Digital Autonomy?
Measuring the Global Digital Dependence Structure

Summary

The concern with "digital sovereignty" is animating heated political discussions around the world. However, the emphasis on autonomy tends to underestimate the extent to which major economies rely on digital technologies from abroad. Decades of neoliberal deregulation, trade, and technology-driven globalization created far-reaching dependencies that cannot be reversed overnight. This paper presents key results of the Digital Dependence Index (DDI). This new index draws on a broad range of indicators and three data sets to measure the dependency of 23 countries on digital technologies from abroad. While results differ greatly concerning different sectors (software, hardware, and Intellectual Property) and dimensions (such as trade, infrastructure), the overall picture shows a high average degree of digital dependence. In 2019, 87 percent of countries were highly vulnerable. Although the global dependence structure appears remarkably stable over time, there are substantial changes. China, South Korea, Russia, Kenya, and the US became more autonomous during the last decade. Japan and Indonesia, in contrast, experienced the most pronounced increases in digital dependency while the remaining 16 countries' positions changed very little. In addition, the DDI reveals a very uneven global landscape of digital dependence. The US is by far the least digitally dependent country with a value of 0.47. It managed to widen the "autonomy gap" vis-à-vis the other countries. The most pronounced asymmetry between the US and the world exists for infrastructure dependence. This means that the US is most autonomous regarding the infrastructural level of the "stack." Only China and South Korea could reduce the distance to the leader. China, in particular, made the greatest gains during the last ten years. European countries have maintained a highly vulnerable status while their autonomy gap to the US, China, and South Korea widened.

The results of measuring digital dependence suggest a sober reassessment of the status of "digital autonomy". The DDI has implications for various actors involved in digital policymaking at the national and EU level. The key message is that the degree of digital dependence of EU members is far greater, more pervasive and multifaceted than often assumed:

- European countries are falling behind in every dimension compared to China, South Korea, and the US. In the last decade, Europe's digital autonomy has eroded as digital interactions have become more asymmetric with China (ICT trade dependence), with the US (infrastructure and platform dependence), and the East Asian region (IP dependence).
- European capitals need to rethink their entire approach to digital technologies. If the goal of improving "technological autonomy" is taken seriously, a much more comprehensive and bold approach (policy-wise, financially, and strategic vision) would be required.
- European companies and governments should put a stronger emphasis on reducing their growing ICT-IP dependency.
- Germany should draw lessons from other "technological middle powers," especially from South Korea and Japan.

Contents

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The debate about digital autonomy

Concerns with digital dependence and vulnerability are growing. Digital technologies, ecosystems, and big data became central drivers of competition and geopolitics. Some see data as the new oil.[1] Others stress the geopolitical power of platform giants.[2] Because powerful actors now perceive all information as geopolitically relevant, "information power is altering the nature and behavior of the fundamental building block of international relations, the state, with potentially seismic consequences." Technologies such as 5G, artificial intelligence applications, and blockchain provoked a redefinition of national security[3] concerns and forced great powers to position themselves strategically.[4] In addition, some governments began to weaponize existing trade and infrastructural interdependence by implementing restrictions against third parties.[5] The globalized use of social media, smart algorithms, and the process of platformization are highly consequential, as it reshuffles business models and even the very conditions for growth, trade, and industrial policies worldwide.[6] In response, parliaments introduced a range of new data regulations while governments adapted new trade and industrial policies to cope with the disruption of societies, business relationships, and markets. This transformative dynamic could lead to more financial concentration, foster societal polarization, and deepen digital inequalities regardless of antitrust regulations and tax policies. The distribution of digital capabilities is already highly unequal. The new models of data extraction and dependency could even lead to forms of "digital colonialism."[7]

In Europe, the Covid-19 pandemic, too, has reinforced public anxieties about technological vulnerabilities.[8] Politicians recognized the effects of supply shocks and the fragility of just-in-time production networks. Many problematized the reliance on the import of critical goods. Before the pandemic, the notion of "digital sovereignty" emerged as a popular yet elusive expression of these uneasy sentiments. It seems that the basic tenets of trade globalization and ever-deepening technological connectivity are questioned across various policy fields.

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[1] "The World's Most Valuable Resource Is No Longer Oil, but Data," The Economist, May 6, 2017, https://www.economist.com/leaders/2017/05/06/the-worlds-most-valuable-resource-is-no-longer-oil-but-data.

[2] Ian Bremmer, "The Technopolar Moment," Foreign Affairs, November 16, 2021. https://www.foreignaffairs.com/articles/world/2021-10-19/ian-bremmer-big-tech-global-order.

[3] "For China's Business Elites, Staying Out of Politics Is No Longer an Option," July 6, 2021, https://www.nytimes.com/2021/07/06/technology/china-business-politics-didi.html.

[4] Eric Rosenbach and Katherine Mansted, "The Geopolitics of Information," Harvard Kennedy School, May 28, 2019, https://www.belfercenter.org/publication/geopolitics-information; William Rankin, *After the Map: Cartography, Navigation, and the Transformation of Territory in the Twentieth Century* (Chicago: University of Chicago Press 2016); Milton Mueller, *Will the internet fragment? Sovereignty, globalization and cyberspace* (John Wiley & Sons 2017).

[5] Henry Farrell and Abraham L. Newman, "Weaponized interdependence: How global economic networks shape state coercion," *International Security*, 44(1) (2019): 42-79.

[6] Anne Helmond, "The platformization of the web: Making web data platform ready," *Social media+ society*, 1(2) (2015): 1 –11; Jeroen De Kloet, et al., "The platformization of Chinese society: Infrastructure, governance, and practice," *Chinese Journal of Communication*, 12(3) (2019): 249-256; Steven Weber, "Data, development, and growth," *Business and Politics*, 19(3) (2017): 397-423; Lizhi Liu, "The Rise of Data Politics: Digital China and the World," *Studies in Comparative International Development*, 56 (2021): 45-67; Philipp Staab, *Digitaler Kapitalismus: Markt und Herrschaft in der Ökonomie der Unknappheit* (Suhrkamp Verlag 2019).

[7] Michael Kwet, "Digital colonialism: US empire and the new imperialism in the global south," *Race & Class*, 60(4) (2019): 3-26; Renata Ávila Pinto, "Digital sovereignty or digital colonialism?" *Sur International Journal on Human Rights*, 15(27) (2018): 15-27. Engin Isin and Evelyn Ruppert, "Data's empire: Postcolonial data politics." In: *Data Politics Worlds, Subjects, Rights*, eds. Didier Bigo, Engin Isin and Evelyn Ruppert. Routledge (2019): 207-227.

[8] Ulrike Franke and José Ignacio Torreblanca, "Geo-Tech Politics: Why Technology Shapes European Power," ECFR, July 15, 2021, https://ecfr.eu/publication/geo-tech-politics-why-technology-shapes-european-power/.

Interdependence within the world economy, and especially reliance on foreign controlled platform companies, was viewed as a potential security threat, an economic risk, and a political problem for democratic systems needing solutions. The resulting debates have moved from mere ideas to concrete measures to regain some degree of national autonomy or even on "autarky"[9]. The EU Commission's "2021 Strategic Foresight Report"[10] states that Europe's "digital sovereignty will depend on the capacity to store, extract and process data." Arguably, China got a head start with implementing its conception of information sovereignty ten years ago. Comparable notions are now commonsense around the world.[11] Related initiatives, policy measures, and strategic goals are heatedly discussed within the political discourses in the US, Europe[12], and other regions.

Composition of Digital Dependence Index (DDI)

Subindex A (Hardware)		Subindex B (Software)		Subindex C (Intellectual Property)
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 •Basic communication processes •Computer technology •IT methods for management •Semiconductors

Table 1. Composition of DDI consisting of 3 subindexes and 23 indicators

But how autonomous or dependent are European countries in the digital realm? Comprehensive empirical assessments are lacking thus far. A pressing issue, as Ramon Fernandez and Katrin Suder point out, is to evaluate "the European actors' dependencies on foreign companies, and especially across the ICT stack."[13] Against this background, the digital dependence index (DDI) systematically measures the degree and tendencies of national digital dependence that goes beyond particular sectors or certain technologies such as semiconductors.[14] The DDI compares data from 23 leading countries regarding their software, hardware, and digital intellectual property and computes them on a scale from zero (meaning autarkic) to one (meaning absolute

[9] Scott Malcomson, "The New Age of Autarky," Foreign Affairs, October 19, 2021, https://www.foreignaffairs.com/articles/united-states/2021-04-26/new-age-autarky.
[10] Rep. "2021 Strategic Foresight Report The EU's Capacity and Freedom to Act," European Commission, September 8, 2021, https://ec.europa.eu/info/sites/default/files/foresight_report_com750_en.pdf.
[11] Milton Mueller, "Against sovereignty in cyberspace," *International Studies Review*, 22(4) (2020): 779-801.
[12] Maximilian Mayer, "Europe's Digital Autonomy and Potentials of a U.S.-German Alignment toward China," AICGS, December 16, 2020, https://www.aicgs.org/2020/12/europes-digital-autonomy-and-potentials-of-a-u-s-german-alignment-toward-china/.
[13] Ramon Fernandez and Katrin Suder, "Digital Compass: Europe's Digital Sovereignty?" Institut Montaigne, April 6, 2021, https://www.institutmontaigne.org/en/blog/digital-compass-europes-digital-sovereignty; Cf. Kagermann, Henning, Karl-Heinz Streibich and Katrin Suder, "Digital Sovereignty Status Quo and Perspectives". Acatech, 2021, https://en.acatech.de/publication/digital-sovereignty/.
[14] Jan-Peter Kleinhans and John Lee, "Two Part Series: Taiwan and the Global Semiconductor Supply Chain," Stiftung Neue Verantwortung (SNV), October 6, 2021, https://www.stiftung-nv.de/en/publication/two-part-series-taiwan-and-global-semiconductor-supply-chain.

dependent).[15] Its results are interpreted within a four-tier framework (table 2) that distinguishes different degrees of dependence regarding the reliance on non-domestic digital technology components, products, services, or infrastructures.[16]

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

Table 2. Four degrees of digital dependence

The DDI is based on the following basic definition of digital dependence: "the extent to which actors in a particular country have to rely on foreign-controlled digital technologies to perform digital activities." Foreign control refers to different aspects of DDI's three pillars utilized to measure digital dependence. 1) ICT products and services manufactured and provided by suppliers based abroad (measurable by share of imports in foreign trade statistics). 2) Information infrastructures: digital ecosystems or platforms and connected devices *controlled and/or provided by foreign* companies (measurable by market shares). 3) Intellectual property: patents for digital technologies *owned* by foreign firms (measurable by patent grant statistics). Digital dependence needs to be conceptualized in terms of a country's relationships either vis a vis the rest of the world or regarding a specific country or region. Compared with the overall ICT trade, the bilateral picture can be quite different.[17]

Key insights from the digital dependence index

The overall picture that emerges from the DDI is striking: all actors, which pursue digital activities, regardless of whether individuals, firms, communities, or countries, are deeply, and perhaps inescapably, embedded in a global dependence structure (figure 1). From zero to 100 percent, 19 out of 23 countries have a DDI Value above 0.8. This means all but three countries

[15] These 23 countries cover several continents, regions, and different levels in terms per capita income and development of digital industries. They account for 100% of all ICT-related patents and 63% of international trade in ICT goods. For a detailed description of the methods used for the DDI see: https://digitaldependence.eu.

