 and 2019, the autonomy gap – i.e. the difference between the DDI score of the least dependent state (the US) and other advanced economies – has widened by an average of 11 percentage points (excluding South Korea). For the second least dependent state, China, the gap widened even more, by an average of 14 percentage points. These trends suggest that both the US and China have been successful in reducing their digital dependence relative to other advanced economies, with China's progress being particularly notable over the period. China's digital progress has also allowed it to significantly narrow its autonomy gap with the US.

Figure 2 shows the infrastructural power of the US and China in terms of two different dimensions. The US has established a technopole position in the platform dimension. The average bilateral dependence of other DDI countries on US platforms is 0.8 (high vulnerability), while the US scores 0.93 in terms of autonomy from foreign platforms.² China is a clear technopole in the hardware dimension. The average bilateral dependence of other DDI countries on Chinese hardware supply is 0.88 (high vulnerability). In terms of autonomy from foreign hardware, China scores 0.5. Consequently, China and the US have great potential to exercise infrastructural power by weaponising other countries' dependence on their platform or hardware supply. At the same time, the low level of vulnerability in their respective domains can insulate the US and China from potential countermeasures with comparable economic and political damage. However, the technopoles diverge in crucial respects: the US has comparatively little hardware autonomy, while China has very limited infrastructural power in the platform dimension. Moving to a more detailed analysis, the next section examines the structural similarities and differences between the two technopoles.

The US as technopole

The dominant position of the US is mainly due to the platform and patent sectors. In 2019, the US has the lowest dependency on IP, relying almost entirely on domestic platform providers (see Table 2). To fully measure US platform dominance, it is crucial to highlight bilateral dependencies. Figure 3

More Infrastructural Power

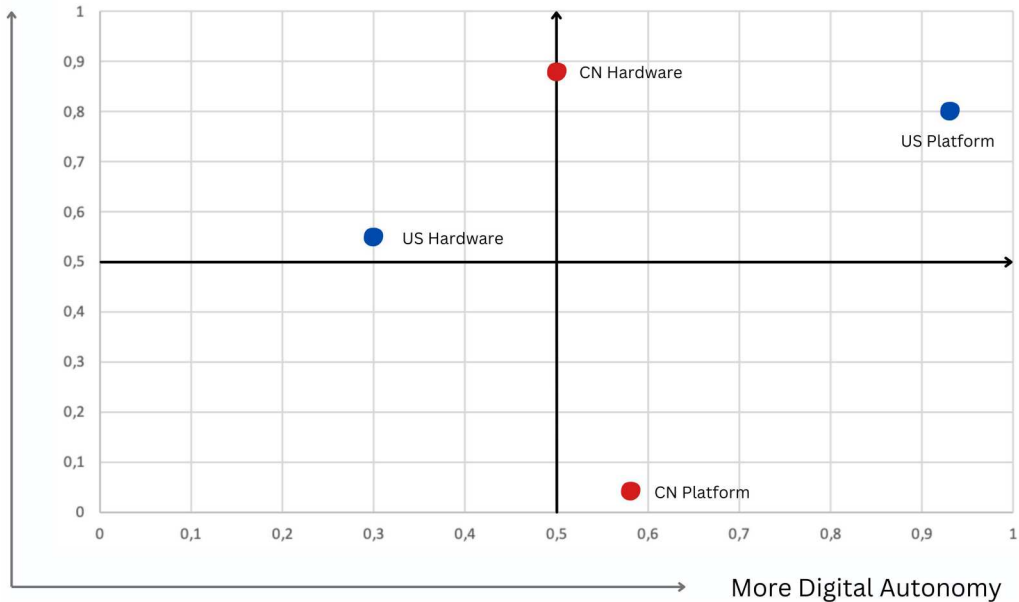


Figure 2. Technopole positions in the hardware and platform dimension (2019).

compares the bilateral dependence of 22 DDI countries on American software and communications platforms in 2019. American companies provide the majority of platform services and products worldwide. Only six countries fall into the low dependency category. Of these, China is the least dependent, with a bilateral dependence score of 0.56. Interestingly, developed countries such as Canada, Australia and Japan are even more dependent on US platforms than some developing countries.

