UNIVERSITÄT BONN

CASSIS

Getting Strategic Priorities Right – Towards a Framework for Reducing Digital Dependencies

In cooperation with

Vodafone Institute for Society and Communications

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Foreword

University of Bonn and Vodafone Institute cooperation

This policy study is the culmination of a one-year collaboration between the Vodafone Institute and the University of Bonn aimed at analyzing Europe's digital dependencies and the associated challenges and opportunities. Through this collaboration, we aim to provide innovative assessments of how Europe's digital capabilities are developing and identify the implications of these trends for Europe's economic and political autonomy.

Our first policy brief unpacked Europe's digital trade deficit, showing how hidden trade dependencies on the US and China fundamentally challenge the effectiveness of current European strategies. Our second policy brief looked into the future, examining the growing costs and implications of Europe's shrinking share of global technology patents. This study rounds out the series by presenting the Digital Dependence Index – a comprehensive tool for comparing the digital dependencies of 51 countries, including 16 European countries. In the study, we demonstrate how nuanced analysis of Europe's digital dependencies can generate evidence-based sets of priorities which can be used to coordinate national and European action to increase Europe's digital autonomy and resilience in years to come.

Acknowledgements

Many thanks to Simona Autolitano, Cindy Cheng, Nina Frahm, Kunhan Li, Hendrik Ohnesorge, Caja Thimm, Paul Timmers and the Vodafone Institute team, especially Ben Wreschner and Nathalie Brandmeyr, for their invaluable insights, ideas and criticisms throughout the research and writing processes. Thanks also to Johannes Doerfert for his support throughout the research process, including with manuscript preparation and team organization. Any remaining errors are our responsibility.

Citing this study

Mayer, Maximilian, Laura Mahrenbach, Rogelio Madrueño, Yen-Chi Lu and Philip J. Nock. 2026. Getting Strategic Priorities Right – Towards a Framework for Reducing Digital Dependencies. CASSIS, University of Bonn and Vodafone Institute.

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Executive summary

Europe is at a strategic crossroads. Long-term economic resilience, technological opportunities and Europe's geopolitical positioning all depend on making explicit choices regarding Europe's digital dependencies while the fragmented, "business as usual" trajectory risks exacerbating strategic vulnerabilities. But which dependencies matter most? And how can they be addressed?

To find effective and efficient solutions to this dilemma, policymakers in Brussels and in European capitals need systematic, transparent and comparable data. This study introduces the Digital Dependence Index (DDI) to address this need. The DDI tracks digital dependencies of 51 countries, including 16 in Europe, over 14 years.

KEY FINDINGS RELEVANT TO EUROPEAN POLICYMAKERS

- **MODERATE TO HIGH DEPENDENCE**
  European nations fall in the middle of the spectrum of global regions, consistently displaying moderate to high digital dependence overall since 2010. Alarmingly, Europe's digital dependence is increasing further.

- **UNIQUE BUT COMPLEMENTARY DEPENDENCE PROFILES**
  European nations' digital dependence profiles vary, with most countries grouped in the supply chain node or the post-industrial clusters. This points to industrial and research strengths which can be operationalized to support European digital resilience.

- **NON-FIXED TRAJECTORIES**
  European nations demonstrate evolving digital dependence profiles. Targeted policy decisions can consequently impact Europe's and individual nations' digital trajectories, how they cope with challenges and how they utilize opportunities.

- **A NEED FOR NUANCED MEASUREMENT**
  Baseline dependence metrics such as digital goods or services trade balances or foreign direct investment (FDI) levels require context and rigorous methodological interpretation to avoid making decisions based on distorted perceptions (see Box 3, the "Ireland Effect").

POLICY TRAJECTORIES AND RECOMMENDATIONS

We identify four distinct packages of priorities to address Europe's digital dependencies. Each prioritization package has its own unique trade-offs, level of ambition and long-term consequences – and none is a miracle cure – but all represent evidence-based pathways for mitigating Europe's digital dependencies (Table E.1).

Prioritization package	Level of ambition	Strategic profile
Supply chain node replication	Moderate to high	Focuses on duplicating critical node infrastructure. Highly compatible and can be paired with diversification strategies.
Technopole imitation	Very high	Requires massive financial investment, sustained political capital, and deep institutional reform to build frontier capacity.
Vulnerability minimization	Moderate	Focuses on targeted risk reduction in existing dependencies. Least transformative but easiest to implement.
Diversification	High	Extends existing EU trade and tech mechanisms to broaden partner ecosystems and spread supply risk.

TABLE E.1
Prioritization packages for mitigating Europe's digital dependencies

Implementing these pathways – whether alone or in combination – is not merely a technical exercise, but rather a choice between different sociotechnical visions for Europe's future. Decreasing digital dependence and improving digital resilience consequently requires moving beyond top-down mandates. In that context and building on DDI data, we recommend the following:

- **DEVELOP STRATEGIC PRIORITIES SOON**
  Develop a plan to address Europe's digital dependencies as soon as possible to decelerate its increase in dependence and improve its autonomy of action.

- **COORDINATE POLICIES TO ACHIEVE PRIORITIES**
  Align regulation, innovation, public investment and procurement across countries and technologies to build on European strengths and direct policy action towards achieving shared priorities.

- **SEQUENCE ACTIONS FOR LONG-TERM IMPACT**
  Order short-, medium- and long-term action to ensure policies boost the likelihood of policy success.

- **ESTABLISH STRATEGIC INTERNATIONAL PARTNERSHIPS**
  Choose global alliances that diversify dependencies, boost resilience, and maintain key external relationships by engaging in concrete, joint technological missions.

- **BUILD A SHARED SOCIETAL VISION**
  Craft and communicate a compelling long-term narrative to engage citizens, businesses, and researchers in decreasing dependence and promoting resilience.

Reshaping and reducing Europe's digital dependence is not a simple task but it is an urgent one. Ensuring policy is grounded in empirical analysis can maximize the digital strengths of European nations and point them collectively towards a shared digital future.

An evidence-based approach to addressing digital dependence

European policymakers increasingly view digital technologies as essential to securing the continent's economic prosperity, competitiveness, security and resilience in adapting to an evolving geopolitical context.[1] Recent events – including restrictions on access to critical digital technologies and rare earths, and the sudden withdrawal of advanced artificial intelligence (AI) services from certain markets[2] – have intensified concerns about relying on external providers for key digital capabilities and services.

To respond effectively to this challenge and avoid costly or inefficient strategies, policymakers must understand which digital dependencies matter most for Europe's long-term technological resilience and strategic autonomy[3] as well as the implications of addressing or ignoring each. This study presents a new tool – the Digital Dependence Index (DDI) – to help European decisionmakers assess different strategic options.[4]

The DDI systematically measures digital dependencies in goods and services trade, platforms, and patents, ranking 51 countries worldwide, including 16 countries in Europe (Figure 1).[5]

1	USA	0.38	14	Malaysia	0.64	27	Canada	0.74	40	Indonesia	0.81
2	**Ireland**	0.40	15	**Estonia**	0.65	28	Japan	0.75	41	Argentina	0.83
3	Israel	0.40	16	Singapore	0.65	29	**Denmark**	0.75	42	Saudi Arabia	0.84
4	China	0.43	17	**Poland**	0.66	30	**France**	0.76	43	**Norway**	0.84
5	Philippines	0.50	18	UAE	0.66	31	**Switzerland**	0.77	44	Qatar	0.86
6	Kenya	0.56	19	**Netherlands**	0.66	32	Azerbaijan	0.78	45	Australia	0.88
7	Vietnam	0.57	20	**UK**	0.67	33	Kazakhstan	0.78	46	Brazil	0.88
8	South Korea	0.57	21	**Sweden**	0.70	34	**Italy**	0.78	47	South Africa	0.89
9	India	0.58	22	Egypt	0.71	35	Rwanda	0.78	48	Nigeria	0.90
10	Türkiye	0.58	23	**Finland**	0.71	36	Ghana	0.79	49	Ethiopia	0.91
11	**Serbia**	0.61	24	**Austria**	0.73	37	Uganda	0.80	50	Chile	0.94
12	Morocco	0.61	25	**Germany**	0.73	38	Mexico	0.80	51	Peru	0.97
13	**Czechia**	0.62	26	Thailand	0.73	39	Russia	0.80			

FIGURE 1
Country ranking by 2023 DDI score
European countries in **blue**. Source: DDI

1 In this study, "Europe" refers to EU member states as well as Norway, Serbia, Switzerland and the United Kingdom (UK). "EU" refers only to European Union member states.

2 Théophane Hartmann (2026). Commission official points to US 'kill switch' on Anthropic AI models, Euractiv, 23 June, www.euractiv.com/news/commission-official-points-to-us-kill-switch-on-anthropic-ai-models/; China's rare earth curbs endanger $6.5 trillion of Western industry, IEA says, July 16, www.reuters.com/business/autos-transportation/chinas-rare-earth-curbs-endanger-65-trillion-western-industry-iea-says-2026-07-16/; Arjun Kharpal (2023). Netherlands, home to a critical chip firm, follows U.S. with export curbs on semiconductor tools, CNBC, 30 June, www.cnbc.com/2023/06/30/netherlands-follows-us-with-semiconductor-export-restrictions-.html.

3 Resilience refers to Europe's capacity to respond effectively to evolving geopolitical and geotechnological contexts, both constructive (e.g., availability of new technologies) and disruptive (e.g., supply chain interruptions). Autonomy refers to "a state's ability to pursue policy goals despite limitations imposed upon it through external constraints;" see Laura Carsten Mahrenbach, The Trade Policy of Emerging Powers. Basingstoke: Palgrave Macmillan, 2013, p. 21.

4 A previous, smaller scale version of the DDI was developed in 2022 by the University of Bonn with financial support from Konrad Adenauer Stiftung.

5 The 51 DDI countries include all G20 countries and selected developed and developing countries from Europe, Asia, Africa, and Latin America. The large number of countries makes the index representative of the global political-economic landscape and captures geographic diversity.

It is consistent and comparable, both across countries and over time. As such, the DDI not only adds nuance and depth to existing, complementary understandings of Europe's digital dependencies. It also creates a baseline for assessing competing proposals from the European Commission and think tanks[6] for decreasing Europe's digital dependence and enhancing its digital resilience.

Building on DDI data, this study assesses European countries' digital dependencies and evaluates the strengths and weaknesses of different policy approaches for mitigating Europe's vulnerabilities. We begin by contextualizing Europe's dependence position within regional and national trends. We then identify clusters of countries based on similarities in their digital dependence profiles. We conclude by examining four different prioritization packages for reducing digital dependence and enhancing digital resilience. For each package, we evaluate its applicability across Europe, its feasibility of implementation as well as associated trade-offs and costs.