[16] We use the concept of sensibility and vulnerability from Nye and Keohane to describe the four levels of digital dependence. This concept is defined as follows: "In terms of the cost of dependence, sensitivity means liability to costly effects imposed from outside before policies are altered to try to change the situation. Vulnerability can be defined as an actor's liability to suffer costs imposed by external events even after policies have been altered." See Joseph S. Nye Jr. and Robert O. Keohane, *Power and Interdependence*, 4th ed. (Boston u.a.: Longman 2011): 11.

[17] Even if a country's ICT trade relations are highly assymetric, its overall trade balance might still be positive due to other exported goods such as raw materials.

belong to the “highly vulnerable” group in which digital dependency appears irreversible, at least in the light of usual political time scales. Although some countries are less dependent than others, in 2019, even the most autonomous have a “low vulnerability” (DDI between 0.75 and 0.5). In 2019, the US was the only country with “high sensitivity” (DDI between 0.5 and 0.25). The political emphasis on autonomy tends to underestimate how major economies rely on digital technologies from abroad. Decades of neoliberal deregulation, trade, and technology-driven globalization have created far-reaching dependencies and complex risks that are still poorly understood and barely documented.

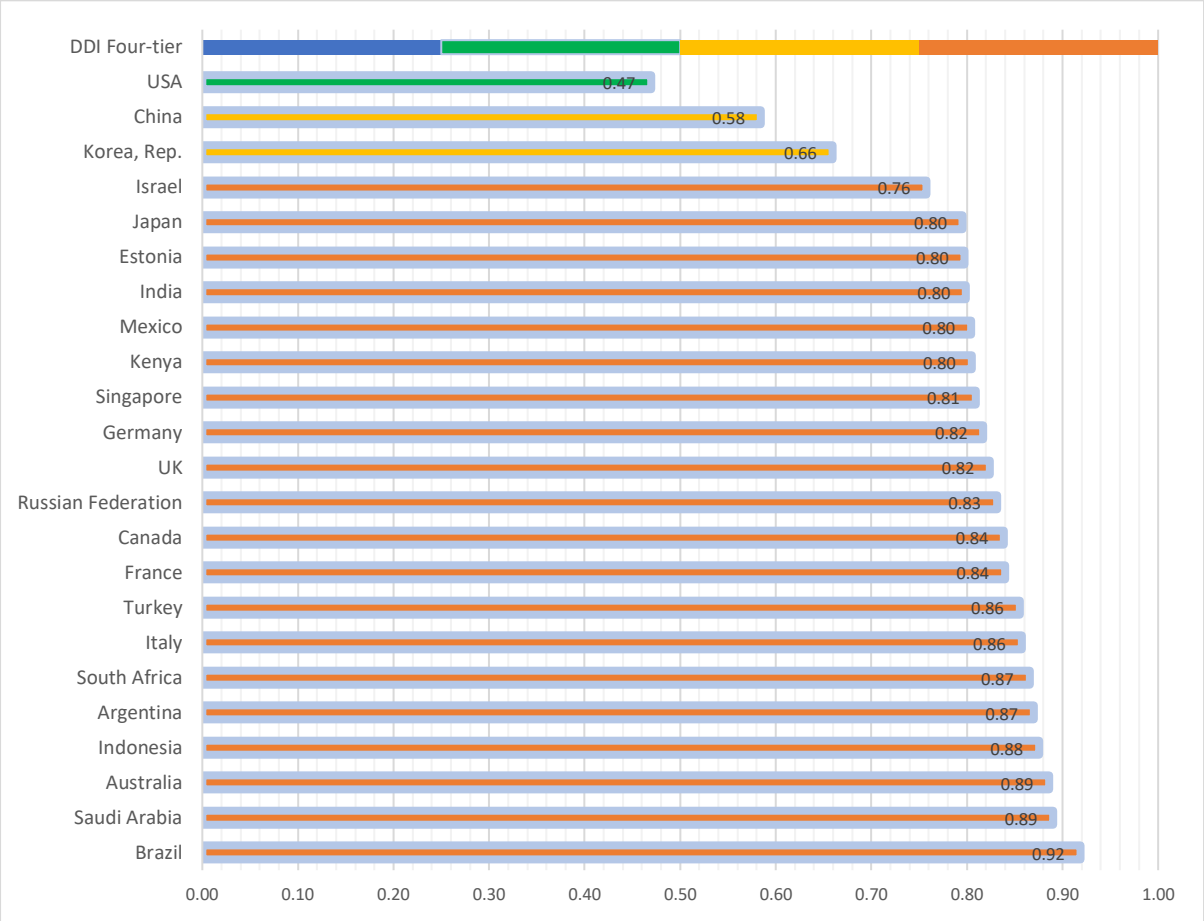

Figure 2. 2019 Overall Digital Depedence (DDI Values equal-weighted)

In addition to its standard value (all subindices equally weighted), the DDI sheds light on the differences between software and hardware dependencies on the one hand, and offers three weightings that render visible the differences concering trade with information technologies, infrastructures and IT-related patents. Figure 2, for instance, shows the variations for sectors that may partially reflect the relative success of domestic industries. Most countries, such as India, Israel, the US, and Russia, are more dependent on foreign hardware sources and less on software. Others, including South Korea, Singapore, and Indonesia, have the reverse pattern. There is also a group of economies (Germany, France, and Mexico) equally dependent in terms of software and hardware.

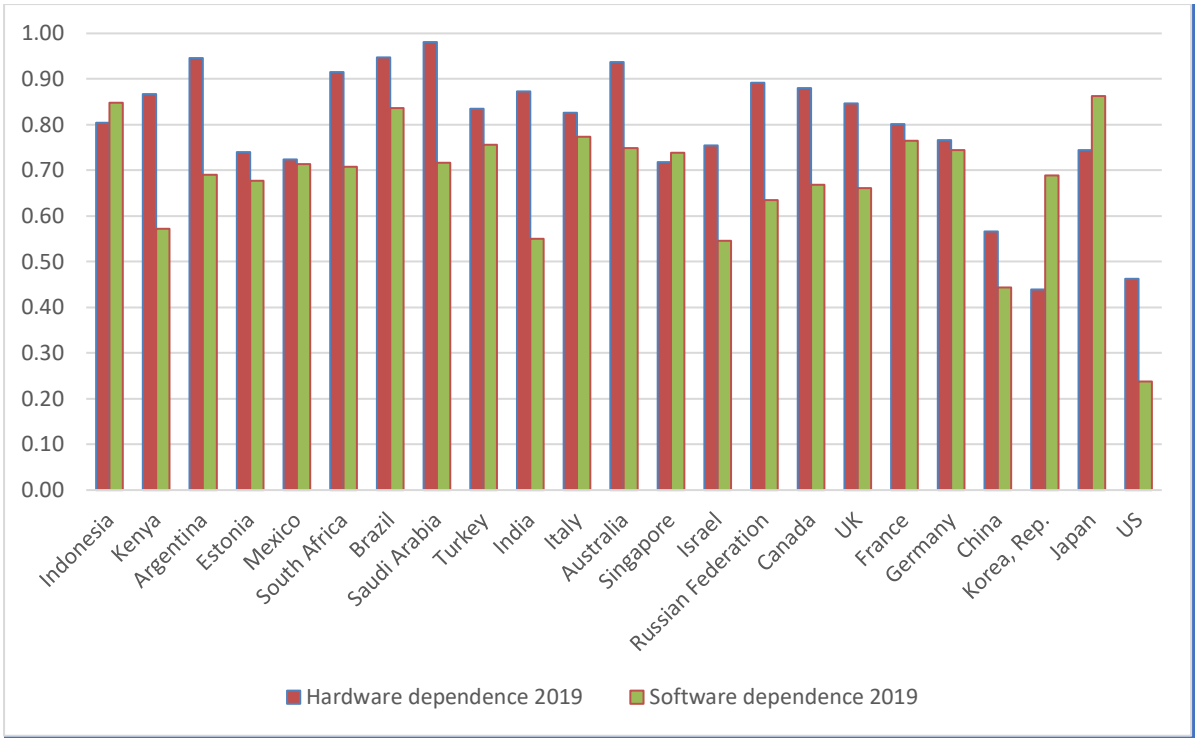

Figure 2. 2019 Dependence in hardware and software.

According to the 2019 data presented in figure 3, a significant pattern of divergence is revealed. Countries are least digitally dependent on ICT trade (average 0.68), while infrastructural dependence averages 0.88. For IP, the average is 0.92, while most countries have a dependence level close to 100 percent. The DDI indicates, thus, the immense disruptive effects and adjustments costs that would stem from any possible "decoupling" policies, especially for IP and information infrastructures.

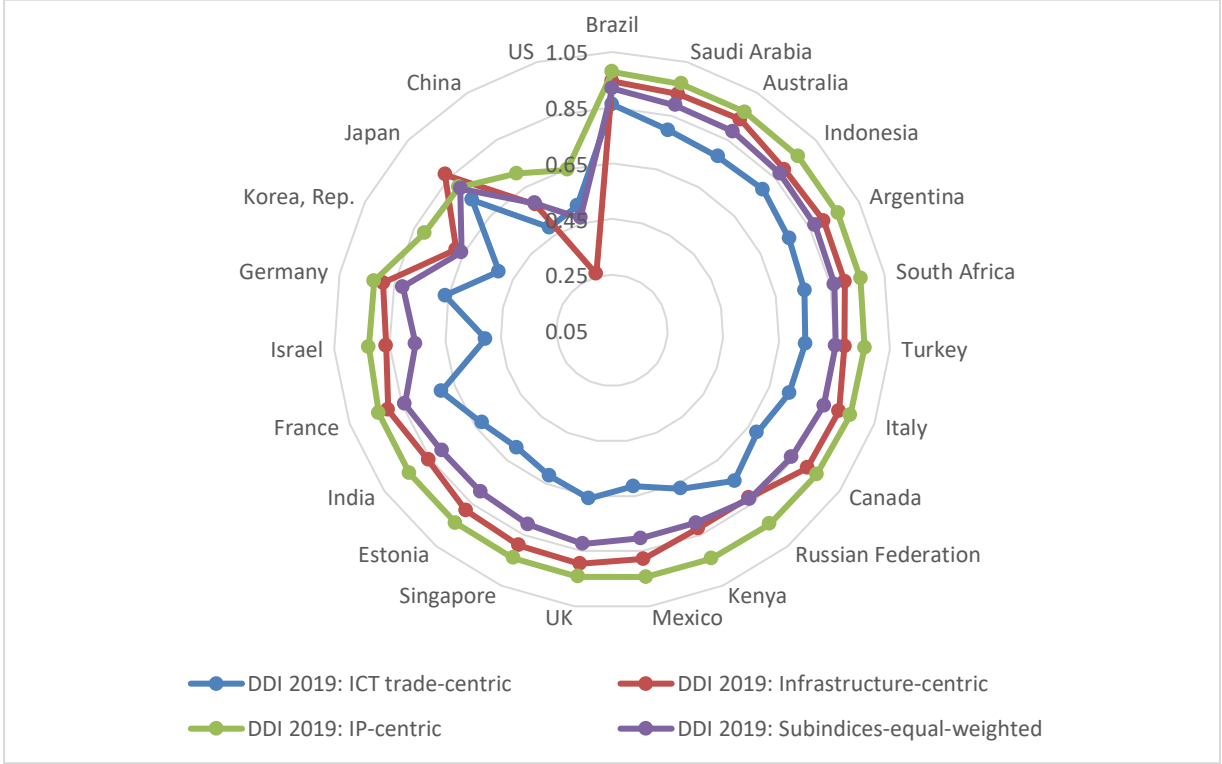

Figure 2. 2019 DDI Values for four different weightings

The DDI reveals a very uneven global landscape of digital dependence in general absolute terms. In 2010 and 2019, the US was by far the least digitally dependent country. With a value of 0.47 (2019), it is outstanding as the only country that does not fall into the vulnerable category. As for intellectual property, the uneven distribution is also present while East Asian countries control a growing share. Patents are concentrated in the hands of a few companies that are, in turn, registered in a small number of jurisdictions. Therefore, all economies are highly dependent concerning foreign firms' IP, with South Korea, Japan, and the US being the least dependent.