Between 2010 and 2019, the dominance of US platform companies increased in most DDI countries (Figure 4). 14 out of 22 countries were more dependent on the US in 2019 than they were a decade earlier. Five countries, including Saudi Arabia, China, Brazil, Russia and Indonesia, saw their bilateral DDI value increase by ten or more percentage points. Even China's bilateral dependence on US platforms has increased by 15 percentage points over the last decade. This increase is mainly driven by a heavy reliance on tablets (score of 0.85 in 2019) and mobile operating systems (score of 0.99 in 2019) provided by US technology companies. At the same time, US firms have lost influence in markets such as France, Germany, South Korea and Canada. This decline in these countries' bilateral dependence on the US can be explained by the import trends of different types of platforms. In the case of France, for example, its dependence on the supply of US smartphones and tablets has fallen by 47 and 19 percentage points, respectively, to 0.29 and 0.61 in 2019, while France's dependence on US software platforms remains extremely high, ranging from 0.94 (browser) to 1 (mobile OS).

Moreover, these structural shifts in the US technopole appear to be consistent with recent US economic statecraft. On the one hand, the relative gain in digital infrastructure autonomy, which makes the US the least vulnerable country, insulates it from external shocks and thus strongly incentivises the use of weaponised interdependence (see Oatley 2021). On the other hand, as the US faces a growing dependence on foreign hardware products (see Figure 6), the decision to introduce industrial policies (i.e. the Chips Act and the Inflation Reduction Act) targets this loss of autonomy.

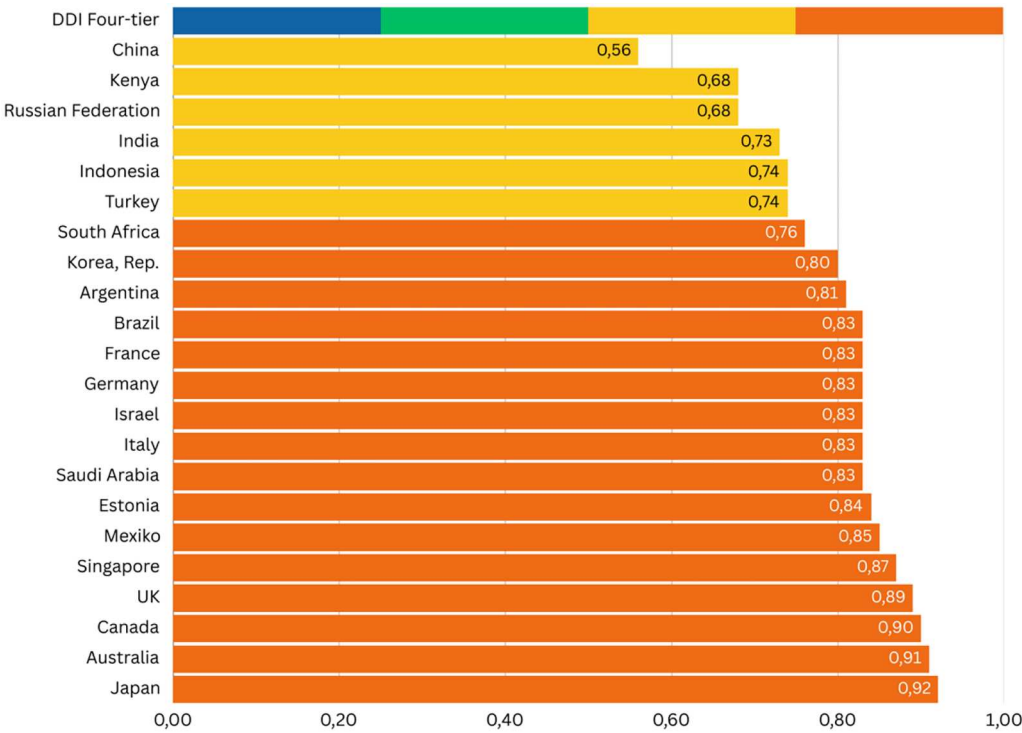


Figure 3. Bilateral dependence on US-American platforms 2019 (software and communication). Calculated based on DDI data: <https://digitaldependence.eu/en/>.