Key findings and recommendations

This study offers four main findings relevant for policymakers concerned about Europe's digital dependencies. First, Europe consistently displays a moderate to high degree of digital dependence since 2010 – and that dependence is increasing. Second, European nations' digital dependence profiles are not uniform, with most European countries located in the supply chain node or post-industrial clusters in 2023. This points to industrial and research strengths which can be employed to support Europe's digital resilience. Third, European nations' digital dependence profiles are evolving, suggesting targeted policy decisions can impact both Europe's and European nations' digital trajectories. Finally, we show that high-level measurements of Europe's digital dependencies are insufficient for determining how digital dependencies relate to Europe's digital autonomy and resilience. This points to a need for more nuanced metrics including but not limited to the DDI.

OUR FINDINGS SUGGEST FIVE BROAD RECOMMENDATIONS:

1. **DEVELOP STRATEGIC PRIORITIES AS SOON AS POSSIBLE.**
   Policymakers cannot eliminate every form of digital dependence, many of which are structurally unavoidable in the short and medium terms, but they must develop a plan to address Europe's digital dependencies as soon as possible. Our four "prioritization packages" can help policymakers evaluate different strategic priorities related to digital dependence as well as the costs, opportunities and implications of pursuing these policies.

2. **IMPROVE COORDINATION.**
   To achieve its strategic priorities and maximize Europe's position – as a single market, within global value chains, as a technological leader – Europe must coordinate action across multiple countries, clusters, technologies and policy levels. Regardless of whether Europe seeks to implement a single prioritization package or combine more than one, it will require a coherent industrial policy that combines regulation, innovation policy, public investment, procurement, and strategic international cooperation – all building on Europe's existing strengths.

6 Gerda Falkner et al., "Digital Sovereignty—Rhetoric and Reality," Journal of European Public Policy 31, no. 8 (2024): 2099–2120; Daniel Lambach and Kai Oppermann, "Narratives of Digital Sovereignty in German Political Discourse," Governance 36, no. 3 (2023): 693–709; Maximilian Mayer and Yen-Chi Lu, "Illusionen der Autonomie? Europas Position in den globalen digitalen Abhängigkeitsstrukturen," SIRIUS–Zeitschrift für Strategische Analysen 7, no. 4 (2023): 390–410.

3. PAY ATTENTION TO SEQUENCING AND BE PATIENT.

All four prioritization packages combine immediate measures with medium- and long-term actions to reduce digital dependencies. Successful implementation depends on sequencing measures appropriately. In many instances, this will require sustained commitments of funding and political will as well as a willingness to wait for visible results as Europe builds its capabilities and transitions to a less dependent status.

4. CHOOSE STRATEGIC PARTNERS CAREFULLY.

Europe cannot mitigate its digital dependencies on its own. International partnerships and beneficial interdependencies will be essential – but they must be selected strategically rather than opportunistically. Any long-term strategy must balance the pursuit of greater autonomy, diversified dependence, and improved resilience with the need to maintain stable relationships with key external partners.

5. DEVELOP AND COMMUNICATE A LONG-TERM VISION.

Mitigating digital dependence is not only a matter of technocratic prioritization, but also of societal imagination. Europe needs a compelling narrative articulating what kind of innovative society it wants to create. This narrative must be communicated effectively to mobilize citizens, communities, businesses and researchers to support Europe's long-term digital trajectory.

Measuring digital dependence

In this study, digital dependence refers to the extent to which individuals, businesses, and public institutions rely on digital technologies that are owned, controlled, or supplied by foreign entities to conduct digital activities. In line with today's world, digital activities are broad in scope, ranging from industrial production, communication, education, and research to public services, transportation and critical infrastructure operation. They also incorporate a wide range of technologies, from cloud infrastructure, software ecosystems and semiconductors to AI and satellite systems.

Why digital dependence matters

Digital dependence is not just a question of how much digital technology and applications a country uses or produces. It is also about who develops, controls, owns, and profits from technology and how reliant a country is on foreign actors to perform critical economic and societal functions.

Buzzword	Definition	Why it's a challenge	Example
Lock-in	Entrenched reliance on a technology provider	Path dependencies and sunk costs make switching providers costly or even prohibitively expensive	Platform providers like Google or Apple have created digital ecosystems to lock users in and make leaving unappealing.
Disruption	Rapid and dramatic change by emerging technology or the convergence of multiple interacting innovations	The speed and scale of change forces firms or industries to adapt their business models or become obsolete ("creative destruction")	The expansion of LLMs like ChatGPT or Gemini since 2022 has disrupted data access and processing, raising costs for slow-adapting service providers.
Choke point	A central position in global networks that enhances political leverage (e.g., denying access to key technologies)	Network structures and effects impede building viable alternatives while maintaining quality of service	Japan and the Netherlands tightened export restrictions in 2023 to prohibit microelectronic firms like ASML from exporting state-of-the-art lithography machines to China, choking off Chinese access to this key technology.
Kill switch	Constellation in which another actor can turn off or disrupt the usage of vital digital services	External control of critical digital infrastructure gives the controller a knowledge advantage and the power to disrupt its use, such as by interfering with rebooting or disabling access	The 2nd Trump administration mandated Anthropic to globally disable access to its most advanced models for foreign nationals in 2026.

BOX 1
Dependence-relevant digital challenges

In this setting, digital dependencies can generate vulnerabilities. For example, heavy reliance on foreign suppliers may expose countries to supply chain disruptions, export restrictions, political coercion, or sudden changes in market access via so-called weaponized interdependence (Box 1).[7] Dependence on external technologies can also limit a country's ability to shape technological development according to its own economic and societal priorities and to develop its workforce's technological skills. Digital dependence can even shift terms of trade and limit the capacity of industrial policy to remedy trade imbalances.[8] Unsurprisingly, many of these concerns focus geographically on the world's digital great powers – China and the United States (US) – whom we will call technopoles.[9]

Yet not all dependencies are problematic. International technological specialization and global value chains often increase efficiency, innovation, and economic growth. For example, access to the world's most advanced AI systems may improve productivity and competitiveness, even when those systems are developed abroad. Simultaneously, many decades of globalization have made trade of raw materials and components a functional requirement for many production networks. Hence, efforts to reduce digital dependence involve important trade-offs between resilience, economic efficiency, innovation, and strategic autonomy.

The Digital Dependence Index

In this context, the DDI measures different dimensions of digital dependence to determine how they affect countries' strategic options. The DDI combines market- and non-market-based forms of dependence into a single score for each country – simplifying the complexity of policy discussions without losing the nuances inherent in digital technologies. We do this by measuring digital dependence along four critical dimensions in 51 countries:

- **TRADE IN INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) GOODS**
  Reliance on imported hardware, such as semiconductors or computers, to process, share, and display information.

- **TRADE IN ICT SERVICES**
  Dependence on foreign telecommunications services, computer services, and computer software for data processing and information exchange.

- **DIGITAL PLATFORMS**
  Dependence on digital ecosystems where people connect, work and access data, such as search engines and social media, that are created or hosted by foreign operators/companies.[10]

- **ICT PATENTS**
  Reliance on foreign intellectual property owners and licensing procedures for key technologies crucial to innovation and production.

7 Lock-In: Maha Rafi Atal, "The Janus Faces of Silicon Valley," Review of International Political Economy 28, no. 2 (2021): 336–350, www.doi.org/10.1080/09692290.2020.1830830; José van Dijck, "Governing Platforms and Societies," Platforms & Society 1 (2024). Disruption: Henry Wai-chung Yeung, "Troubling Economic Geography: New Directions in the Post-Pandemic World," Transactions of the Institute of British Geographers 48 (2023): 672–680; Timothy R. McIntosh et al., "From Google Gemini to OpenAI Q* (Q-Star): A Survey on Reshaping the Generative Artificial Intelligence (AI) Research Landscape," Technologies 13, no. 2 (2025): 51, www.doi.org/10.3390/technologies13020051. Chokepoint: Henry Farrell and Abraham L. Newman, "Weaponized Interdependence: How Global Economic Networks Shape State Coercion," International Security 44, no. 1 (2019): 42–79; Nik Hynek, "Beyond Weaponized Interdependence: The Corporate Chokehold in Frontier Semiconductor Governance," Review of International Political Economy (2026), www.doi.org/10.1080/09692290.2026.2715454. Kill switch: Oshani Seneviratne, "The Feasibility of a Smart Contract 'Kill Switch,'" in 2024 6th International Conference on Blockchain Computing and Applications (BCCA) (IEEE, 2024), 473–480, www.doi.org/10.1109/BCCA62388.2024.10844477; Alan Z. Rozenshtein, "A Kill Switch for Frontier AI," Lawfare, June 15, 2026, www.lawfaremedia.org/article/a-kill-switch-for-frontier-ai.`

8 Maximilian Mayer, Laura C. Mahrenbach, Rogelio Madrueño, and Yen-Chi Lu, "Digital Trade Trap? A Wake-Up Call for the EU's Digital Decade," Vodafone Institute for Society and Communications and CASSIS, University of Bonn, March 30, 2026, accessed June 10, 2026, www.vodafone-institut.de/wp-content/uploads/2026/03/wake-up-call-for-the-eus-digital-decade.pdf.

9 Maximilian Mayer and Yen-Chi Lu, "Global Structures of Digital Dependence and the Rise of Technopoles," New Political Economy 30, no. 5 (2025): 755–774, www.doi.org/10.1080/13563467.2025.2497766.

10 Platforms are one key element of digital infrastructure. Appendix 1 details why other digital infrastructure components like data centers cannot (yet) be included in the DDI due to data availability.

The dimensions are broken down into 23 sub-indicators (Figure 2). Each dimension's indicator scores combine into an annual dimension score for each country between 2010 to 2023. A country's overall DDI score is then calculated based on these dimension scores.[11] Final DDI scores range from 0 to 1. The closer a country's score is to 1, the higher its digital dependence is.