In addition, the DDI quantifies the distance between the least dependent country and the rest. The "autonomy gap" measures digital dependency in relative terms (figure 4). Its size is assumed to have formative effects on nation-states' technology choices and industrial and ultimate foreign policy. The most significant autonomy gaps occur for Brazil (45 percentage points more dependent than the US), Saudi Arabia (42), Australia (42), Indonesia (41), Argentine (40), and South Africa (40). The smallest difference is measured for China (11), South Korea (19), and Israel (29).

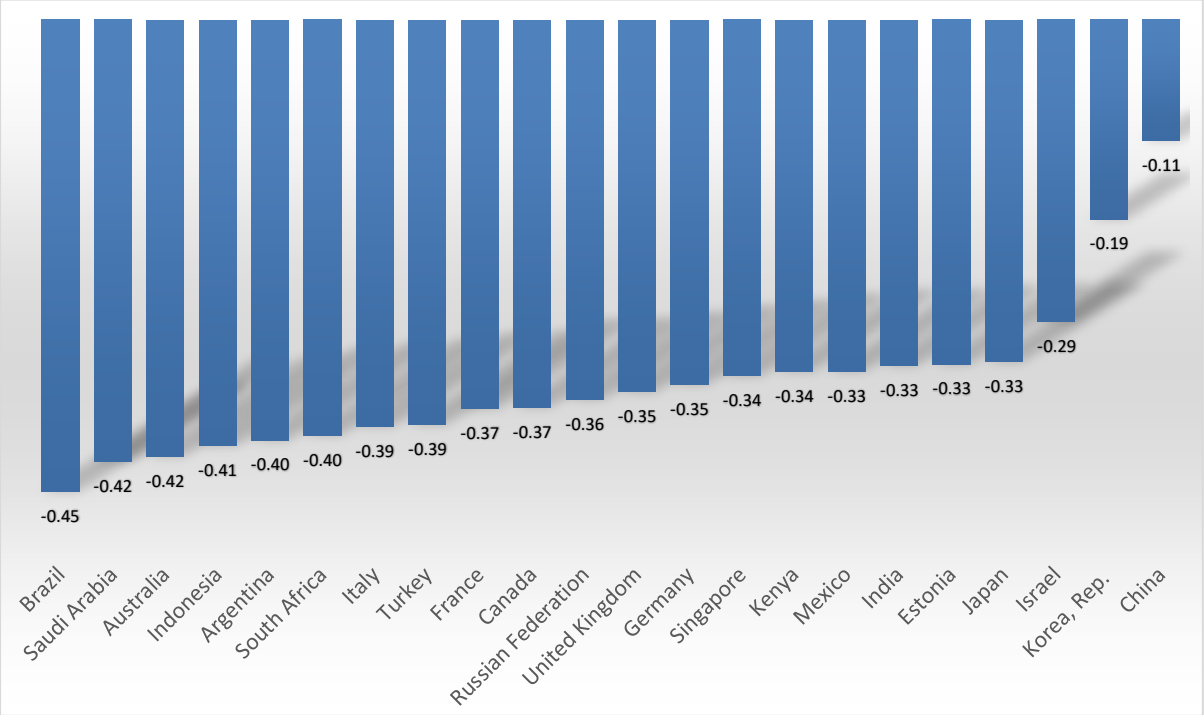

Figure 4. Autonomy gap in 2019

Aside from an equal weighting of all subindices, the DDI can also calculate the autonomy gap for three different weightings. The gap follows a pattern based on the measuring subjects (trade, information infrastructure, and IP) (figure 5). In 2019, the average information infrastructure-centered autonomy gap was 0.58. For the IP-centered, the value is 0.27, while the trade-centered version is only at 0.19. That means that the average gap between the leader and other countries is the smallest in trade relations while the largest in terms of information infrastructures.

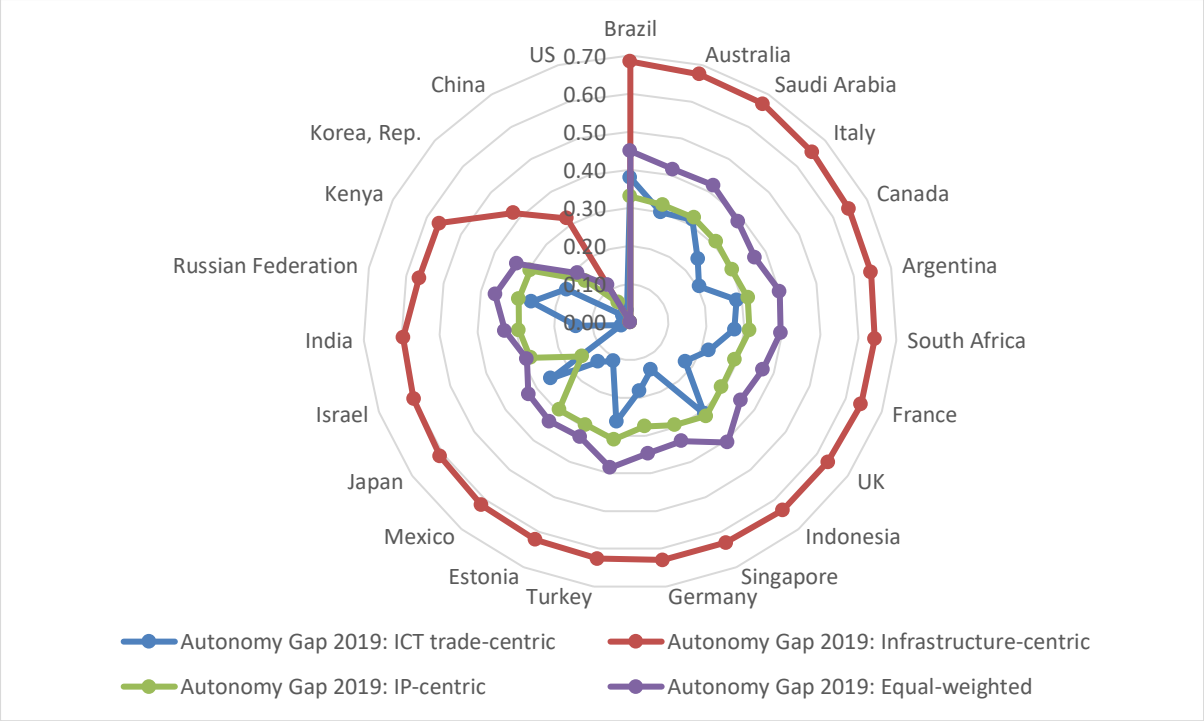

Figure 5. 2019 Autonomy gap of four different DDI weightings

Moreover, the variations between countries are also enormous. The most pronounced asymmetry exists between the US and the world concerning information infrastructure. For this indicator, the US is autarkic (figure 6). US users or companies can rely almost 100 percent on firms operating under US jurisdiction whenever they need platform services. The reverse is true for all other countries (except China), in which digital activities have to rely on foreign-owned platforms and related technology. The near total dependence of most economies on foreign platforms means that data collection is completely in the hand of foreign companies, overwhelmingly from the US. The DDI values for information infrastructures and platforms combined suggest that the US is most autonomous regarding the infrastructural levels of the "stack."

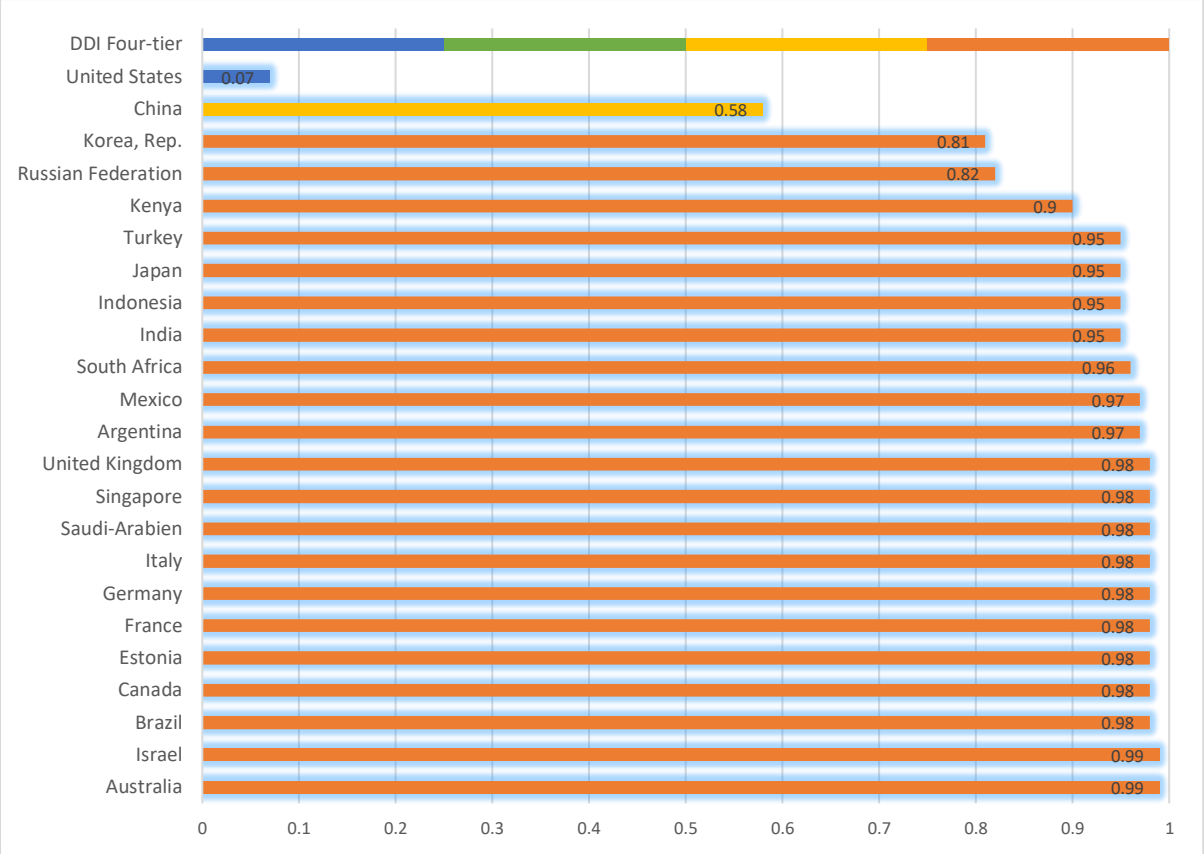

Figure 6. Information Infrastructure dependence in 2019

European countries dependence on US and China

The data on digital dependence presented above suggests that actors in most countries have to rely heavily on foreign-controlled digital technologies.[18] What are the implications for the notion of "autonomy"? Table 3 compares the bilateral digital dependencies (trade and infrastructure) of selected European countries with China and the US, the world's current two technopoles.[19] A clear pattern is observable. With respect to their bilateral trade with China in ICT goods, Germany, France, UK, Italy, and Estonia are highly vulnerable (between 0.86 and 0.95). The dependency values are much higher than in their overall ICT trade, while China's bilateral dependencies with these countries are minuscule (between 0.5 and 0.14). The bilateral trade dependence on the US is, by comparison, close to symmetrical or even at the sensitive level. The US's bilateral dependencies with these countries is significantly higher than China's (between 0.35 and 0.94). Concerning information infrastructure, we find the situation largely reversed. European countries bilateral digital dependence on China is minuscule (0.02 to 0.05), while infrastructure dependence on the US is very high (0.83 to 0.89). At the same time, China and the US are largely autarkic from European countries regarding infrastructure.