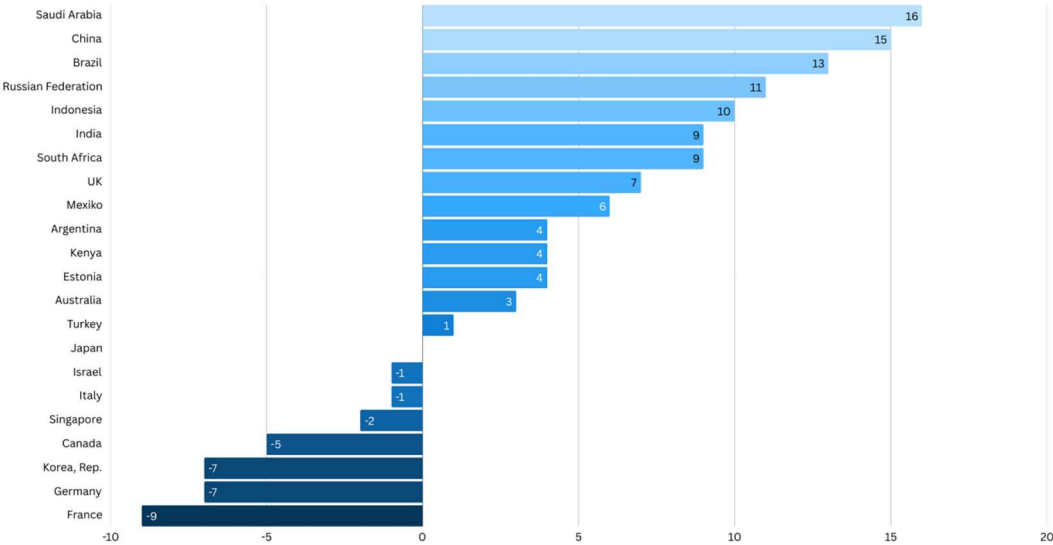


Figure 4. Change of bilateral dependence on US-American Platforms between 2010 and 2019 (in percentage points). Calculated based on DDI data: <https://digitaldependence.eu/en/>.

China as a technopole

In line with China's emergence as a digital power (Naughton 2020, Hillman 2021), the country has reduced its overall digital dependence by 12 percentage points between 2010 and 2019, to a score of 0.58. Over the same period, China narrowed the autonomy gap with the US from 0.17–0.11 (Mayer and Lu 2023, p. 13). China is now the second least dependent country, with significant gaps in most of the DDI measures discussed in the previous two sections. In software-driven platforms, China has achieved a high degree of self-sufficiency (0.56), but has not been able to compete with US firms as an alternative platform provider globally (see Huang and Mayer 2023). China's position as a technopole stems from its competitiveness in global hardware and infrastructure markets, which has created an asymmetric bilateral relationship. Indeed, as US firms have experienced a relative decline in hardware, China's share of the ICT market has grown steadily. Chinese hardware platform providers such as Xiaomi, OPPO and Huawei have become leading companies in global markets (Sacks 2021, Xing 2022).

In a major structural shift, China has not only become autonomous in the supply of hardware, but the bilateral dependencies between China and other major economies in the supply of communications equipment also illuminate China's growing ability to weaponise digital technology and production networks. At the level of bilateral dependencies on Chinese communications equipment, the average dependency score of all 22 DDI countries in 2019 was 0.94 (Figure 5) – exactly the same as the average bilateral dependency score on US platforms in 2019. South Korea (0.59) was the least dependent country in this ranking, while the other 21 DDI countries were all highly dependent, many of them close to absolute dependence on China.