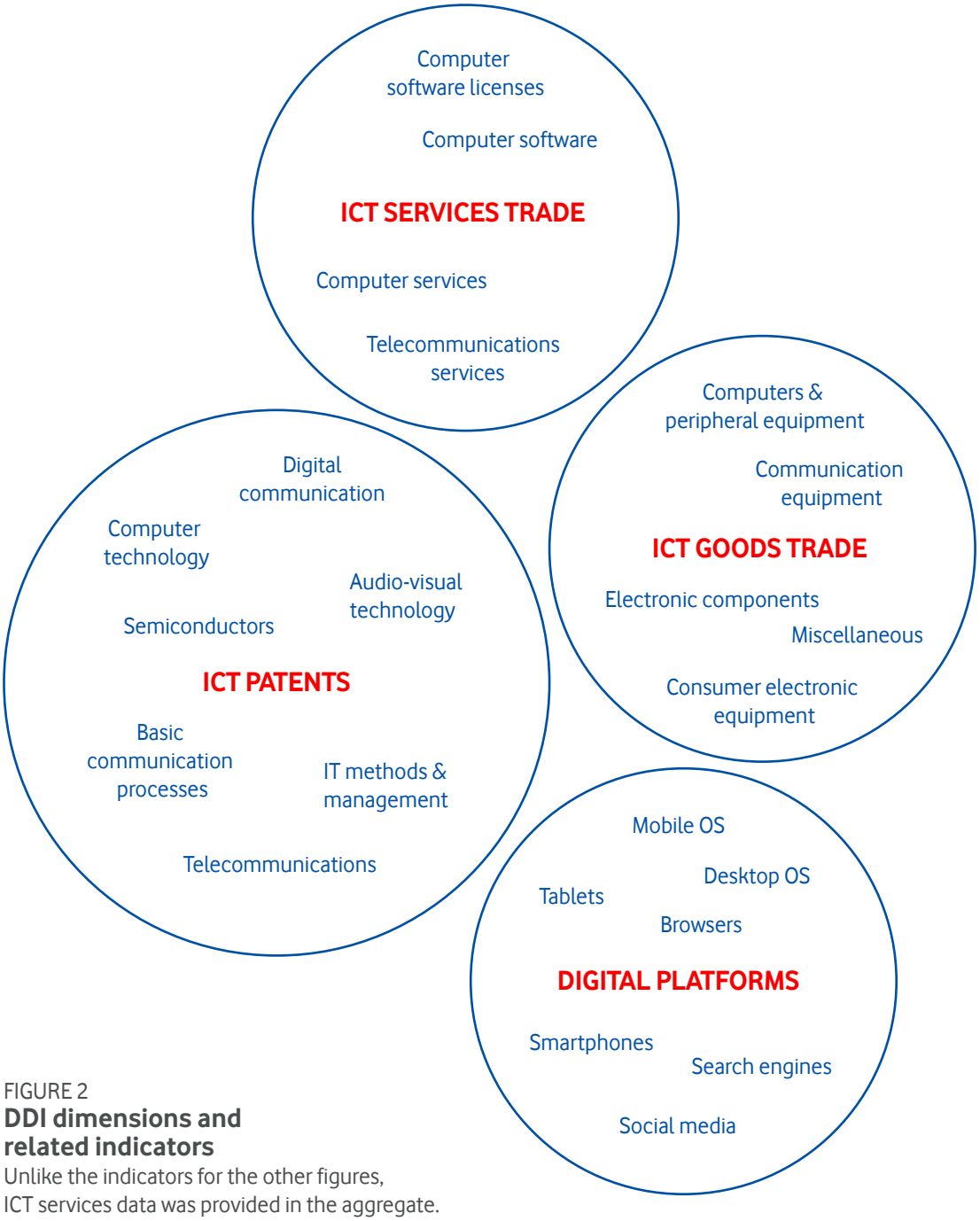


FIGURE 2
DDI dimensions and related indicators
Unlike the indicators for the other figures, ICT services data was provided in the aggregate. This means that, while all indicators are included in the annual values, they cannot be broken down by indicator, as is true for ICT goods, ICT patents, and digital platforms. Source: DDI

11 Please note: 2023 is the latest period for which necessary data was available. Appendix 1 provides detailed information about how the DDI was calculated.

The multifaceted, time-series nature of the index allows us to assess dependence through different lenses, such as overreliance on foreign partners, lack of access to critical technologies, data extraction, or national capabilities related to goods, services, platforms, and patents. It complements other measurements and methodologies by providing a broader and more systematic range of assessment criteria (Box 2). The rest of this study uses data and insights from the DDI to examine the implications of different digital dependencies for Europe.

Name	Institution	Approach	Capacity to measure digital dependence
Critical Technology Tracker	Australian Strategic Policy Institute (ASPI)	Tracks 64 critical technologies between 2003 and 2023 using research outputs, citations, and STEM talents	Broad time and technology scope but dependence measurement limited to academic output
Digital Economy and Society Index & Indicators	European Commission	Monitors digital progress on connectivity, public services, skills, and business against an EU baseline and 2030 trajectory	Strong contextual information but focuses on measuring digital transformation of EU member states
EuroStack	EuroStack Initiative	Models the European digital ecosystem across 64 categories and seven layers in the global digital stack with strong focus on identifying European alternatives	Showcases the complexity of dependence but does not quantify indicators or dependence values of stack layers
Weaponized interdependence datasets	Academic publications including Hynd et al (2025) and Cha (2023)	Collects data on economic coercion and resilience strategies for over 20 years with a broad geographic scope	Acknowledges structural dependencies and offers a global scope but is less systematic in tech coverage and inclusion
Digital Dependence Index	University of Bonn	Measures digital dependence of 51 countries between 2013 and 2023 based on digital platforms, patents and trade in digital goods and services	Uses real-world indicators to measure dependence over time and foregrounds state-centric nature of dependence

BOX 2

DDI in comparison to selected alternative digital dependence measurement tools

Contextualizing Europe's dependencies

Discussions of European digital dependency in Brussels make a regional perspective the obvious starting point for examining how and where Europe is most vulnerable. Comparing average dependency levels across different world regions and country groupings can help provide an indication of where Europe stands in a global context.

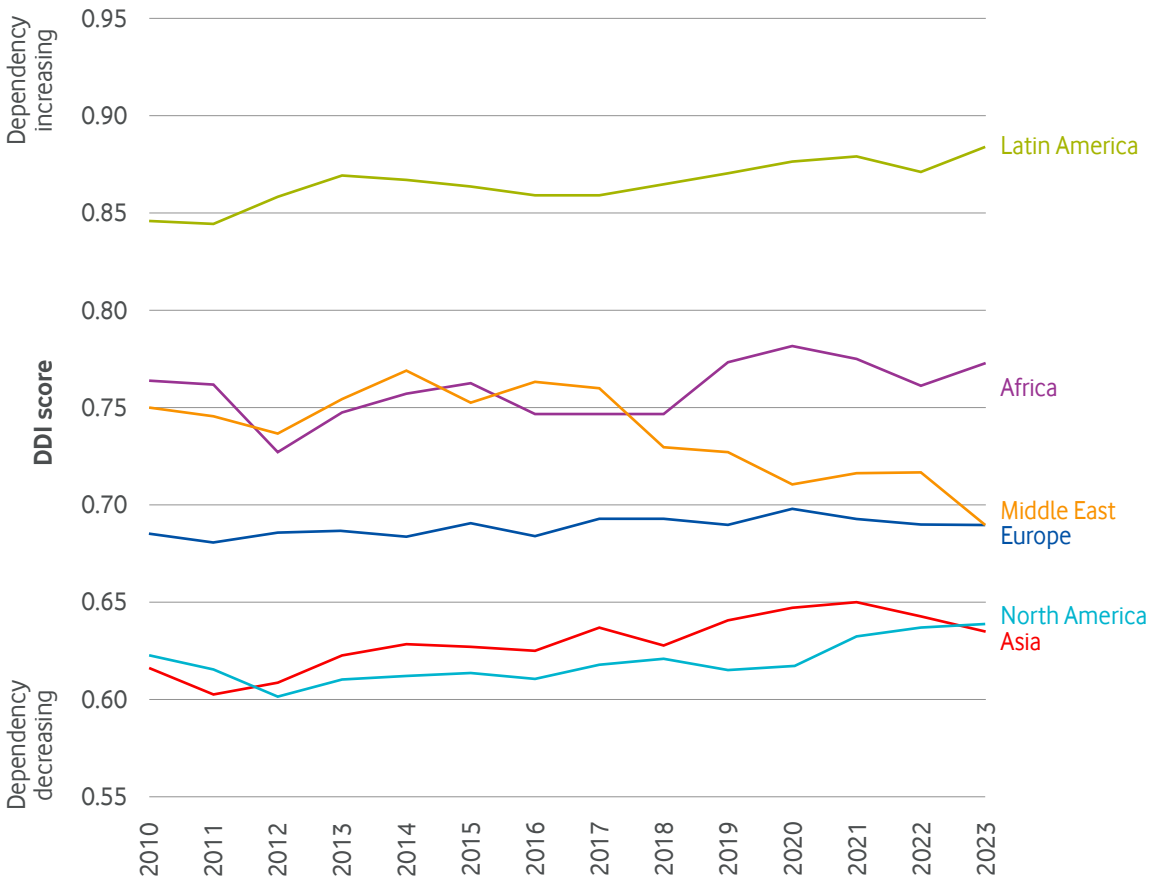


FIGURE 3

DDI values over time by region

The regional score is calculated by averaging each group's country-level, annual DDI scores from 2010 and 2023. It does not refer to the entire region, only to the scores of countries in those regions which are also included in the DDI.
Source: DDI

In regional comparison, Europe is located in the middle of the spectrum, consistently demonstrating moderate to high dependence overall since 2010 (Figure 3).[12] Unlike other global regions, like the Middle East or Asia, Europe has generally maintained its dependence gap to other regions over the past 14 years, meaning its global position remains unchanged despite increasing European dependence.