European countries' bilateral digital dependence on China and US

2019	Germany	France	UK	Italy	Estonia

[18] As our selection of countries, biased toward richer and technologically more advanced countries, already shows a high dependency, we can assume that the DDI values would even be higher for most other countries.
[19] The US and China have the biggest production capacity, the majority share in global exports and imports of ICT goods, and are the least digitally dependent country at the same time (see Appendix).

Total ICT goods trade dependence	0.59	0.65	0.74	0.69	0.52
Bilateral Dependence China	0.86	0.95	0.95	0.92	0.91
Bilateral Dependence on US	0.62	0.65	0.55	0.38	0.06
China's bilateral dependence on	0.14	0.05	0.05	0.08	0.09
US's bilateral dependence on	0.38	0.35	0.45	0.62	0.94
Overall communication infrastructure dependence	0.98	0.98	0.98	0.98	0.98
Bilateral Dependence on China	0.03	0.03	0.02	0.05	0.04
Bilateral Dependence on US	0.83	0.83	0.89	0.83	0.84
China's bilateral dependence on	0	0	0	0	0
US's bilateral dependence on	0	0	0	0	0
Share of global ICT goods exports	3.21%	0.93%	0.82%	0.46%	0.06%
Volume ICT goods exports (US dollar in millions)	73181	21059	18716	10424	1277
Volume ICT goods imports (US dollar in millions)	103743	39744	52422	23227	1394

Table 3. European countries' bilateral digital dependence on China and US

If digital autonomy refers to self-determined choices of trading partners or technologies, i.e. realistic "outside options",[20] European countries display a low level of autonomy because they are subject to double dependencies: 1) They can hardly replace Chinese trading partners (China's share of overall ICT trade with the UK is 29 percent, with Germany 26 percent) while bilateral ICT trade relations are highly asymmetric. 2) They likely remain highly dependent on US firms which effectively control all information infrastructures. The bilateral dependencies on the two technopoles (US and China) are key factors behind Europa's decreasing digital autonomy (see also fig. 9). Working toward digital autonomy would require Europe to decrease in particular bilateral digital dependencies on the technopoles – in different subindices and overall – and to improve the status from high vulnerability towards a more symmetrical relationship. Given the prominence of China (in ICT trade) and the US (in infrastructures), decreasing the double dependencies is a titanic undertaking.

[20] Cf. IT-Planungsrat, *Strategie zur Stärkung der Digitalen Souveränität für die IT der Öffentlichen Verwaltung Strategische Ziele, Lösungsansätze und Maßnahmen zur Umsetzung* (IT-Planungsrat, 2021), https://www.it-planungsrat.de/fileadmin/beschluesse/2021/Beschluss2021-09_Strategie_zur_Staerkung_der_digitalen_Souveraenitaet.pdf, p. 6.

A decade of structural continuity and shifts

The high overall dependence has been a persistent condition for most countries. A comparison of DDI data from 2010 and 2019 shows that the general structure looked very similar a decade ago (figure 7). The average DDI value of 23 countries was 0.82 in 2010 and 0.8 ten years later. But we found significant changes in a few countries. On the one hand, a group became substantially more autonomous, including China (12 percent), South Korea (8 percent), the US (7 percent), Russia (6 percent), and Kenya (6 percent). On the other hand, Japan and Indonesia became more dependent (8 percent and 5 percent respectively).

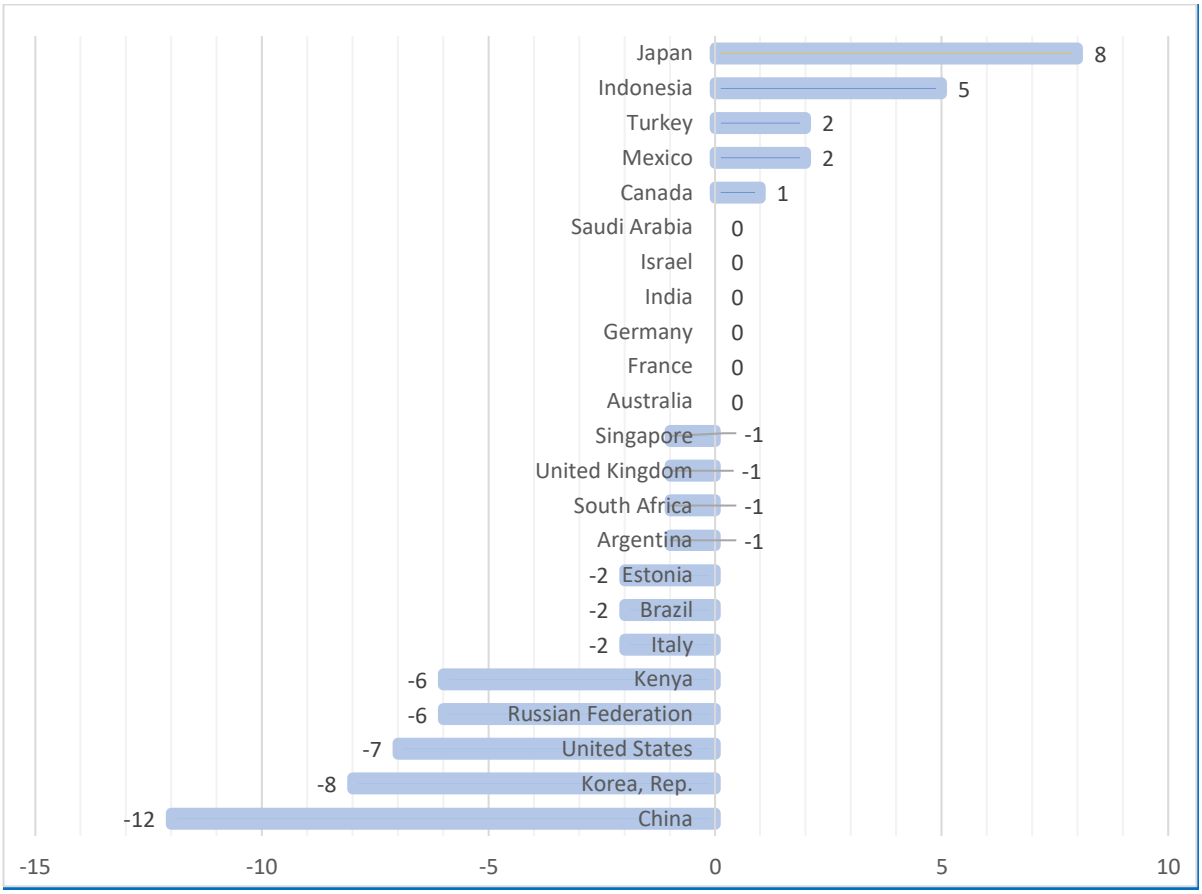

Figure 7. Change of DDI Value (Equally Weighted) between 2010 and 2019 (in percentage points)

Crucial changes are visible in the relative distance to the least digitally dependent country (figure 8). Between 2010 and 2019, the US widened the "autonomy gap" vis-à-vis the rest of the countries measured by the index. The autonomy gap grew most extremely for Japan (15 percentage points), Indonesia (11 percentage points), and Mexico (9 percentage points). The autonomy gap between Germany, France, the UK, and the US increased by six percentage points. The change was smaller for Estonia (5 percent), Italy (4 percent), Russia (1 percent), and Kenya (1 percent). The two exceptions defying this trend were China and South Korea. Both could reduce their distance from the leader (US). The decadal shifts of the trade-centric DDI are most pronounced for Russia (gaining eight percentage points) and Indonesia (losing 13 percentage points). The information infrastructure-centric weighing shows that five countries reduced their dependency substantially: China's value went from 0.75 down to 0.58, South Korea from 0.83 to 0.68, the US from 0.39 to 0.26, Kenya from 0.92 to 0.83, and Russia from 0.91 to 0.83 (see appendix). While the DDI cannot *explain* these and other developments, its results indicate, for instance, that the effects of new data-driven growth models such as

"vertical integration," which are assumed in the literature,[21] might be possibly already observable in the case of China and, to a lesser degree, South Korea.

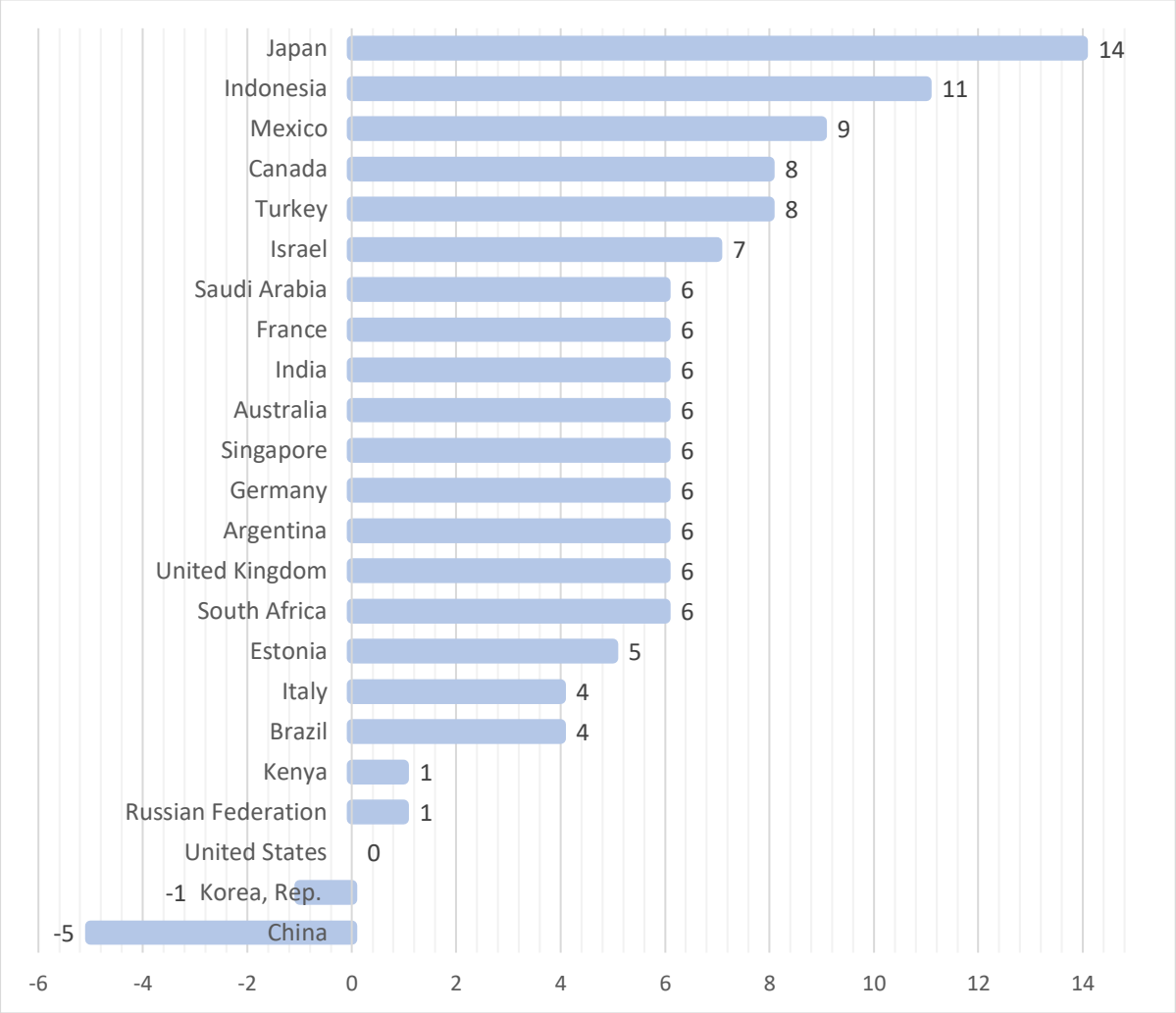

Figure 8. Change of autonomy gap vis-à-vis USA between 2010 and 2019 (in percentage points)