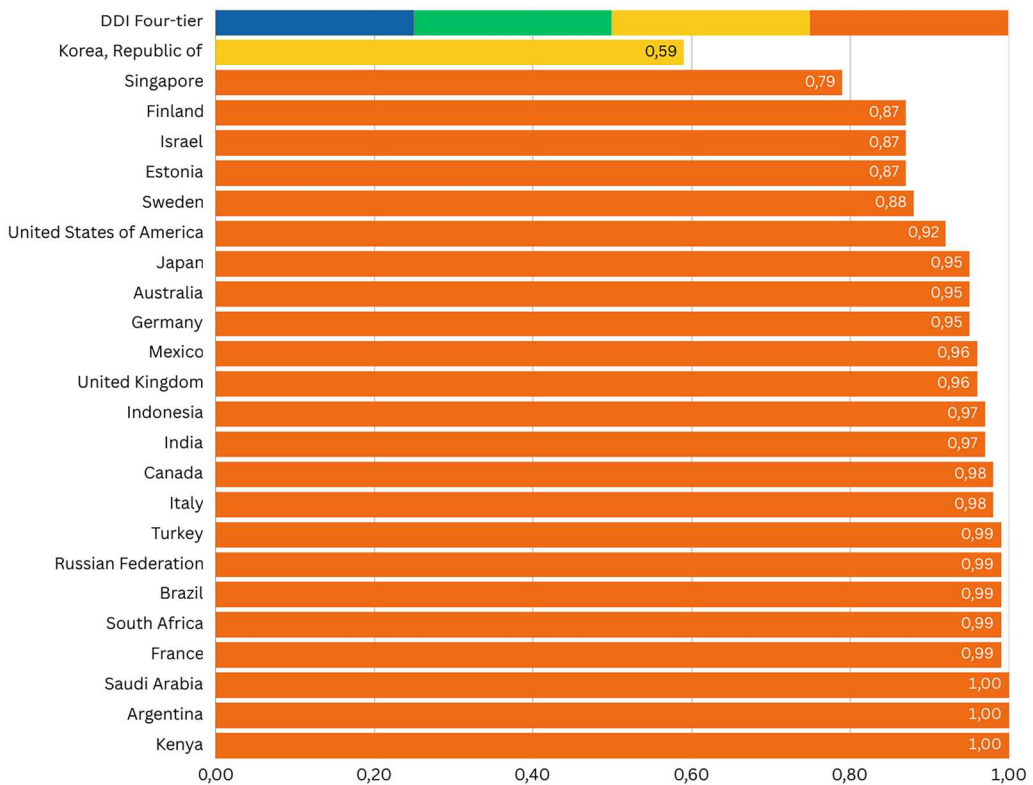


Figure 5. Bilateral dependence on Chinese communication equipment 2019 (ICT trade in goods). Calculated based on DDI data: <https://digitaldependence.eu/en/>

Between 2000 and 2019, the world as a whole became increasingly dependent on Chinese communication equipment (Figure 6). All DDI countries increased their dependence on Chinese manufacturing. The most dramatic increase was in Indonesia (92 percentage points). Other advanced economies such as Japan (72 percentage points), France (48 percentage points), South Korea (46 percentage points), the United Kingdom (45 percentage points) and Germany (41 percentage points) were also unable to halt this trend of increasing dependence on China.

Major shifts in dependencies within global production networks and supply chains for communication equipment indicate that China has established itself as the second technopole after the US. In 2019, China was the dominant supplier for ten major economies (import share above 50 percent) and the main supplier for eight major economies (import share between 30 and 50 percent). Only four economies had a Chinese import share below 30 percent.