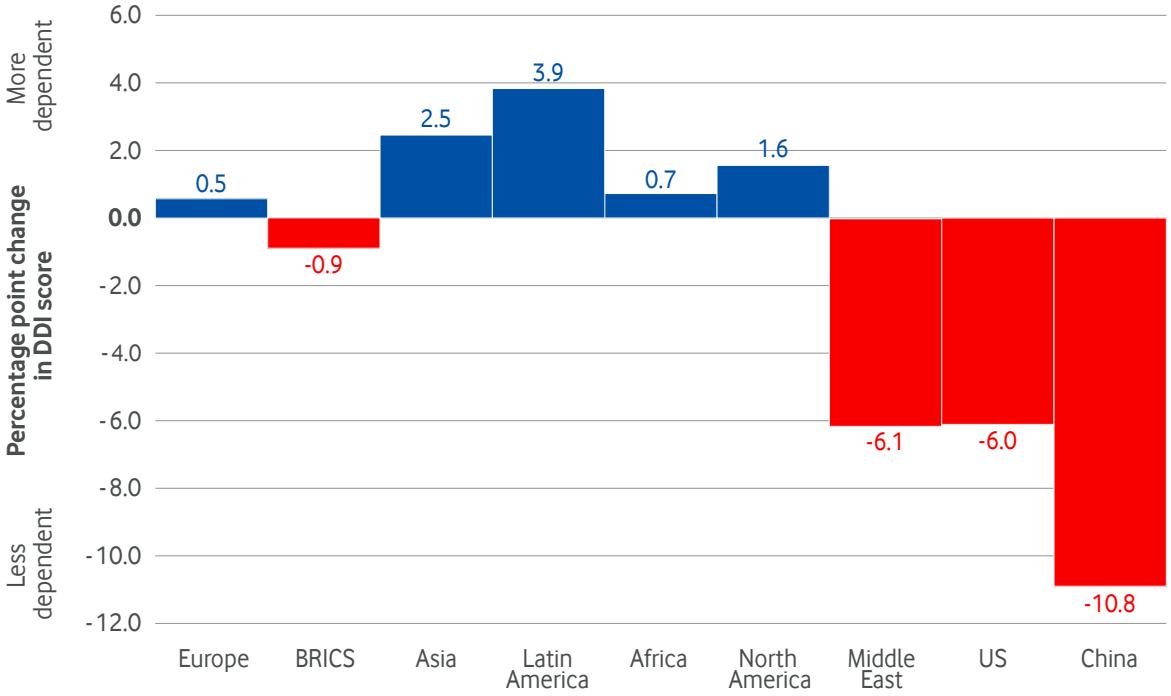


FIGURE 4

Change in DDI scores for DDI countries arranged in trans-/regional groups, 2010–2023

The regional score is calculated by averaging each group's country-level DDI score changes between 2010 and 2023. It does not refer to the entire region, only to the scores of countries in those regions which are also included in the DDI.
Source: DDI

Europe's increasing dependency trend is not unique: DDI countries in Asia, Latin America, Africa, and North America are all more dependent in 2023 than they were in 2010 (Figure 4). Yet other groups of states, including the BRICS and DDI Middle Eastern countries as well as both technopoles, China and the US, have managed to decrease their digital dependence over this period. Crucially the scale of changing dependence varies widely around the world, with the technopoles and Middle Eastern countries showing the most success in decreasing dependence and Latin American and Asian DDI countries the least.

12 Regional membership is as follows: Europe: Ireland, Czechia, Serbia, Poland, Netherlands, Estonia, UK, Finland, Sweden, Austria, Germany, Denmark, France, Italy, Switzerland, Norway | BRICS: Brazil, Russia, India, China and South Africa | Asia: China, Philippines, South Korea, Vietnam, Malaysia, Singapore, Thailand, Japan, Indonesia, Australia, India | Latin America: Mexico, Argentina, Brazil, Chile, Peru | Africa: Kenya, Uganda, Rwanda, Ghana, Ethiopia, Nigeria, South Africa, Morocco, Egypt | North America: Canada, US, Mexico | Middle East: Israel, UAE, Saudi Arabia, Qatar

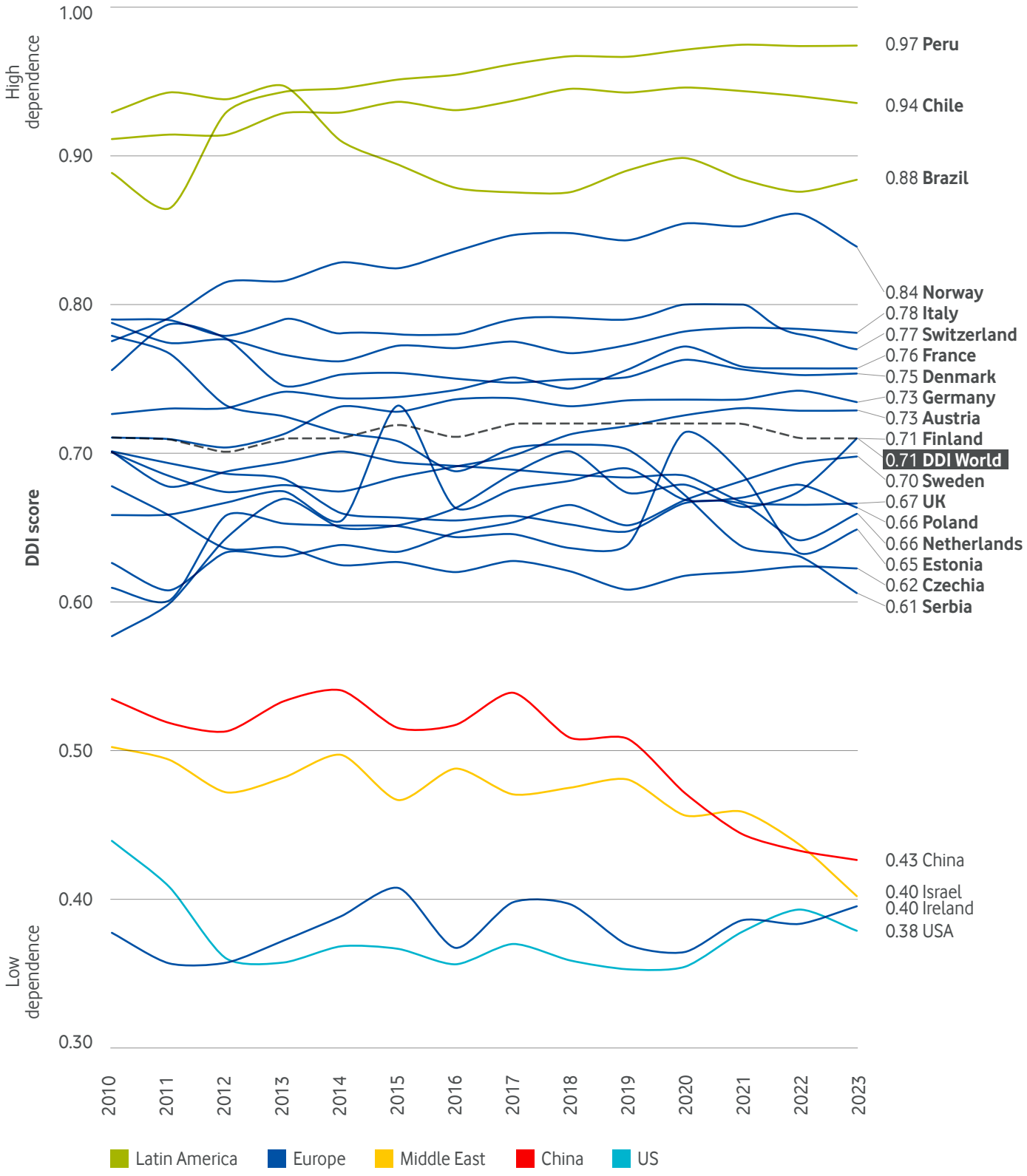


FIGURE 5

DDI values over time, selected countries colored by region

Countries were chosen to show contrast. DDI world represents the average score for all DDI countries.
Source: DDI

Europe's intermediary position in regional trends is also reflected in European countries' annual performance on the index. While some year-to-year fluctuation is evident for most European countries, rarely do they move outside the middle values of the index between 0.6 and 0.8 (Figure 5). In other words, Europe's digital dependence is consistently moderate to high at the regional and national levels.

Despite these similarities, this high-level approach to determining European priorities is likely to miss crucial nuances. A more granular picture indicates that European countries display significant variation in how digital dependence has developed over time. Finland and Serbia, for instance, are almost mirror opposites, with Finland becoming significantly more dependent and Serbia significantly less.

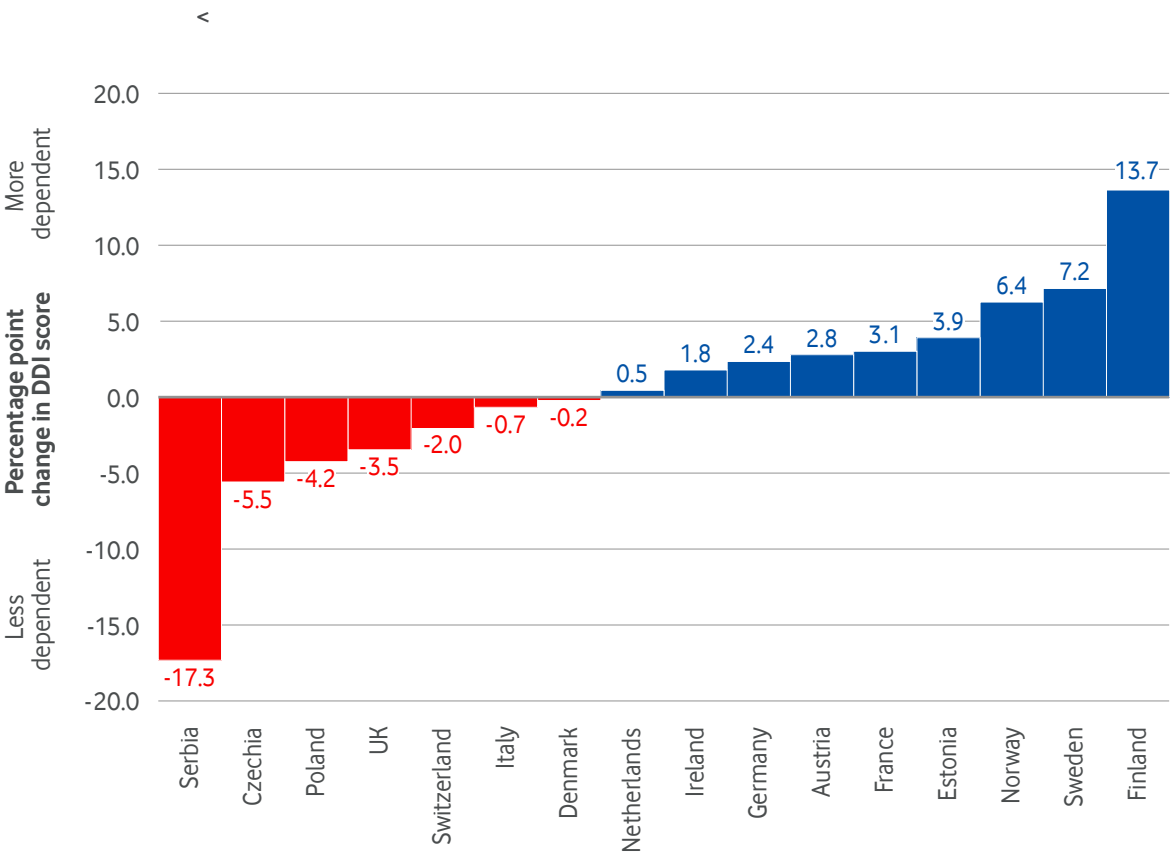


FIGURE 6
Change in DDI scores for European DDI countries, 2010-2023
Source: DDI

A purely regional approach also risks ignoring how national policies and regulations impact Europe more broadly. For instance, Ireland is the least dependent European country, with a very low DDI score of 0.4. Ireland's score is largely a reflection of its success in attracting US technology companies – essentially eliminating foreign dependence by transforming foreign suppliers into domestic ones. While this transformation has had some strong positive effects for the Irish economy – highlighted most recently in a report on data centers[13] – it also poses significant risks to the Irish and European economies (Box 3). Ireland's experience

13 KPMG International Limited, "The Value of Data Centres to Ireland," Report prepared for the Irish Department of Enterprise, Tourism and Employment, June 2026, accessed September 4, 2026, www.gov.ie/en/department-of-enterprise-tourism-and-employment/publications/report-on-the-value-of-data-centres-to-ireland/.