A truly tectonic shift is observable in the data about trade in ICT goods. Here, the DDI's data cover 20 years from 2000, before China entered the WTO, to 2019 (figure 9). The volume of traded ICT goods between China and other countries grew manifold while the Chinese share of countries' total trade with ITC goods increased. In 2000, no country had a bigger share than 15 percent; 20 years later, China's share was bigger than 15 percent for any single country, while South Korea, India, and Japan reached 50 percent and higher. These data evidence the massive relocation of production networks and supply chains which have genuinely become China-centered over the last 20 years—especially in East Asia. The bilateral dependence on China increased immensely across the board, bringing China into a powerful position. Most countries, including the US, India, and EU-27, have reached a digital dependency on China close to 90 percent or above for ICT goods. In contrast, Singapore, South Korea, and Taiwan have defied the trend and kept their bilateral DDI below 0.35.[22] This progression allows for two competing interpretations concerning digital autonomy: On one hand, if China's growing

[21] See e.g. Steven Weber, "Data, development, and growth," *Business and Politics*, 19(3) (2017): 397-423.
[22] Taiwan is included here as it plays a critical role in the global hardware supply chain. The Chinese ICT sectors and manufacturers have been highly reliant on and vulnerable to the Taiwanese suppliers of semiconductors and other products.

share in a country's ICT trade is seen as a measure for losing autonomy, then East Asian countries became relatively less autonomous vis-à-vis China than European countries. But if, on the other hand, the growing asymmetry within bilateral trade flows is seen as a measure for losing autonomy, then European countries among many others became relatively less autonomous towards China, whereas the East Asian region—except Japan—managed to maintain roughly the same level digital autonomy towards the technopole China than twenty years ago. India is an example that displays significantly less digital autonomy in its ICT trade relationship with China on both accounts.

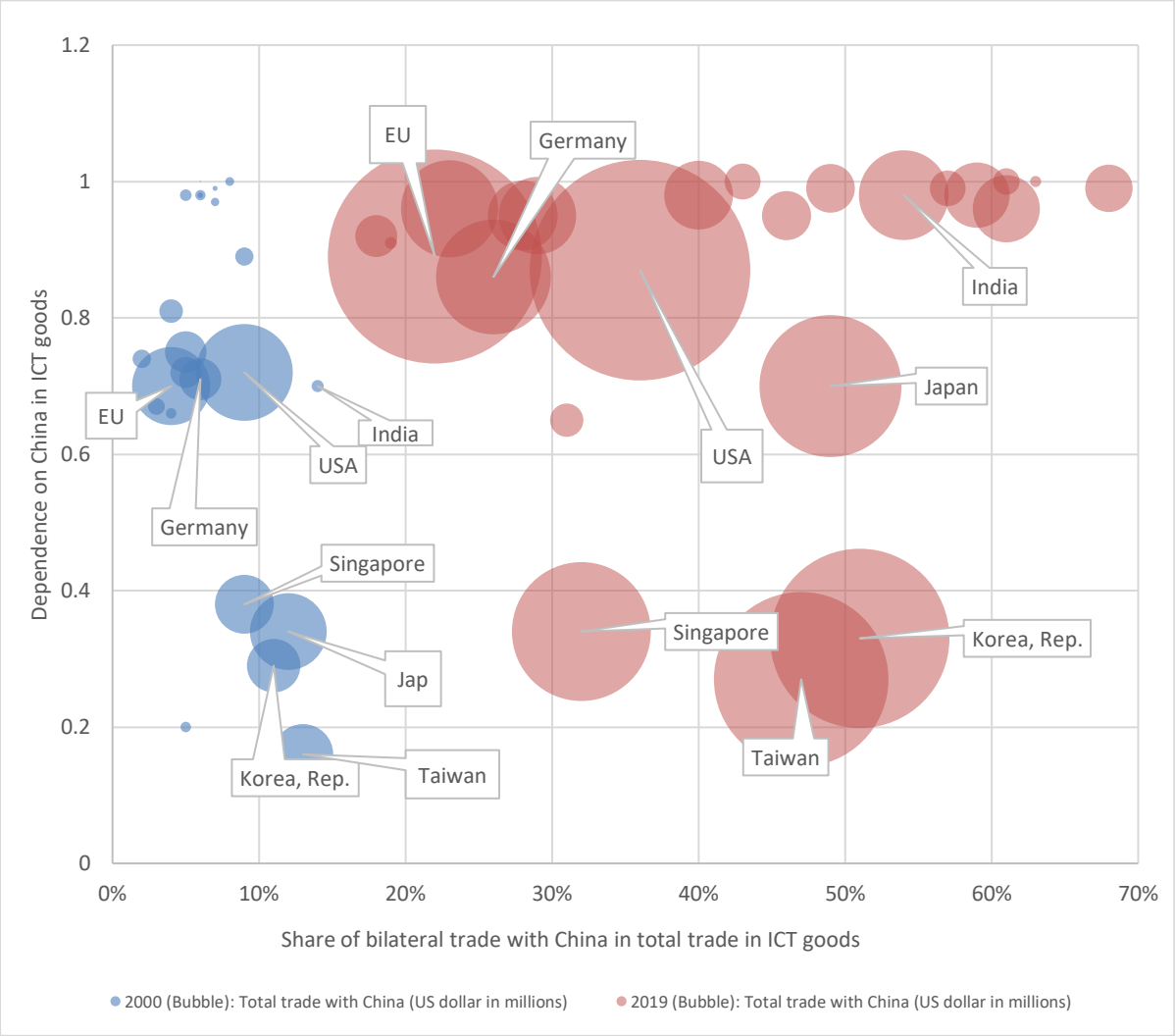

Figure 9. Shifting dependence structures and ICT trade volume between China and other countries (2000 vs. 2019)

The DDI uses flow data in figure 10 to cover 20 years of annual patent grants. It measures the share from one country's firms in terms of globally granted patents over time. For most countries, the IP dependence did not change much. However, it was not the case for China and Japan. While the Chinese annual share in 2019 was 24 percentage points larger than in 2000, the share of Japanese companies was 18 percent smaller. The values for IP-centered DDI reflect the same trend (see appendix). Germany, Singapore, Israel, and South Korea saw instead slight increases in 2020. Although the patent office in Beijing granted a good part of Chinese patents, this remains a significant global dynamic—especially in the light of recent economic policy

changes by the Chinese government aiming at "internalizing global value chains."[23] The annual flows eventually impact the cumulative IP structure, where Japan is still in a strong position. They reshape the ownership distribution of intellectual property and thus the control of various emerging digital technologies. This change affects non-Chinese companies in all significant markets (including China) by increasing the inflow of royalties and license fees and progressively strengthening the IP pillar of Chinese digital autonomy.

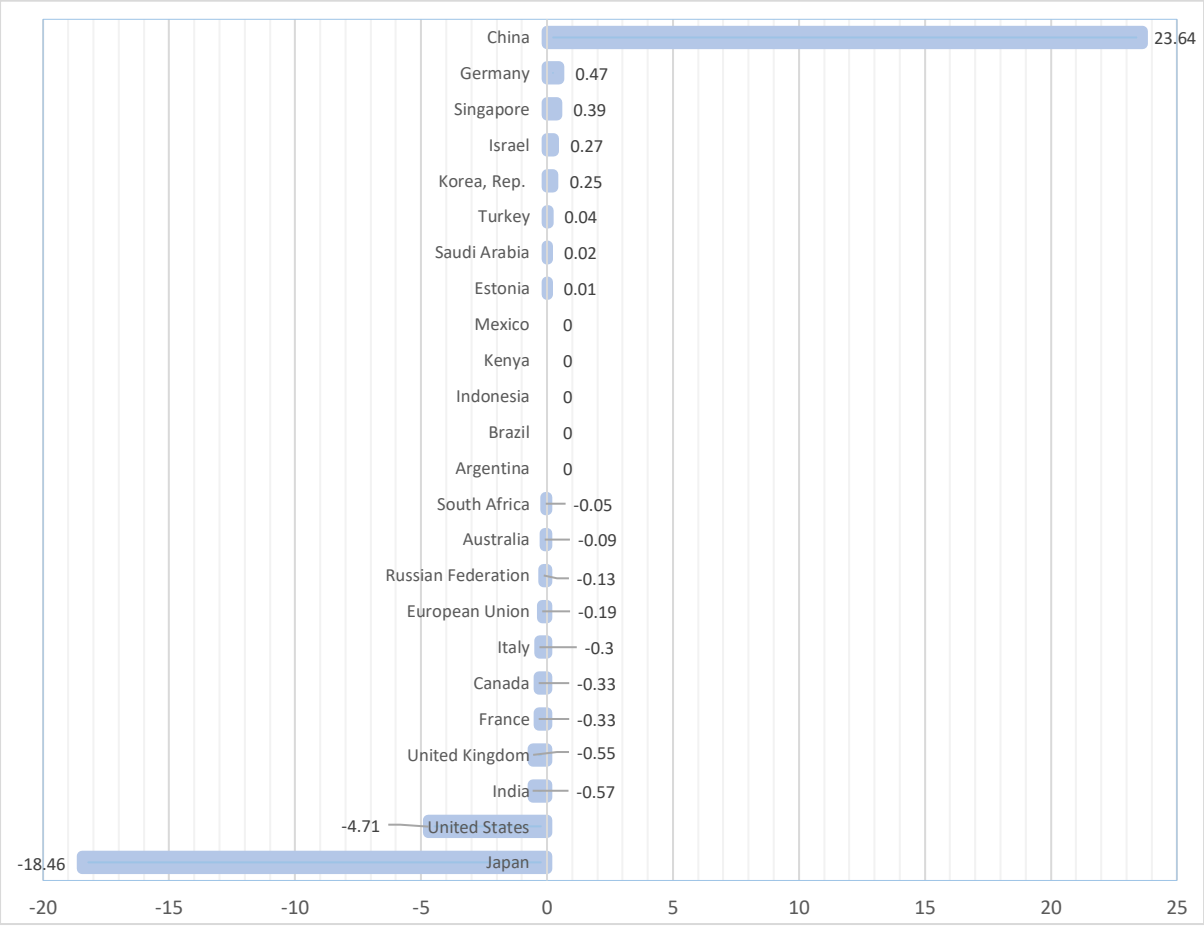

Figure 10. Difference between globally granted ICT patents owned by the firm of index countries in 2000 and 2019 (change in percentage points)

Diverging paths of technological middle powers

A look at the data of "technological middle powers," not only China's digital dependence was subject to significant changes. Countries such as Japan, Germany, Singapore, Israel, and South Korea, all digital leaders in their own right, also showed huge differences. Table 4 compares different DDI weightings for 2010 and 2019. Singapore, Germany, and Israel display broadly similar trends: minuscule changes in trade-centric, infrastructure-centric, and IP-centric dependence. As a result of this stasis, their autonomy gap to the US grew between 20 and 30 percent. In the same period, the two East Asian countries ended up at opposite ends. Japan's

[23] Alexander Brown, et al., "Course Correction: China's Shifting Approach to Economic Globalization," Merics, October 19, 2021, https://merics.org/en/report/course-correction-chinas-shifting-approach-economic-globalization.

autonomy gap increased more than any technological middle power (74 percent), whereas the South Korean gap was reduced by 5 percent.