Double dependence in the global digital periphery

All major economies are asymmetrically dependent on the US and China. Figure 7 shows that this dual dependency structure (platforms and hardware) remains stable between 2010 and 2019. Almost all DDI countries are in the upper right quadrant. With the exception of South Korea, whose dependency on China was 0.36 in 2010, all other DDI countries maintain highly asymmetric dependency relationships with the US and China (dependency ratio above 0.5). The bilateral dependency structures show that the US and China are the only actors that are not only significantly more self-sufficient than the others, but also have considerable infrastructural power to influence the global supply of platform services and hardware products to other economies – a pattern that can be described as double dependency.

As such, the emergence of two technopoles competing for influence and control has important structural implications for the global political economy, which can be described through the lens of an emerging 'digital periphery'. Platform dependency has the most asymmetric substructure. It is dominated by US firms. The US is the only country without asymmetric dependence on foreign

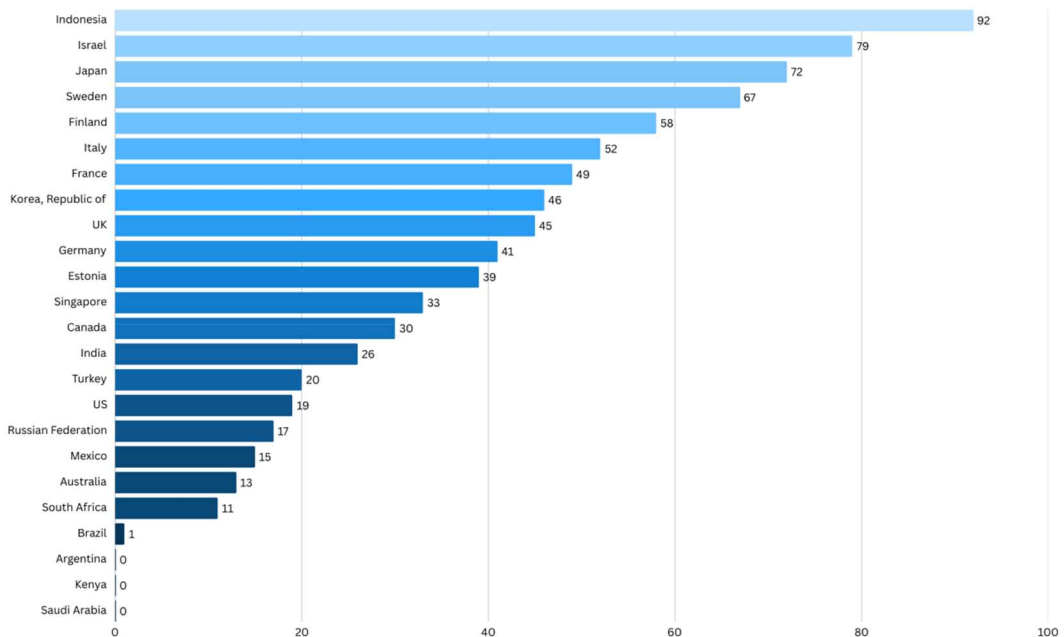


Figure 6. Change of dependence on Chinese communication equipment between 2000 and 2019 (in percentage points). Calculated based on DDI data: <https://digitaldependence.eu/en/>.