Ireland's digital sector is so large relative to its size in the global economy that it distorts how Europe's digital trade performance looks on paper. We call this the "Ireland effect."

THE BASICS

- **Ireland is a digital trade giant.** Despite accounting for only about 0.4% of global GDP, it accounted for 23% of global digital services exports between 2020 and 2024.
- **Ireland generates most of Europe's digital trade surplus.** It accounted for over 87% of the EU's cumulative ICT services trade balance between 2020 and 2024.
- **Without Ireland, the EU's digital trade balance moves from surplus to deficit (Figure B.1).** That cumulative trade deficit was equivalent to US$350.1 billion between 2022 and 2024.
- **The Ireland effect is driven largely by the presence of US technology companies,** which have long used Ireland's competitive tax policies to limit their tax burdens.

WHY IT MATTERS

- **The Ireland effect overstates Europe's digital strength.** In distorting regional and global digital trade statistics, the Ireland effect corrupts the evidence base upon which European policymakers make decisions.
- **The Ireland effect shows how governments address digital dependence matters.** Ireland's strategy has generated great benefits but is also accompanied by significant risks as the global tax and trade contexts evolve. This raises questions about how to best decrease digital dependence and how to navigate the spillover effects of doing so.

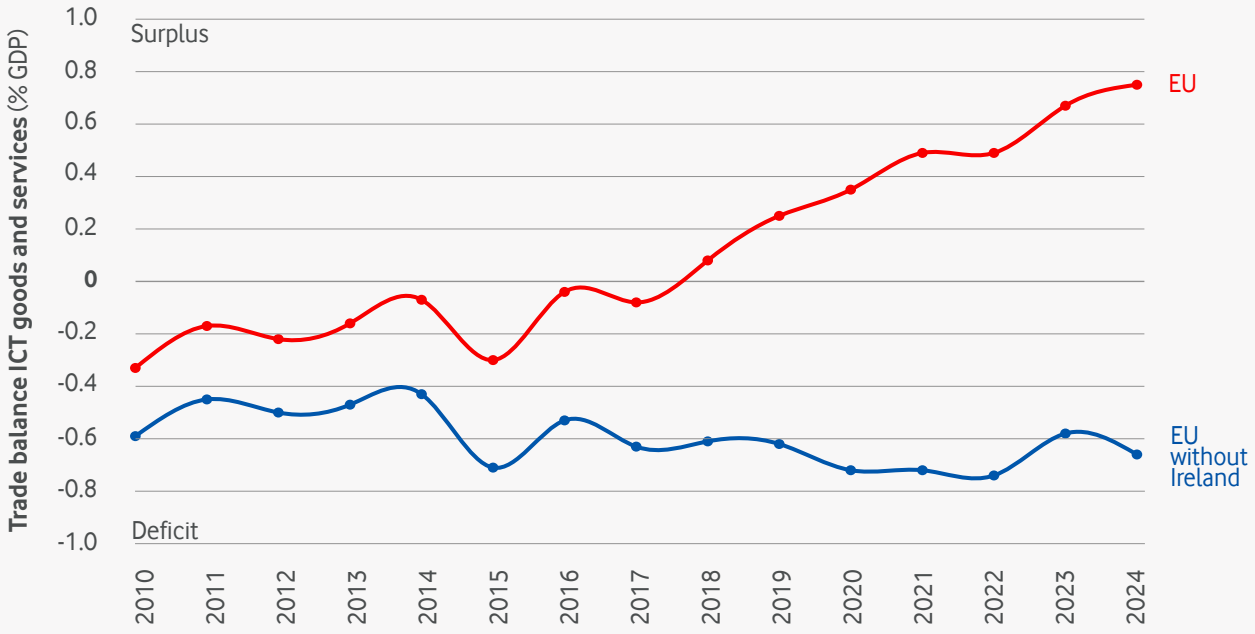


FIGURE B.1
EU trade balance in ICT goods and services with and without Ireland

BOX 3
The Ireland effect
Source: Mayer, et al. 2026. "A Wake-Up Call."

consequently highlights the centrality of addressing digital dependence in a way that balances improvements in national positions with related and potentially negative regional spillover effects.

The complexity of addressing Europe's digital dependence is further reinforced when zooming in to examine the performance of individual European nations on the four DDI dimensions (Figure 7). European dimension score patterns are diverse and the drivers of increasing or decreasing digital dependence differ across countries. Sometimes changes in a single dimension can have a visible impact on the overall DDI score. For instance, in France and Germany, a strong increase in ICT services dependence corresponds to an increase in overall dependence. In other settings, countries show a similar change in dependence overall but that change is the result of a different DDI dimension. For example, Sweden and Norway show similar dependence increases, but this correlates to enhanced services dependence in Norway whereas Sweden becomes more dependent in services and goods. Yet others, like France and Estonia, have similar DDI scores but widely varying dimension profiles. Crucially, while services appear to be a driver in the countries whose DDI scores improved most since 2010, alternative routes to DDI improvement exist. For instance, Italy appears to have improved its position largely based on ICT goods trade.

Mapping the pattern of Europe's digital dependence generates several takeaways. First, not only do European countries perform differently overall when it comes to digital dependence. They also derive different vulnerabilities from these dependencies and have different capacities to address those vulnerabilities. Second, despite this diversity, European countries show a crucial similarity: except for Ireland most are highly dependent. They are additionally united in their location in the middle of the index and by their shared vulnerabilities in digital trade, patenting and infrastructure.

In this context, reducing Europe's digital dependence is advisable. To do so successfully, Europe must address unique national needs without losing sight of the shared and evolving regional and geopolitical contexts. Doing so will require strong coordination at the regional level and strategic priorities derived from national experiences. The focus should not be on developing different strategies for different countries. Rather, it should be on (1) establishing evidence-based, shared dependence priorities for Europe and (2) evaluating how different country clusters can help achieve those priorities. The DDI provides an empirical basis for meeting both of these challenges.

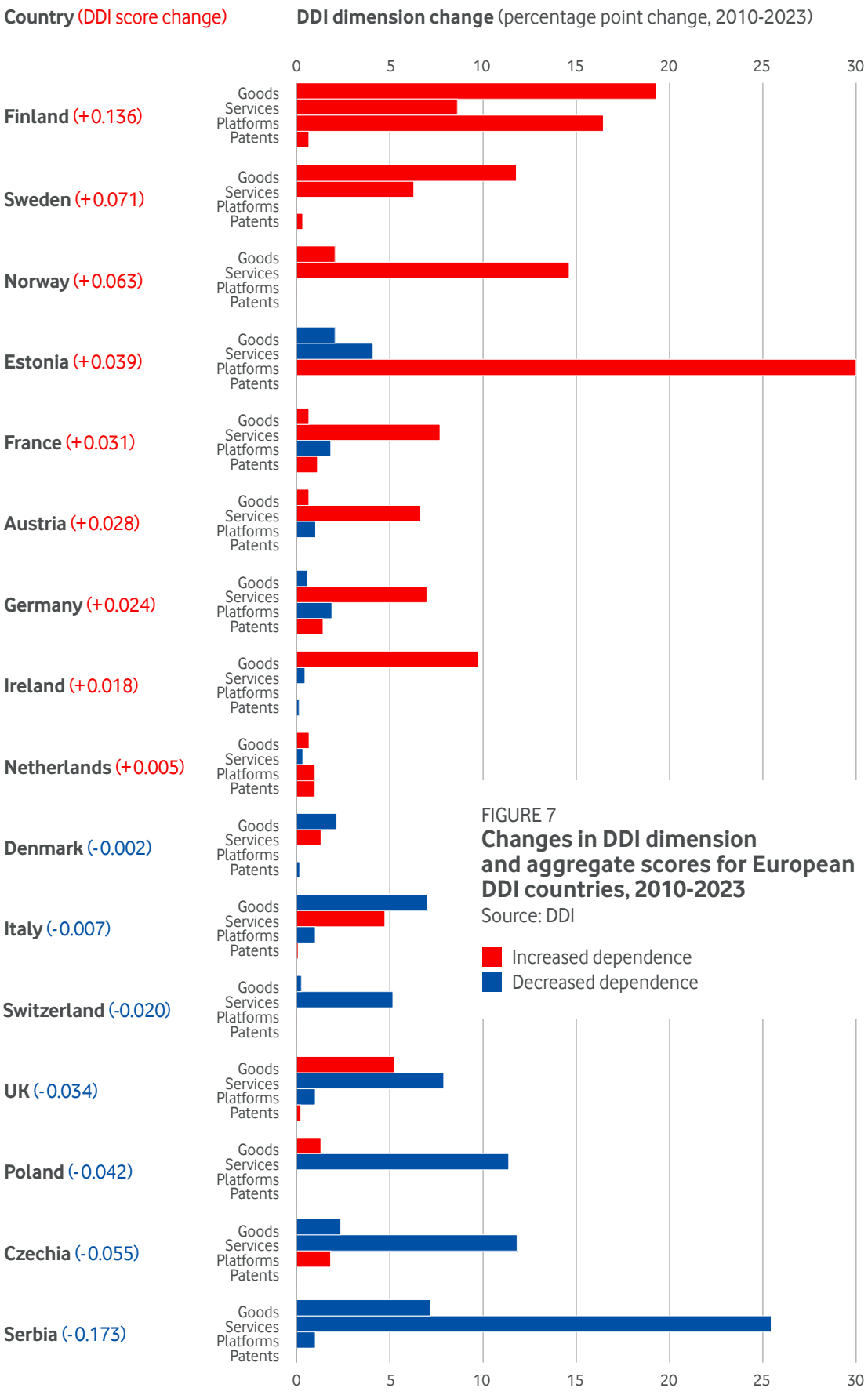


FIGURE 7

Changes in DDI dimension and aggregate scores for European DDI countries, 2010-2023

Source: DDI

Clustered dependencies and strategic opportunities

An efficient way to determine how European countries can achieve their digital dependence priorities is to identify similarities in their dependence profiles and how these relate to a given prioritization package. Statistical analysis of the DDI dimensions and indicators makes it possible to identify six clusters of countries sharing similar digital dependence profiles (Table 1).[14] Two of the clusters are centered around the technopoles, the US and China. The remaining four are more diverse. Since 2010, European countries have belonged to five of the six clusters although in 2023 they are primarily located in the post-industrial and supply chain node clusters.