Comparison of Technological Middle Powers

	Japan	Germany	Singapore	Israel	South Korea
ICT Trade-centric DDI 2010	0.67	0.67	0.62	0.5	0.57
ICT Trade-centric DDI 2019	0.74	0.66	0.62	0.51	0,51
Change in Percent	***10.45%***	***-1.49%***	***0%***	***2%***	***-10.53%***
Infrastructure-centric DDI 2010	0.83	0.91	0.90	0.87	0.83
Infrastructure-centric DDI 2019	0.87	0.89	0.89	0.86	0.68
Change in Percent	***4.82%***	***-2.2%***	***-1.11%***	***-1.15%***	***-18.07%***
IP-centric DDI 2010	0.69	0.92	0.94	0.93	0.83
IP-centric DDI 2019	0.80	0.92	0.94	0.93	0.81
Change in Percent	***15.94%***	***0%***	***0%***	***0%***	***-2.41%***
Autonomy Gap 2010 (Equally Weighted)	0.19	0.29	0.28	0.22	0.20
Autonomy Gap 2019 (Equally Weighted)	0.33	0.35	0.34	0.29	0.19
Change in Percent	***73.68%***	***20.69%***	***21.43%***	***31.82%***	***-5.00%***

Table 4. Trends of digital dependencies of technological middle powers 2010-2019

The comparison of dependency trends in Germany's and South Korea's ICT trade depicted by figures 11 and 12 points towards another intriguing puzzle. There is a growing divergence for digital dependency on China and the US in the twenty years after 2000. Though on different levels, Germany and South Korea have a quickly growing total trade volume with China (ICT goods). Their trade with the US is at the same time stagnating on a comparably low level. Yet, South Korea's bilateral dependence on both China and the US remained low (0.33 and 0.26 in 2019, respectively). In contrast, Germany's bilateral dependence on the US declined slightly from 0.78 to 0.62, and its dependence on China grew 10.5 percentage points from 0.71 to 0.86.

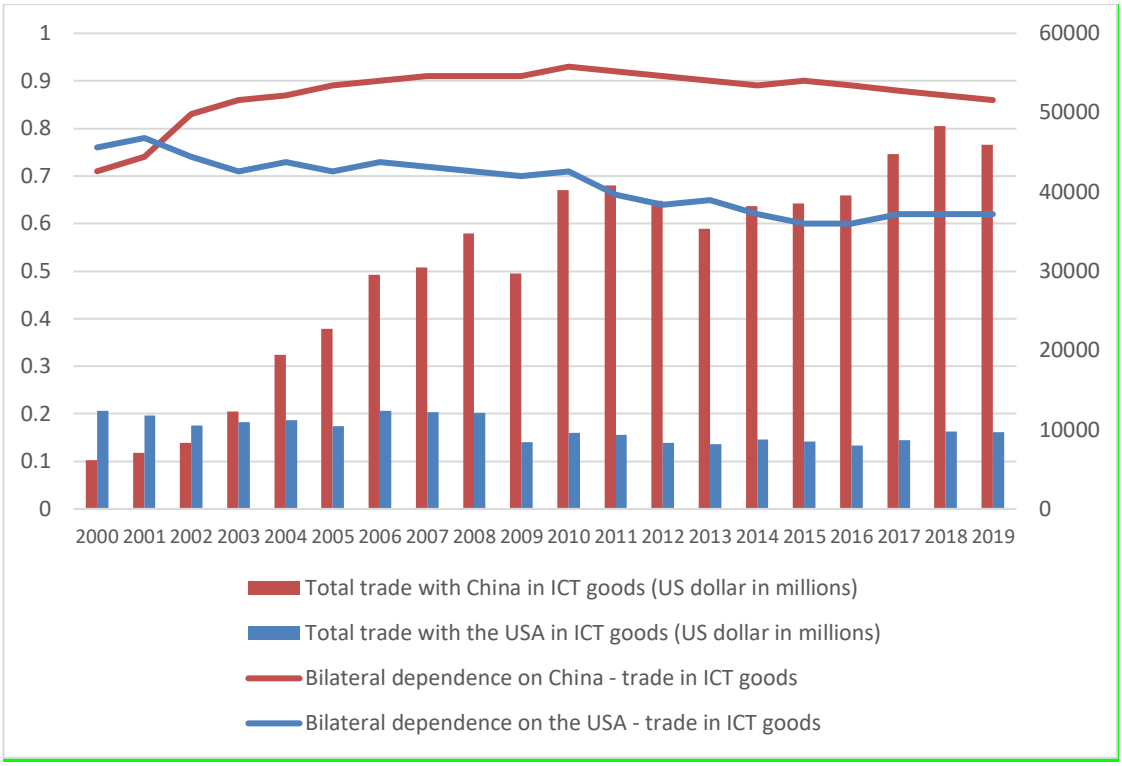

Figure 11. Trend of Germany's bilateral digital dependence on China and the US.

The DDI comparison of Germany and South Korea holds crucial lessons for policymakers about the future choices of Germany's industrial and innovation policy if the goal is to become less digitally dependent. A study of industrial and trade policies, data regulations, and innovations in digital ecosystems in Japan and South Korea should explain the diverging trends of digital dependency.

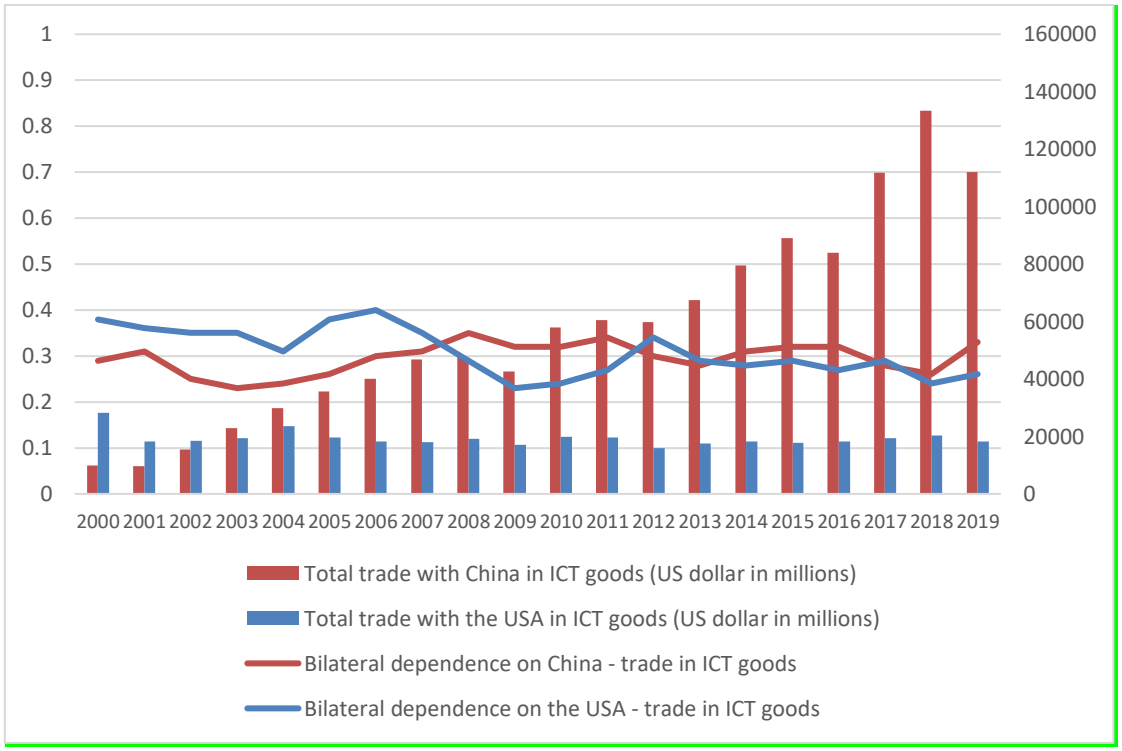

Figure 12. Trend of South Korea's bilateral digital dependence on China and the US.

Implications

The DDI visualizes the aggregated pattern of flows that permeate variegated supply chains, trade relationships, and IP ownership. It offers an assessment of the amount and trends of digital dependencies based on various indicators and time-series data, affirming insights from earlier research.[24] Policies to foster digital autonomy need to consider the structural conditions of economies, innovation processes, and national security in today's global digital civilization. The DDI shows that most countries' degree of digital dependence falls into the category of "high vulnerability." European countries such as Italy (0.86), Germany (0.82), France (0.84), Estonia (0.8), UK (0.82) remained highly vulnerable over the last ten years. The highest measurable digital dependence comes with platforms where the value of most countries ranges between 0.9 and 0.99. While countries such as Saudi Arabia and Australia have the largest digital autonomy gap, the results of the DDI suggest that European countries could not be further away from the ideal of digital "autonomy," which currently animates policy debates.

China and the US, meanwhile, are far less digitally dependent than other countries. The US, the most autonomous country in 2010 and 2019, has reduced its dependence in absolute and relative terms. US dependence values declined from 0.54 to 0.47, while the country widened the "autonomy gap" to all other countries except China and South Korea. As a result, the US has not only consolidated its dominant technological position but has also widened its influence through extending asymmetric digital relations worldwide between US firms and countries, companies, and citizens that must rely on information infrastructure and platform ecosystems.

China is the most important exception to this trend. In the last decade, the country's digital autonomy increased 12 percentage points. China's growing independence presents an extraordinary shift, moving China away from European countries and from BRICS members and closer to the "high sensitivity" range. The DDI pinpoints several drivers for this shift. The entire global structure of ICT trade has become China-centered (figure 9). Yet, the reduction of infrastructure (17 percentage points) and IP dependence (15 percentage points) made China the only country, which has significantly narrowed to "autonomy gap" to the leader (5 percentage points). Arguably, all of this vindicates China's contested technology and industrial policies choices—from the "great firewall," "indigenous innovation," and "Made in China 2025"[25] to data localization laws and other strict digital regulations—aiming at promoting the material-structural basis of China's digital sovereignty and political independence. The ability to enhance digital autonomy results from broader institutional decisions, long-term investment commitments, and other contextual factors. These include, for example, the meticulous construction of a national patent system to protect intellectual property. It also derives from the modernization of China's research and innovation system, which fostered Chinese knowledge power since the 1990s.[26]

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[24] For instance, the structural stability we find is not surprising for scholars of the international political economy. See Christopher May, *The global political economy of intellectual property rights: The new enclosures* (Routledge 2015); John M. Stopford, et al., *Rival states, rival firms: Competition for world market shares* (Cambridge University Press 1991); Yunusa Z Ya'u, "Globalisation, ICTs, and the new imperialism: Perspectives on Africa in the global electronic village," *Africa Development: A Quarterly Journal of CODESRIA,* 30(1-2) (2005): 98-124.

[25] Jost Wübbeke, et al. "MADE IN CHINA 2025. The making of a high-tech superpower and consequences for industrial countries," Merics, December 2, 2016, https://merics.org/sites/default/files/2020-04/Made in China 2025.pdf.