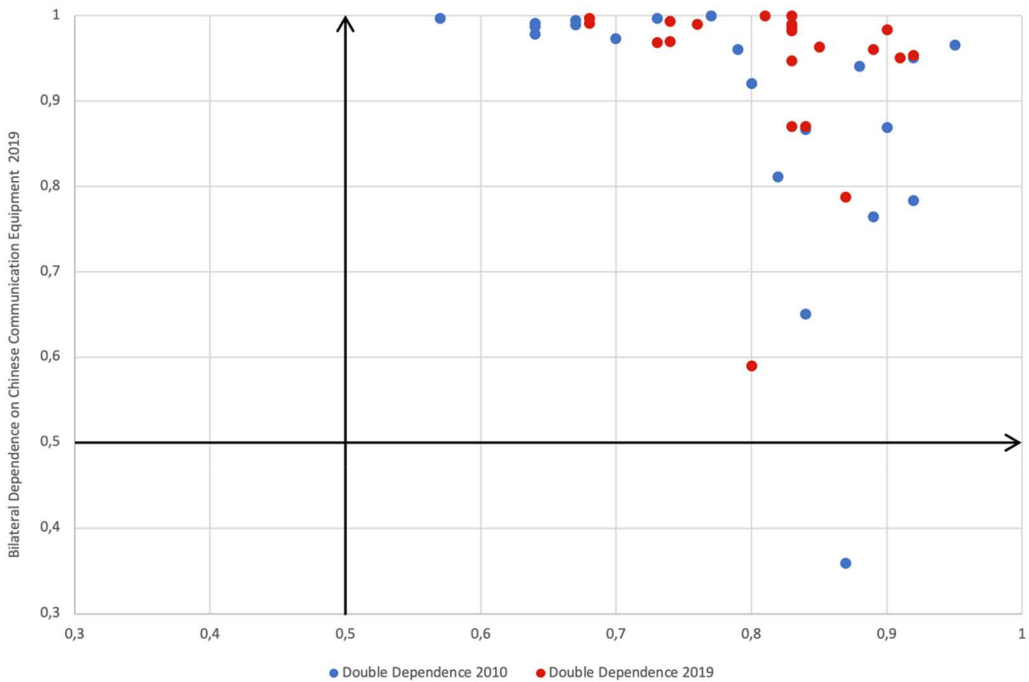


Figure 7. Double dependence structure 2010 and 2019. Figure 7 plots the position of DDI countries in a two-dimensional matrix that includes the bilateral dependence on China (ICT hardware) and on the US (Platform/software) for the years 2010 and 2019. Calculated based on DDI data: <https://digitaldependence.eu/en/>

platform providers. This means that Washington can make policy decisions, especially in the areas of AI, digital and industrial policy related to platforms, with more leverage and room for manoeuvre, less concern and lower risks and costs, because it is neither dependent on foreign firms nor do other countries have leverage to weaponise digital dependence against the US. On the contrary, countries with high vulnerability, such as Japan, Germany and Indonesia, face limited policy options. For example, they must consider how to regulate privacy and cybersecurity issues without negative external political and economic consequences, such as the withdrawal of foreign service providers from their markets. Similarly, it would be very difficult for these countries to replace imported Chinese communications equipment. In the intellectual property dimension, although all countries are highly dependent, China and the US are the least dependent (Table 2). With research and innovation likely to be a geopolitical priority and a critical area of great power competition (Cheung 2022), similar to technology standardisation (Chan 2022, Rühlig and Ten Brink 2021), intellectual property may become even more securitised. From a structural perspective, this implies potentially high costs for countries in the digital periphery, as technopoles may seek to impose tighter controls on research and innovation processes.

Discussion

While the DDI data show divergent trends for the three substructures of digital dependency, the aggregate reveals a clear bipolarisation. Consequently, further research needs to focus on the evolution of the associated power dynamics between the two technopoles as well as their interaction with the periphery. Our exploration of technopoles and the dual dependency structure provides crucial input for further theoretical work along neostructuralist lines and on (digital) polarity.³

First, the DDI data provide ample evidence that the digital dependency structure is bipolar. The widening autonomy gap between the two technopoles and other countries over the past decade