Clusters	2010	2015	2019	2023
Technopole USA	USA	USA	USA	USA
Technopole China	China, **Estonia**	USA	China	China
Post-industrial countries	**Austria**, Canada, **Denmark, Finland, France, Germany, Ireland,** Israel, **Italy, Netherlands, Norway,** Philippines, South Korea, **Sweden, UK**	**Austria**, Canada, **Denmark, Estonia, Finland, France, Germany,** Israel, **Italy,** Japan, **Norway,** Singapore, **Sweden, Switzerland**, UAE, **UK**	**Austria**, Canada, **Finland, France, Italy**, Japan, Morocco, **Norway, Switzerland, UK**	**Austria**, Canada, **Denmark, Finland, France, Germany, Ireland, Italy**, Japan, **Norway, Serbia**, Singapore, **Sweden, Switzerland**, UAE, **UK**
Supply chain nodes	**Czechia,** Indonesia, Malaysia, Mexico, **Poland,** Singapore, Thailand, Vietnam	**Czechia, Ireland**, Malaysia, Mexico, **Netherlands**, Philippines, **Poland**, South Korea, Thailand, Vietnam	**Czechia, Ireland**, Malaysia, Mexico, **Netherlands**, Philippines, Singapore, South Korea, Thailand, Vietnam	**Czechia**, Egypt, **Estonia**, Indonesia, Mexico, **Poland**, Thailand, Vietnam
Digital South	Argentina, Australia, Azerbaijan, Brazil, Chile, Egypt, Ethiopia, Ghana, India, Kazakhstan, Kenya, Morocco, Nigeria, Peru, Qatar, Russia, Rwanda, Saudi Arabia, Serbia, South Africa, **Switzerland,** Türkiye, Uganda	Argentina, Australia, Azerbaijan, Brazil, Chile, Ethiopia, Ghana, India, Kazakhstan, Kenya, Morocco, Nigeria, Peru, Qatar, Russia, Rwanda. Saudi Arabia, **Serbia**, South Africa, Uganda	Argentina, Australia, Azerbaijan, Brazil, Chile, Egypt, Ethiopia, Ghana, India, Kazakhstan, Kenya, Nigeria, Peru, Qatar, Russia, Rwanda, Saudi Arabia, **Serbia**, South Africa, Türkiye, Uganda	Argentina, Australia, Azerbaijan, Brazil, Chile, Ethiopia, Ghana, India, Kazakhstan, Kenya, Morocco, Nigeria, Peru, Qatar, Russia, Rwanda, Saudi Arabia, South Africa, Türkiye, Uganda
Transitional countries	Japan	Egypt, Indonesia, Türkiye	**Denmark, Estonia, Germany,** Indonesia, Israel, **Poland, Sweden**, UAE	Israel, Malaysia, **Netherlands**, Philippines, South Korea

TABLE 1
Clusters of digital dependence, DDI countries, 2010–2023
European countries in **blue**. The typology is derived from a cluster analysis (k-means). Please see Appendix 2 for details. Source: DDI

14 Details of the factor and cluster analyses are included in Appendix 2.

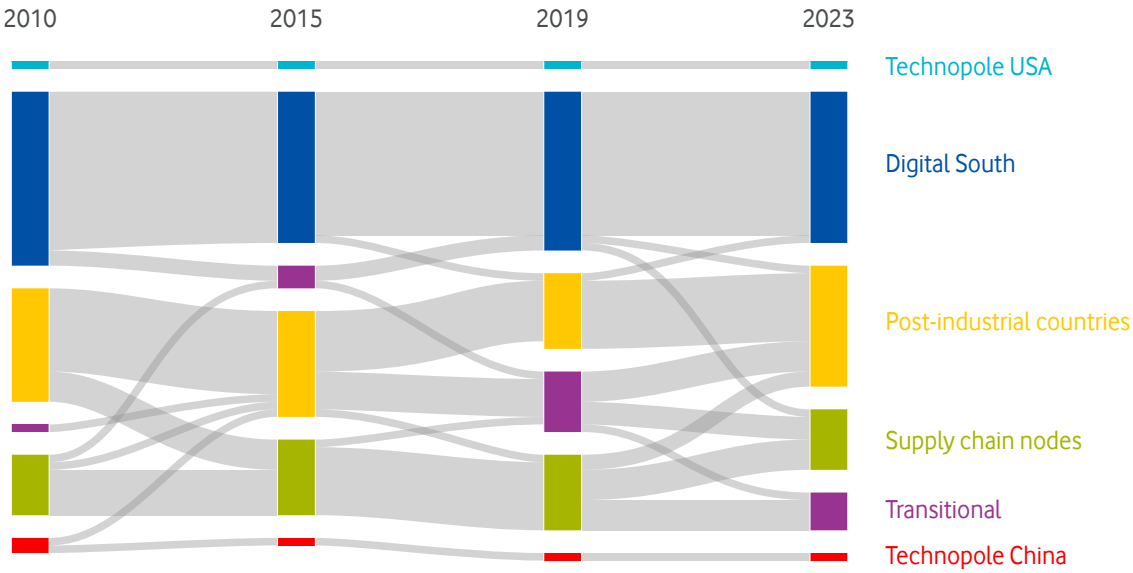


FIGURE 8
Evolution of DDI cluster membership, 2010-2023
Source: DDI

As Figure 8 indicates, while the membership of the technopole clusters has been stable since 2010, the membership of many non-technopole clusters, including the post-industrial, supply chain and transitional clusters, has evolved over time. The clusters also demonstrate different dependence scores and rankings along the DDI dimensions (Table 2).

Rank	Category	ICT goods
1	Transitional countries	0.364
2	China	0.452
3	Supply chain nodes	0.510
4	Post-industrial	0.628
5	US	0.677
6	Digital South	0.909

Rank	Category	Platforms
1	US	0.080
2	China	0.580
3	Transitional countries	0.944
4	Digital South	0.946
5	Supply chain nodes	0.969
6	Post-industrial	0.974

Rank	Category	ICT services
1	China	0.240
2	Transitional countries	0.341
3	Post-industrial	0.444
4	Supply chain nodes	0.499
5	US	0.476
6	Digital South	0.519

Rank	Category	ICT patents
1	China	0.526
2	US	0.800
3	Transitional countries	0.974
4	Post-industrial	0.985
5	Digital South	1.000
6	Supply chain nodes	1.000

TABLE 2
Ranking of DDI clusters by DDI dimension, average cluster value in 2023
Source: DDI

This section presents key features of technopole and non-technopole clusters before zooming in on Europe's location in the cluster landscape as well as the implications for addressing digital dependence and boosting digital resilience in Europe.

Technopole clusters

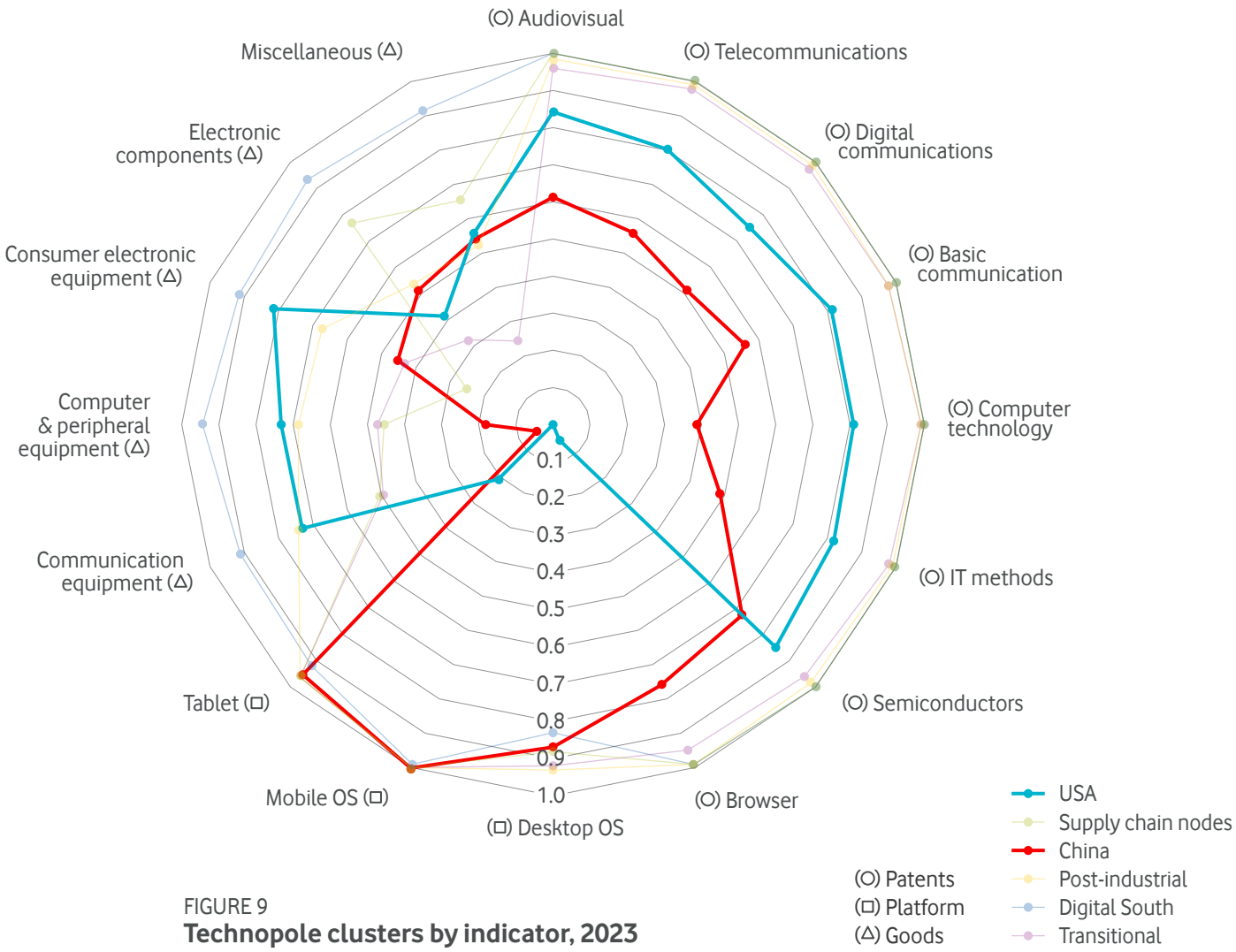


FIGURE 9
Technopole clusters by indicator, 2023
Source: DDI

The technopole clusters are distinct in their attributes – both from one another and from all the other clusters (Figure 9). The US shows the index's strongest performance in platforms in 2023, where it is not only almost independent of foreign providers but also 50 percentage points less dependent than any other DDI country. It does well in some ICT goods such as electronic components – a category which includes semiconductors[15] – but is generally moderately dependent on that dimension. The US is a bit less dependent on services but nonetheless places behind almost all clusters here. Despite demonstrating moderate to high dependence in ICT patents, including semiconductor patents, the US remains near the top of the cluster ranking on this dimension.