[26] Feng-chao Liu, et al., "China's innovation policies: Evolution, institutional structure, and trajectory," *Research Policy,* 40(7) (2011): 917-931; Richard P. Appelbaum, et al., *Innovation in China: Challenging the global science and technology system* (John Wiley & Sons 2018); Yutao Sun and Cong Cao, "Planning for science: China's

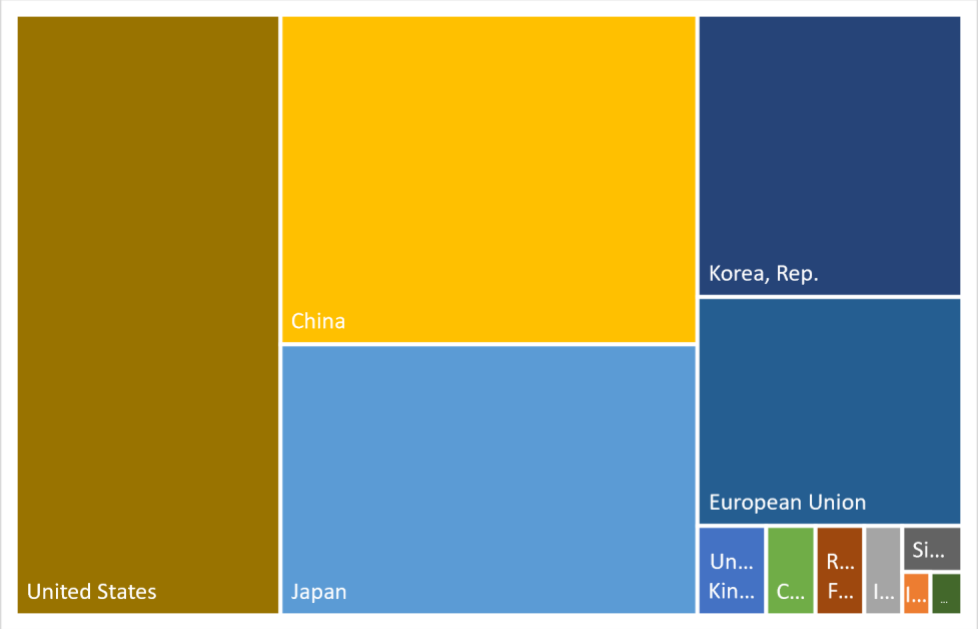

Figure 13. Global share of 2019 granted ICT patents (in percent)

Japan, in contrast, became more digitally dependent over the last decade (8 percentage points), mainly due to weaker IP activities. Its autonomy gap to the US even widened by 14 percentage points. Hence, while we can expect a more independent foreign and technology policy in line with the notably growing digital sovereignty of China and South Korea, the opposite is expected from Japan, which has incurred the biggest loss thereof. Meanwhile, France, Germany, and the UK roughly kept their absolute value in overall digital dependence. Yet, their autonomy gap to the US became wider by six percentage points. The most concerning development for Europe is not the shift of trade-centric dependencies towards the East—a well-known economic phenomenon related to the reconfiguration of global production networks and supply chains—but the fast growth of Chinese patent grants in all jurisdictions that reached 24 percent of the global total in 2019 (figure 13). Although some Chinese domestic ICT patents might not have a quality comparable to patents in industrial countries,[27] these numbers indicate that European economies and enterprises competing in the Chinese market and globally are likely to become more IP dependent on Chinese firms. In 2020, Chinese companies collectively received 8,5 billion US dollars from users of their intellectual property—a ten-fold increase from 2010 payments.[28]

Recommendations concerning the realization of digital autonomy

Measuring digital dependence has crucial implications for various actors involved in digital policymaking at the national and EU level. The key message is that EU members' degree of digital dependence is far greater and more pervasive than often assumed. As a result, current

'grand experiment' and global implications," *Humanities and Social Sciences Communications*, 8(1) (2021): 1-9; Maximilian Mayer, "Exploring China's rise as knowledge power," *Power in the 21st Century* (Springer 2012): 287-311.

[27] Philipp Boeing and Elisabeth Mueller. "Measuring China's patent quality: Development and validation of ISR indices," *China Economic Review*, 57 (2019): 101331; Albert GZ Hu, et al., "China as number one? Evidence from China's most recent patenting surge," *Journal of Development Economics*, 124 (2017): 107-119.

[28] See data from World Bank: https://data.worldbank.org/indicator/BX.GSR.ROYL.CD?locations=CN-JP.

initiatives to enhance European digital autonomy do not recognize the magnitude of the challenges ahead.[29] This preliminary analysis of the DDI data suggests six points to consider:

- European countries are falling behind compared to China, South Korea, and the US. The immediate diagnosis flowing from the DDI contradicts the rhetoric of the EU Commission. The planned "Digital Decade"[30] will hardly bring Europe in a position to compete for "digital leadership" on a global level. In the last decade, our data indicate that Europe's digital autonomy has eroded as digital interactions have become more asymmetric with China (ICT trade dependence), with the US (infrastructure and platform dependence), and the East Asian region (IP dependence).
- Consequently, European capitals need to rethink their entire approach to digital technologies. The regulatory impact of the GDPR does not mitigate the vast inequalities of infrastructural power that stem from the high degree of vulnerability.[31] If the goal of improving "technological autonomy" is taken seriously, a much more comprehensive, systemic, and bold approach (policy-wise, financially, and strategic vision) would be required.
- Globally, the DDI shows that digital dependency is on a high level but is most pronounced for platforms and the information infrastructure. Therefore, it seems relatively more costly to win back a degree of autonomy in these areas. This observation calls into question whether projects such as GAIA-X are the right choice to become the poster child of the EU's ambitions for technological autonomy unless Brussels alters the magnitude of funding commitments across the entire European innovation system.
- European companies and governments should put a stronger emphasis on reducing their growing ICT-IP dependency to counteract an emerging trend: US, Chinese, and South Korean firms consistently file more ICT-related patents. In 2019, the combined share of global IP owned by EU-27 firms added up to 11 percent; the share of South Korean firms was 13 percent, the Japanese share, though shrinking, was still at 20 percent. US companies held 28 percent, while Chinese firms owned 24 percent.
- Germany, which still has a relatively strong ICT capacity, should draw lessons from other "technological middle powers." The DDI suggests that South Korea and Japan offer valuable insights. South Korea is the only middle-sized economy that reduced digital dependence in the last ten years. The country also slightly closed the "autonomy gap" towards the US. Japan provides a counterexample instead. It experienced a decrease in ICT exports and a dramatic rise in digital dependence (8 percentage points), especially vis-à-vis China in terms of ICT goods (36 percentage points change). Both cases raise intriguing puzzles for scholars and policymakers. The understanding of the effects of industrial and technology policies that drive the actual state of digital sovereignty beyond official declarations and public discourses is still limited.
- Only Germany and the Netherlands are currently under the top 10 global export countries (both have a 3 percent share of global ICT goods exports). Another option to achieve more symmetrical forms of dependence for Europe (DDI around 0.5) would be to massively expand the production of ICT goods. Current trends indicate, instead, that the trade relationship with China (and East Asia) is likely to become even more

[29] This conclusion is unlikely changed by additional indicators. The current version of the DDI does not include, for instance, cloud services, submarine cables, cyber security capabilities or industrial IT systems, for which there is a lack of systematic and publicly accessible data.

[30] "2030 Digital Compass: the European Way for the Digital Decade," European Commission, March 9, 2021, https://ec.europa.eu/info/sites/default/files/communication-digital-compass-2030_en.pdf.

[31] Reinforcing arguments made earlier: Jan-Hendrik Passoth. "Europa braucht digitale Selbstbestimmung," *Süddeutsche Zeitung*, 23 June 2019. https://www.sueddeutsche.de/digital/passoth-internet-google-europa-infrastruktur- plattformen-1.4492770.

asymmetric. Europe as a whole could suffer the "Indian fate," that is, a growing share of ICT trade with China in overall trade and an increasing bilateral asymmetry in the trading pattern—which would further decrease European autonomy vis a vis China in addition to total dependence on US infrastructure firms.

- European countries should focus on improving their digital resilience as their primary aspiration. The DDI framework suggests an empirical matrix to categorize policy goals. Germany, for instance, currently has a DDI Value of 0.82. Aside from trade in ICT goods (DDI 0.59; low vulnerability), the value for platform dependence (0.98; high vulnerability) and ICT-IP dependence (0.97; high vulnerability) imply that calls for Germany's digital sovereignty resembles the proverbial tilt at windmills. A more realistically qualified aim could be to design policies that move the dependence level of the economy from "high vulnerability" to "low vulnerability" and, in the long-term further towards symmetric dependence (DDI close to 0.5).

Appendix

Index-weightings: Subindices-equally-weighted

Countries with reduced dependence					
	2010		2019		Difference
China	0.7	low vulnerability	0.58	low vulnerability	0.12
Korea, Rep.	0.74	low vulnerability	0.66	low vulnerability	0.08
United States	0.54	low vulnerability	0.47	high sensitivity	0.07
Russian Federation	0.89	high vulnerability	0.83	high vulnerability	0.06
Kenya	0.86	high vulnerability	0.8	high vulnerability	0.06
Italy	0.88	high vulnerability	0.86	high vulnerability	0.02
Brazil	0.94	high vulnerability	0.92	high vulnerability	0.02
Estonia	0.82	high vulnerability	0.8	high vulnerability	0.02
Argentina	0.88	high vulnerability	0.87	high vulnerability	0.01
South Africa	0.88	high vulnerability	0.87	high vulnerability	0.01
United Kingdom	0.83	high vulnerability	0.82	high vulnerability	0.01
Singapore	0.82	high vulnerability	0.81	high vulnerability	0.01
Countries with stable dependence					
Australia	0.89	high vulnerability	0.89	high vulnerability	0
France	0.84	high vulnerability	0.84	high vulnerability	0
Germany	0.82	high vulnerability	0.82	high vulnerability	0
India	0.8	high vulnerability	0.8	high vulnerability	0
Israel	0.76	high vulnerability	0.76	high vulnerability	0
Saudi Arabia	0.89	high vulnerability	0.89	high vulnerability	0
Countries with increased dependence					
Japan	0.72	low vulnerability	0.8	high vulnerability	0.08
Indonesia	0.83	high vulnerability	0.88	high vulnerability	0.05
Mexico	0.78	high vulnerability	0.8	high vulnerability	0.02
Turkey	0.84	high vulnerability	0.86	high vulnerability	0.02
Canada	0.83	high vulnerability	0.84	high vulnerability	0.01

Index-weighting: ICT Trade-centric

Countries with reduced dependence					
	2010		2019		Difference
Russian Federation	0.83	high vulnerability	0.75	low vulnerability	0.08
Korea, Rep.	0.57	low vulnerability	0.51	low vulnerability	0.06
United States	0.57	low vulnerability	0.51	low vulnerability	0.06
Brazil	0.91	high vulnerability	0.86	high vulnerability	0.05