shows that the technopoles have become stronger, while the trend of double peripheralisation continues. Today, the United States occupies a unique position as the primary provider of software-driven platforms. China has become the unquestionable leader in the hardware dimension. In contrast, the European Union and India are deficient in both the necessary infrastructure and the autonomy to be considered technopoles. The result is not only an increase in the infrastructural power of the United States and China in these two dimensions, but also the formation of a complex network of asymmetric dependencies in which other major economies rely on both US software and Chinese hardware. This strategic entanglement provides a crucial explanation for the reluctance of many state actors – such as allied middle powers and countries in the global South – to join US initiatives to decouple technologically from China. These observations also have implications for current debates about world order. In particular, the shape of the digital dependency structure clearly suggests that bipolar, rather than multipolar or multicentric, notions of world order are more salient. At the same time, both the United States and China remain heavily reliant on each other for ICT supplies. Given the current level of technological interdependence, neither country has a clear strategic advantage over the other. The US economy may suffer less damage from an escalation in the technology war with China because it is more autonomous than China at an aggregate level. However, US hardware dependency on China exceeds 90% (figure 5), so a rapid decoupling would have an immensely negative impact.

Second, our findings underscore the importance of technological structures in shaping the nexus of power, autonomy, and agency in the post-digital age (Pohle and Voelsen 2022, Huang and Mayer 2023). While attention to practices of weaponising interdependence provides insight into an increasingly pervasive empirical phenomenon (Drezner *et al.* 2021), further examination of the structural premises of this approach is warranted. For example, our findings inform future research that more closely examines how actors' choices are influenced by their position within a highly asymmetric digital dependency structure. This may require a revival of world-system theory, albeit with a revised core–periphery model. Indeed, the majority of developed countries, which are typically considered to be the economic core, have significant digital dependencies. From an IPE perspective, the way in which the dual dependency structure limits the range of policy options available to almost all countries other than the technopoles, and makes them more vulnerable to the coercive actions of the technopoles, raises new questions about future forced decoupling, fragmentation and technological bifurcation (Mayer and Nock 2025).

Third, to assess the impact of technopoles on remaking the global order, it is necessary to examine how changes in actors' structural positions affect their collective mobilisation capacities and realignment behaviour (see Goddard and Nexon 2016). For example, it can be argued that two technopoles offer more options for countries that are highly dependent on foreign digital technologies than a structure with a single technopole. However, the dual dependency structure is likely to make the foreign policy environment of countries in the digital periphery more volatile and unpredictable than a unipolar dependency structure. This is because the US and China dominate two different sectors (software-driven platforms and communications equipment), and therefore cannot offer their allies and partners the full range of digital technologies covering all layers of the 'stack'. In addition, technopoles are engaged in increasingly intense geopolitical competition to reduce their dependence on technologies from the other side and to dominate the digital domain, leading to fragmentation and disruption of digital ecosystems, standard setting and digital governance (Schindler *et al.* 2023, Mahrenbach and Mayer 2025). Notwithstanding the intensification of the 'tech war' and the aggressive mutual targeting of digital technology companies by both Washington and Beijing, technopoles have thus far been unable to achieve complete decoupling from one another through the establishment of independent supply chains (Ryan and Burman 2024). The 'new Cold War' is therefore unfolding very differently from the old Cold War, under conditions of interdependence both between the technopoles and in the periphery. Taken together, these dynamics pose a major challenge for dependent countries, which must try to maintain good relations with both technopoles, since decoupling is largely impossible in the short term.

Under these circumstances, the pursuit of ‘digital sovereignty’ seems both timely and, to some extent, illusory (Mayer and Lu 2023).

Finally, several limitations of our approach are worth mentioning. The DDI data are collected using a state-centric and highly aggregated approach that does not capture the intricate transnational complexity of digital ecosystems and supply chains. The choice of sub-indicators is mainly due to the fact that few publicly available datasets contain the necessary comprehensive comparative information. Supply chain-focused research (Grimes and Du 2022, Xing 2022) may therefore reveal other capabilities of states to manage vulnerabilities or forms of infrastructural power that cannot be fully captured by a structural approach such as the one developed here. There is also a lack of reliable global data sets. In particular, our 23 indicators do not include data on critical digital infrastructure such as undersea cables, cloud services, satellites, online payment systems and online gaming. However, based on the information available, it is unlikely that adding such indicators would significantly alter our current findings. Furthermore, our account of technopoles reveals quantitative differences between technopoles, but does not do justice to the complexities and interactions between states and firms (Mueller 2010, Schindler *et al.* 2023, Schmid *et al.* 2025), especially in terms of how these might differentiate the US and China. Further research is needed to qualitatively explore the links between digital dependency structures and domestic political institutions and the autonomy-seeking innovation, industrial and defence policies of technopoles that affect other states and technological ecosystems.