Since 2010, the US has become more dependent on foreign partners in ICT goods and patents and decreased its dependence on foreign ICT services and platforms. However, except for the US's growing patent dependence, all of these changes were slight, doing little to alter the US's overall digital dependence.

15 Saif M. Khan, Alexander Mann, and Dahlia Peterson, The Semiconductor Supply Chain: Assessing National Competitiveness, CSET Issue Brief (Center for Security and Emerging Technology, January 2021), www.doi.org/10.51593/20190016; Jan-Peter Kleinhans and Nurzat Baisakova, The Global Semiconductor Value Chain: A Technology Primer for Policy Makers (Stiftung Neue Verantwortung, October 2020).

Relative to other clusters, China performs best in ICT services. It is the least dependent country on foreign ICT patents by a substantial margin and performs well in ICT goods too, with a dimension score of 0.45 and particularly strong performance in communications equipment and computers and peripheral equipment. It trails the US by a huge margin in platforms – 0.58 to the US's 0.08 – but nonetheless leads other clusters by a similar margin on that dimension, with the transitional countries 36 percentage points more dependent on foreign platforms than is China.

Like the US, China has become slightly more dependent in ICT goods and slightly less dependent in ICT services since 2010. Unlike the US, China has significantly decreased its dependence in platforms and made drastic improvements in patent dependence. In other words, while both technopoles remain in a strong overall dependence position relative to other clusters, only China appears to be improving its position further.[16]

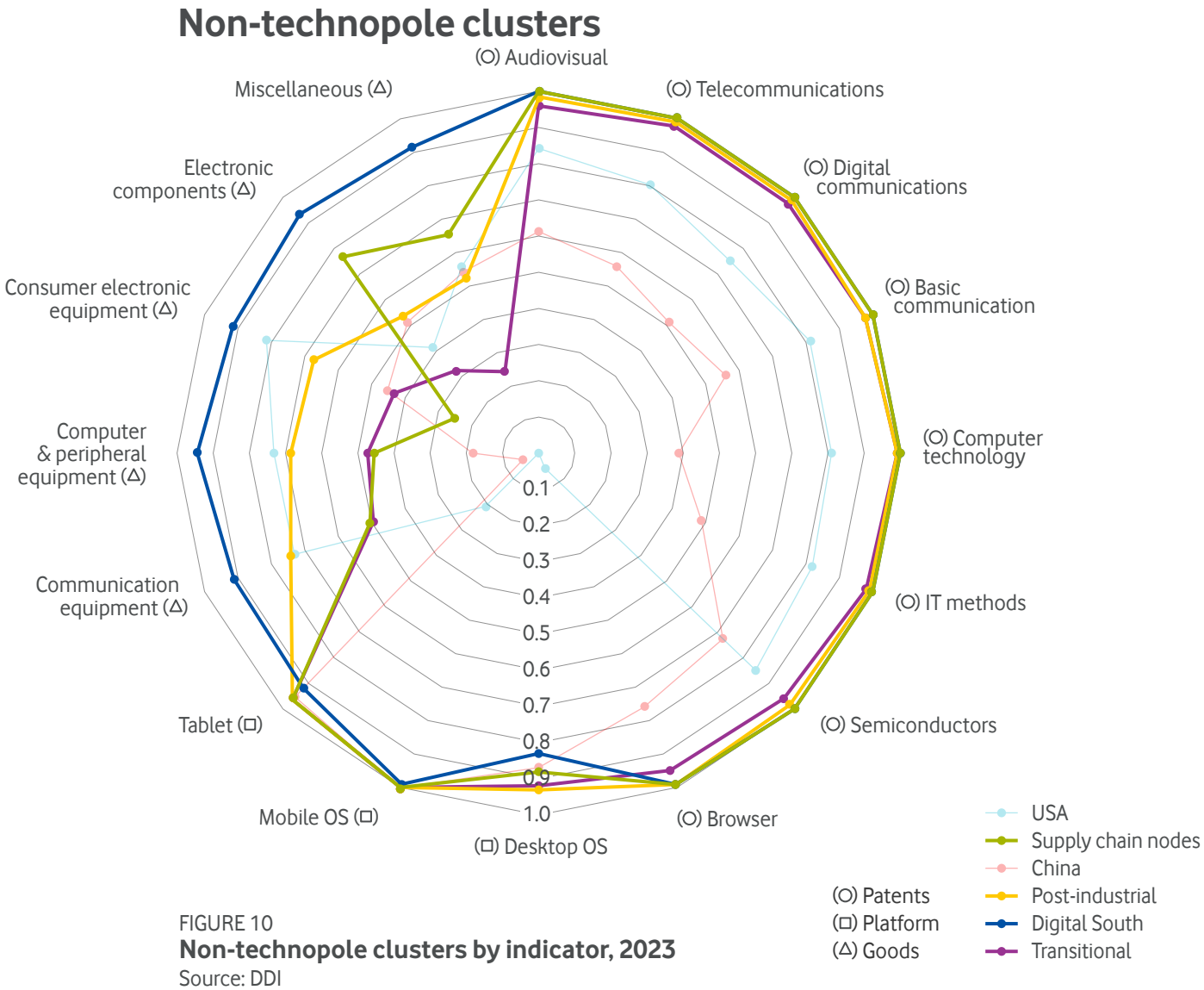


FIGURE 10
Non-technopole clusters by indicator, 2023
Source: DDI

16 Please see our previous policy briefs for a discussion of these differences and their implications for Europe's digital sovereignty: Mayer et al., "Digital Trade Trap?" and Laura Mahrenbach, Rogelio Madrueño, Yen-Chi Lu, and Maximilian Mayer, "Digital Patent Decline: The Economic and Political Costs of Europe's Shrinking ICT Patent Share," Vodafone Institute and CASSIS, University of Bonn, July 2026, www.vodafone-institut.de/wp-content/uploads/2026/07/digital-patent-decline.pdf.

The remaining four non-technopole clusters show significant similarities, especially their shared strong dependence on foreign ICT patents and platforms in 2023 (Figure 10). However, their dependence on foreign ICT goods and services is more differentiated.

The post-industrial cluster includes major European economies like Germany, Italy, France and the United Kingdom (UK) as well as so-called "like-minded countries" like Japan, Canada and (sometimes) South Korea. This is the most dependent cluster in platforms, with a dimension score of 0.97. It performs absolutely worse – 0.98 – but relatively better – ahead of Digital South and supply chain node clusters – in ICT patents. In comparison, the post-industrial cluster is only moderately dependent in ICT goods and even less dependent in ICT services. Crucially, most post-industrial countries got more dependent across most dimensions between 2010 and 2023, with some drastic increases in platform dependence, particularly in Finland and Singapore (Table 3).

European countries, including Estonia, Poland and Czechia, were also prominent in the supply chain node cluster in 2023. This cluster is populated with supply chain hubs active in advanced manufacturing, technology R&D and engineering. The cluster shows near total dependence in patents (1.0) and platforms (0.97) and was the second most dependent cluster in ICT services – albeit with a much better dimension score of 0.50. Its score in ICT goods is roughly the same but puts the cluster in a better relative position, placing it behind only China and the transitional countries. The supply chain node cluster's trajectory mirrors that of the post-industrial cluster but with two key improvements: (1) the supply chain node cluster maintained a stable position in patents between 2010 and 2023; and (2) a smaller proportion of supply chain node states became more dependent in ICT goods and services in that period when compared with the post-industrial cluster.

The transitional cluster is more mixed in its membership and is the final cluster to include European states – here, the Netherlands – in 2023. Apart from Indonesia and Israel, the countries in this cluster largely move elsewhere from one time period to the next. Like China, this cluster ranks in the top 3 across all DDI dimensions in 2023 (see Table 2 above). Dimension scores for ICT goods and services were particularly strong at 0.36 and 0.34, respectively, indicating a low degree of digital dependence. Despite this, the transitional countries remain heavily dependent on others in platforms and patents. Since 2010, the cluster has slightly decreased its dependence on foreign platforms but shows an increase in dependence across the other three dimensions.

Lastly, the Digital South cluster contained no European countries in 2023, although Serbia and Switzerland were members in earlier years. The cluster is primarily populated by emerging market states from South America, Africa, Eurasia and the Middle East. It includes all of the core BRICS member states apart from China. The Digital South cluster shows relatively high dependence on all dimensions except in ICT services, where their average score is 0.52. This is also the only cluster to show general improvement in most dimensions: almost half of the Digital South states decreased their dependence in ICT goods and services between 2010 and 2023 and more than three-quarters are less dependent in platforms. ICT goods, services and platforms. Interestingly, Digital South countries managed improvements despite showing little change in patent dependence, raising questions about the centrality of facilitating innovation as a first step towards decreasing digital dependence.