Kenya	0.72	low vulnerability	0.67	low vulnerability	0.05
China	0.52	low vulnerability	0.48	high sensitivity	0.04
Estonia	0.63	low vulnerability	0.59	low vulnerability	0.04
Italy	0.76	high vulnerability	0.73	low vulnerability	0.03
Australia	0.79	high vulnerability	0.78	high vulnerability	0.01
Germany	0.67	low vulnerability	0.66	low vulnerability	0.01
United Kingdom	0.67	low vulnerability	0.66	low vulnerability	0.01
Countries with stable dependence					
France	0.7	low vulnerability	0.7	low vulnerability	0
Singapore	0.62	low vulnerability	0.62	low vulnerability	0
South Africa	0.76	high vulnerability	0.76	high vulnerability	0
Countries with increased dependence					
Indonesia	0.66	low vulnerability	0.79	high vulnerability	0.13
Japan	0.67	low vulnerability	0.74	low vulnerability	0.07
Turkey	0.69	low vulnerability	0.75	low vulnerability	0.06
Mexico	0.56	low vulnerability	0.62	low vulnerability	0.06
Canada	0.67	low vulnerability	0.69	low vulnerability	0.02
Argentina	0.76	high vulnerability	0.77	high vulnerability	0.01
India	0.61	low vulnerability	0.62	low vulnerability	0.01
Israel	0.5	high sensitivity (symmetric dependence)	0.51	low vulnerability	0.01
Saudi Arabia	0.79	high vulnerability	0.8	high vulnerability	0.01

Index-weighting: Infrastructure-centric

Countries with reduced dependence					
	2010		2019		Difference
China	0.75	low vulnerability	0.58	low vulnerability	0.17
Korea, Rep.	0.83	high vulnerability	0.68	low vulnerability	0.15
United States	0.39	high sensitivity	0.26	high sensitivity	0.13
Kenya	0.92	high vulnerability	0.83	high vulnerability	0.09
Russian Federation	0.91	high vulnerability	0.83	high vulnerability	0.08
India	0.89	high vulnerability	0.86	high vulnerability	0.03
South Africa	0.93	high vulnerability	0.9	high vulnerability	0.03
Turkey	0.92	high vulnerability	0.89	high vulnerability	0.03
Italy	0.94	high vulnerability	0.91	high vulnerability	0.03
Argentina	0.93	high vulnerability	0.91	high vulnerability	0.02
Brazil	0.96	high vulnerability	0.94	high vulnerability	0.02
Estonia	0.9	high vulnerability	0.88	high vulnerability	0.02
France	0.92	high vulnerability	0.9	high vulnerability	0.02

Germany	0.91	high vulnerability	0.89	high vulnerability	0.02
Israel	0.87	high vulnerability	0.86	high vulnerability	0.01
Singapore	0.9	high vulnerability	0.89	high vulnerability	0.01
United Kingdom	0.91	high vulnerability	0.9	high vulnerability	0.01
Saudi Arabia	0.94	high vulnerability	0.93	high vulnerability	0.01
Countries with stable dependence					
Australia	0.94	high vulnerability	0.94	high vulnerability	0
Indonesia	0.9	high vulnerability	0.9	high vulnerability	0
Mexico	0.88	high vulnerability	0.88	high vulnerability	0
Countries with increased dependence					
Japan	0.83	high vulnerability	0.87	high vulnerability	0.04
Canada	0.9	high vulnerability	0.91	high vulnerability	0.01

Index-weighting: IP-centric

Countries with reduced dependence					
	2010		2019		Difference
China	0.86	high vulnerability	0.71	low vulnerability	0.15
Kenya	0.96	high vulnerability	0.94	high vulnerability	0.02
Russian Federation	0.97	high vulnerability	0.95	high vulnerability	0.02
Korea, Rep.	0.83	high vulnerability	0.81	high vulnerability	0.02
Argentina	0.97	high vulnerability	0.96	high vulnerability	0.01
Brazil	0.99	high vulnerability	0.98	high vulnerability	0.01
Estonia	0.95	high vulnerability	0.94	high vulnerability	0.01
United States	0.66	low vulnerability	0.65	low vulnerability	0.01
Countries with stable dependence					
Australia	0.97	high vulnerability	0.97	high vulnerability	0
France	0.94	high vulnerability	0.94	high vulnerability	0
Germany	0.92	high vulnerability	0.92	high vulnerability	0
India	0.94	high vulnerability	0.94	high vulnerability	0
Israel	0.93	high vulnerability	0.93	high vulnerability	0
Italy	0.96	high vulnerability	0.96	high vulnerability	0
Mexico	0.94	high vulnerability	0.94	high vulnerability	0
Saudi Arabia	0.97	high vulnerability	0.97	high vulnerability	0
Singapore	0.94	high vulnerability	0.94	high vulnerability	0
South Africa	0.96	high vulnerability	0.96	high vulnerability	0
Turkey	0.96	high vulnerability	0.96	high vulnerability	0
United Kingdom	0.94	high vulnerability	0.94	high vulnerability	0

Countries with increased dependence					
Japan	0.69	low vulnerability	0.8	high vulnerability	0.11
Indonesia	0.95	high vulnerability	0.97	high vulnerability	0.02
Canada	0.94	high vulnerability	0.95	high vulnerability	0.01

Further comparative data for DDI countries

Individuals using the Internet (% of population)	**2010**	**2019**
Argentina	45	74*
Australia	76	87*
Brazil	41	74
Canada	80	97
China	34	65
Estonia	74	90
France	77	83
Germany	82	88
India	8	41
Indonesia	11	48
Israel	68	87
Italy	54	76
Japan	78	93
Kenya	7	23
Korea (Rep. of)	84	96
Mexico	31	70
Russian Federation	43	83
Saudi Arabia	41	96
Singapore	71	89
South Africa	24	68
Turkey	40	74
United Kingdom	85	93
United States	72	89

* The values of Argentina and Australia for 2019 are missing. Instead, the two countries' values for 2017 are used for these missing values.
Source: ITU; https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx

Mobile cellular subscriptions (per 100 people)	**2010**	**2019**
Argentina	140	126
Australia	102	111
Brazil	101	96
Canada	76	92
China (only Mainland China)	63	122
Estonia	124	147
France	92	111

Germany	109	128
India	61	84
Indonesia	87	126
Israel	124	137
Italy	158	131
Japan	96	147
Kenya	59	104
Korea, Rep.	102	134
Mexico	80	96
Russian Federation	166	164
Saudi Arabia	188	121
Singapore	144	156
South Africa	98	166
Turkey	85	97
United Kingdom	121	120
United States	92	134

Source: World Bank Open Data; https://data.worldbank.org/?name_desc=false

GDP per capita (current US$)	**2010**	**2019**
Argentina	10 386	9 912
Australia	52 022	55 057
Brazil	11 286	8 897
Canada	47 562	46 327
China	4 550	10 217
Estonia	14 784	23 718
France	40 638	40 380
Germany	41 532	46 468
India	1 358	2 101
Indonesia	3 122	4 135
Israel	30 694	43 589
Italy	36 001	33 567
Japan	44 508	40 113
Kenya	952	1 817
Korea, Rep.	23 087	31 846
Mexico	9 271	9 946
Russian Federation	10 675	11 498
Saudi Arabia	19 263	23 140
Singapore	47 237	65 641
South Africa	7 329	6 001
Turkey	10 743	9 127
United Kingdom	39 537	42 354
United States	48 467	65 280

Source: World Bank Open Data; https://data.worldbank.org/?name_desc=false

GDP (current US$ in Mio.)	2010	2019
Argentina	423 627	445 445
Australia	1 146 138	1 396 567
Brazil	2 208 872	1 839 758
Canada	1 613 464	1 736 426
China	6 343 925	14 699 508
Estonia	19 694	31 471
France	2 642 610	2 715 518
Germany	3 396 354	3 861 124
India	1 675 615	2 868 929
Indonesia	755 094	1 119 191
Israel	233 996	394 652
Italy	2 134 018	2 003 576
Japan	5 700 098	5 081 770
Kenya	40 000	95 503
Korea, Rep.	1 144 067	1 646 739
Mexico	1 057 801	1 268 871
Russian Federation	1 524 917	1 699 877
Saudi Arabia	528 207	792 967
Singapore	239 809	372 063
South Africa	375 349	351 432
Turkey	776 968	761 425
United Kingdom	2 475 244	2 829 108
United States	14 992 053	21 433 226

Source: World Bank Open Data; https://data.worldbank.org/?name_desc=false

ICT patents (cumulative)	Amount of ICT patents 2000	Share of global ICT patents 2000	Amount of ICT patents 2019	Share of global ICT patents 2019
Argentina	0	0.00%	130	0.00%
Australia	157	0.23%	10162	0.25%
Brazil	16	0.02%	810	0.02%
China	449	0.34%	575971	11.06%
Germany	3437	2.98%	167313	3.71%
Estonia	1	0.00%	230	0.01%
France	2507	2.42%	114760	2.46%
United Kingdom	6027	5.04%	196984	4.59%

India	1032	0.78%	20919	0.41%
Indonesia	1	0.00%	33	0.00%
Israel	319	0.32%	30857	0.58%
Italy	706	0.59%	16711	0.39%
Japan	45931	38.11%	1355575	29.39%
Canada	1063	1.10%	55457	1.19%
Kenya	0	0.00%	10	0.00%
Mexico	3	0.01%	386	0.01%
Korea, Rep.	15987	12.76%	615067	13.91%
Russian Federation	912	0.88%	25521	0.70%
Saudi Arabia	210	0.16%	6212	0.15%
Singapore	102	0.09%	14953	0.33%
South Africa	44	0.05%	3637	0.09%
Turkey	403	0.31%	10242	0.24%
United States	43649	41.79%	1692775	37.93%
European Union	11188	10.72%	520743	11.51%

Source: calculated from WIPO IP Statistics Data Center; https://www3.wipo.int/ipstats/index.htm?tab=patent&lang=en

Position in Global Ranking 2019 (ICT Goods Exports)	**Country**	**Volume ICT Goods Exports 2019 (Million US dollar)**	**Share in Global ICT Goods Exports 2019**
1	China	612880	26.92%
3	US	143744	6.31%
4	South Korea	139727	6.14%
5	Singapore	114361	5.02%
8	Germany	73181	3.21%
9	Mexico	68302	3.00%
11	Japan	56447	2.48%
16	France	21059	0.93%
17	UK	18716	0.82%
22	Italy(	10424	0.46%
24	Canada	8563	0.38%
26	India	6478	0.28%
27	Israel	5842	0.26%
30	Indonesia	4635	0.20%
33	Australia	2935	0.13%
36	Russia	2261	0.10%
37	Turkey	2073	0.09%

40	Estonia	1277	0.06%
46	South Africa	825	0.04%
47	Brazil	780	0.03%
70	Argentina	47	0.002%
74	Kenya	25	0.001%
99	Saudi Arabia	4	0.0002%

Source: calculated from United Nations Conference on Trade and Development; https://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx?sCS_ChosenLang=en

Position in Global Ranking 2019 (ICT Goods Imports)	Country	Volume ICT Goods Imports 2019 (Million US dollar)	Share in Global ICT Goods Imports 2019
1	China	617764	25.11%
2	US	331960	13.49%
3	Germany	103743	4.22%
4	Singapore	96471	3.92%
5	Japan	88272	3.59%
6	South Korea	79844	3.25%
8	Mexico	72074	2.93%
11	UK	52422	2.13%
13	India	45285	1.84%
14	France	39744	1.62%
16	Canada	32432	1.32%
20	Italy	23227	0.94%
21	Russia	23126	0.94%
22	Australia	22933	0.93%
25	Brazil	16005	0.65%
28	Indonesia	13614	0.55%
31	Saudi Arabia	11481	0.47%
35	Turkey	8534	0.35%
37	South Africa	7050	0.29%
39	Israel	6722	0.27%
47	Argentina	3977	0.16%
62	Estonia	1394	0.06%
74	Kenya	655	0.03%

Source: calculated from United Nations Conference on Trade and Development; https://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx?sCS_ChosenLang=en