Conclusion

In our account of digital dependency structures, we conceptualise technopoles as a combination of high levels of digital autonomy and significant infrastructural power accumulated through bilateral digital dependencies. Using the DDI dataset to delineate digital dependency structures shaped by hardware, platform, and patents, this article presents a novel approach to understanding the asymmetric global structures of the digitalised global political economy. Over the past decade, asymmetric reliance on foreign platforms and hardware has reinforced a global structure in which the United States and China occupy distinct positions as technopoles. In particular, although China is closing in, the US technopole has generated greater dependencies and lower levels of autonomy than China. At the same time, the dual dependence structure on US platforms and Chinese hardware makes developed and emerging economies highly vulnerable to the use of infrastructural power. Our findings also suggest that the observed shift towards a bipolar pattern of technological geopolitics (Malkin 2022, Yan 2020, Liu and Tsai 2021), which can be explored and explained by a structural account, is an enduring socio-technical constellation shaping asymmetric global relations increasingly organised around the rivalry of two technopoles.

This study provides insights for policy debates on concerns about technological dependence and sovereignty. The dynamics of digital dependency are both country-specific and structurally embedded. As the global dependencies on platforms and communications equipment show, only the US has achieved strong autonomy in the platform dimension, while China, South Korea and two small countries, Singapore and Estonia, have achieved this status in the hardware dimension. For all other major economies, however, the vulnerability of double digital dependence is enormous (DDI values above 0.75) as geopolitical conditions deteriorate and fragmentation trends intensify. As a result, the political goal of achieving ‘technological autonomy’ is more pressing than policymakers and the public have been led to believe. The call for greater autonomy is all the more urgent as the results of our analysis suggest that the increased infrastructural power of technopoles could make the weaponisation of dependency and other coercive practices more common and frequent.

Notes

1. More details on the DDI methodology can be found in the comprehensive methodology description: https://digitaldependence.eu/wp-content/uploads/2022/05/DDI_Methodology.pdf.

2. The degree of autonomy is the inverse value of the total digital dependence score of a state.
3. The pervasive role of digital dependency structures is neither fully acknowledged by classical neorealist approaches nor adequately conceptualised and empirically addressed in contemporary studies of polarity.

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Data availability statement

The data supporting the findings of this study are openly available in statcounter global stats name at <https://gs.statcounter.com/>, in UNCTADSTAT at <https://unctadstat.unctad.org/EN/>, in the WIPO IP Statistics Data Center at <https://www3.wipo.int/ipstats/index.htm?tab=patent&lang=en> and in the Digital Dependence Index at <https://digitaldependence.eu/en/>.

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Appendix

Composition of Digital Dependence Index (DDI)				
Indicator I Trade in ICT goods	Indicator II Information- Infrastructure	Indicator III Trade-in ICT services	Indicator IV Information Infrastructure	Indicator V ICT-related Patents
• Computers peripheral & equipment • Communication equipment • Consumer electronic equipment • Electronic components • Miscellaneous	• Smartphone • Tablet	• Telecommunications- Services • Computer-Software • IT-Consulting, IT-Design, IT-Management, and IT-Training • Licenses to Computer Software	• Browser • Search Engine • Desktop OS. • Mobile OS. • Social Media	• Audio-visual technology • Telecommunications • Digital communication processes • Computer technology • IT methods for management • Semiconductors

Composition of DDI consisting of 3 subindexes and 23 indicators. Source: <https://digitaldependence.eu/en/>