Understanding European clusters and their implications

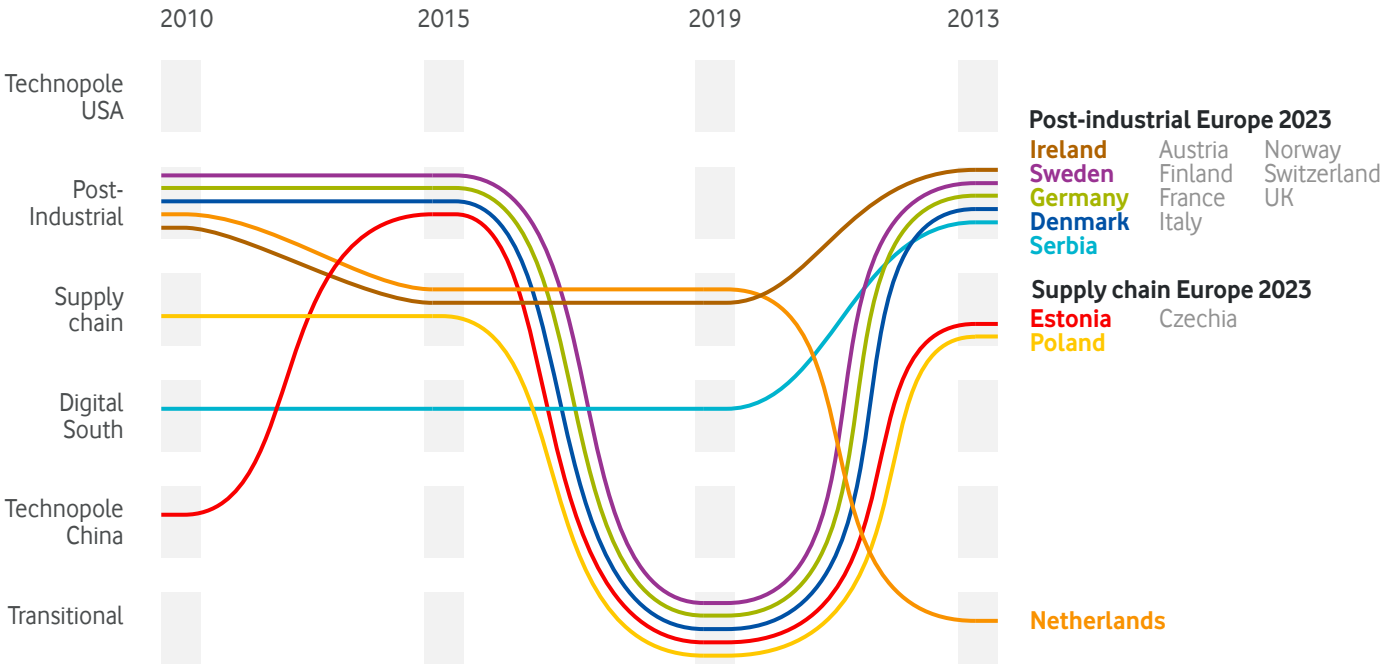


FIGURE 11
European countries by DDI cluster, 2010-2023
Source: DDI

In 2023, European states were primarily located in the post-industrial and supply chain node clusters. Some of these countries, including Austria, Czechia, Finland, France, Italy, Norway and the UK, have been in those clusters since 2010 (Figure 11). Others, like Ireland, Sweden, Germany, Denmark and Poland, moved briefly only to return to where they previously were. Yet others show more dynamism. Estonia has been in four different clusters, moving from technopole China to the post-industrial cluster to the transitional and finally the supply chain cluster. The Netherlands, currently in the transitional cluster, moved through the post-industrial and supply chain clusters in previous years. Finally, Serbia moved from the Digital South cluster to the post-industrial cluster in 2023.

The first lesson from these changes is that many European countries are indeed stuck in a pattern of digital dependence. Overall, states passing through the transitional cluster in 2019 moved back to where they were, implying no lasting changes were made to their digital dependence during the periods outside their main cluster. This implies consistent dependence features in Europe's "home" clusters which can be operationalized in support of Europe's strategic priorities.

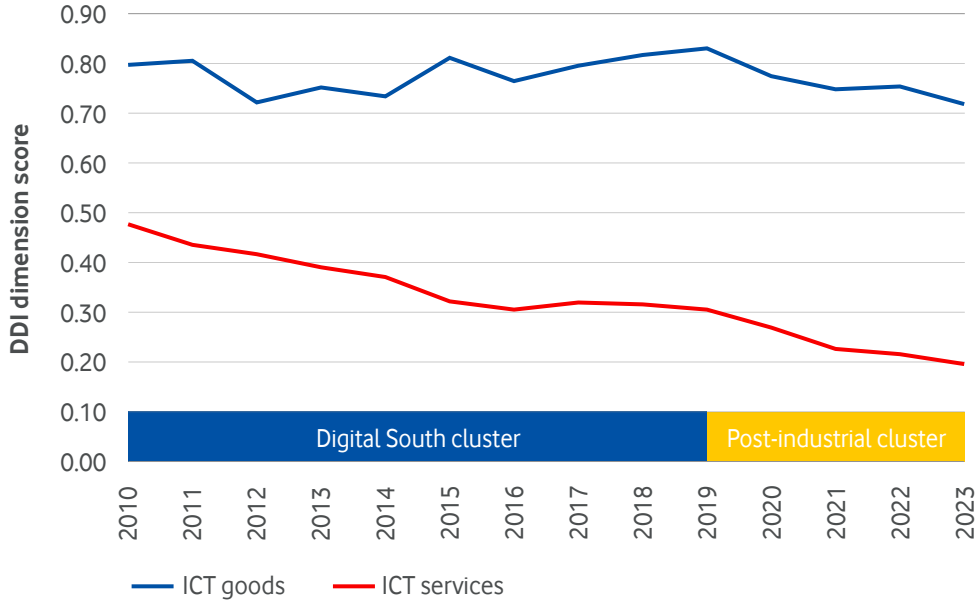


FIGURE 12
Serbian ICT goods and services dimension scores, 2010-2023
Source: DDI

A second and related lesson is that movement is possible – and it can bring improvements. Serbia, for example, was in the Digital South cluster between 2010 and 2019. Moving to the post-industrial cluster between 2019 and 2023 reflects a continuation of Serbia's long-term decline in ICT services dependence as well as a new, steady trend of declining ICT goods dependence (Figure 12). Identifying and building on already existent positive trends in each cluster can consequently generate resource-efficient, tailored approaches to addressing digital dependence and improving European resilience and autonomy. The next section takes a step in this direction, using the findings from the cluster analysis to evaluate four prioritization packages for moving Europe toward a more resilient digital future.

Prioritization packages addressing digital dependence

The comparative and time-series nature of the DDI makes it a useful tool for tracking changes in digital dependence and for understanding digital dependence profiles. It can also be used to generate strategic packages for addressing digital dependence that move beyond the status quo, while offering insights into the likelihood that these packages will deliver desired outcomes for Europe.

The business-as-usual approach in Brussels is encapsulated in the European Commission's recent "Tech Sovereignty package."[17] Key elements include a continued EU-level emphasis on regulation, insufficient investment, weak coordination and sequencing of Europe-wide measures, and a lack of explicit priorities about how, where, and when to effectively reduce digital dependencies. Simultaneously, national and sub-national initiatives – such as decisions in France and in Germany's Schleswig-Holstein to decrease reliance on Microsoft[18] – remain fragmented, isolated and insufficient in scale to drive systemic European change.[19]

Drawing on the previous analysis and the DDI data, this section outlines four distinct prioritization packages to promote a more resilient and less dependent Europe. Each was developed as a distinct response to the digital dependence trends discussed above:

- **SUPPLY CHAIN NODE REPLICATION**
  Following the path of Europe's least dependent and best-performing cluster by prioritizing leverage, that is, other countries' dependence on Europe, over decreasing Europe's own dependence

- **TECHNOPOLE IMITATION**
  Creating a significantly less dependent European technopole to compete with China and the US

- **VULNERABILITY MINIMIZATION**
  Identifying and addressing the digital dependencies which are most threatening for Europe's future resilience

- **DIVERSIFICATION**
  Hedging against the risks of asymmetrical dependence on a limited number of partners – particularly technopoles – by diversifying partners and building Europe's digital capabilities

17 European Commission, "Strengthening Europe's Tech Sovereignty," June 23, 2026, www.digital-strategy.ec.europa.eu/en/policies/eu-tech-sovereignty.

18 "France to Remove Windows from Government Computers in Sovereignty Push," RFI, April 17, 2026, www.rfi.fr/en/france/20260417-france-to-remove-windows-from-government-computers-in-sovereignty-push; Stefan Krempl, "Goodbye, Microsoft: Schleswig-Holstein Relies on Open Source and Saves Millions," heise online, December 7, 2025, www.heise.de/en/news/Goodbye-Microsoft-Schleswig-Holstein-relies-on-Open-Source-and-saves-millions-11105459.html.

19 Antonio Calcara, "European Cloud Computing Policy: Failing in Europe to Succeed Nationally?," West European Politics49, no. 4 (2026): 994–1018, www.doi.org/10.1080/01402382.2025.2491962.

As Table 3 shows, these prioritization packages are diverse in terms of how much change is required, when that change should occur, which digital dependencies should be reduced and the innovations necessary to do so. In this section, we not only discuss the policy priorities and trade-offs implicit in each. We also briefly assess implementation feasibility and how each prioritization package applies to the post-industrial and supply chain clusters dominant in Europe. This gives policymakers a clear, comparable set of policy choices which can be used to identify timelines for action and assess policies' likelihood for success.

	Supply chain node replication	Technopole imitation	Vulnerability minimization	Diversification
DDI dimension focus	ICT goods	Platforms, ICT patents	All dimensions	Platforms, ICT goods, ICT services
Timing of actions	Near- and mid-term	Near- to long-term	Near- to long-term	Near- to long-term
Transformational intensity	Incremental change	System-wide transformation	Significant change for selected sectors and technologies	Substantial policy transformation
Expected technopole reactions	Low resistance	Massive geopolitical pushback	Moderate resistance	High resistance, contestation and coercion
Key innovation(s)	Prioritize leverage over decreasing dependence	European Sovereign Technology Fund + Continental technology champions	Program 30 + Focus on next generation and emerging technologies	Workarounding + 33% rule + E-TECH

TABLE 3
Comparing strategic prioritization packages for Europe[20]

Supply chain node replication

One approach would be to replicate the least dependent European cluster. As Table 4 shows, European supply chain node and post-industrial countries perform similarly on platforms and patents but differ on trade in ICT goods and services. European supply chain node countries are significantly less dependent in ICT services than we see for the supply chain node cluster overall and noticeably less dependent in ICT goods. Hence, European supply chain node countries seem a potential model for other European states.

Cluster	ICT goods	ICT services	Platforms	ICT patents	DDI score
Post-industrial Europe	0.64	0.43	0.98	0.99	0.70
Supply chain node Europe	0.47	0.38	0.98	1.00	0.64
Post-industrial	0.63	0.44	0.97	0.99	0.70
Supply chain node	0.51	0.50	0.97	1.00	0.69

TABLE 4
DDI dimension for different cluster groupings, 2023
"Post-industrial Europe" and "Supply chain node Europe" are the average values of the European members of a given cluster.

20 All of the innovations listed, such as the 33% rule or Program 30, are policy priorities based on the DDI evidence and their application in the related scenarios.

Crucially, despite this relative independence in the European context, the supply chain node cluster remains highly dependent overall. Replicating the supply chain node cluster consequently is less about decreasing Europe's digital dependence and more about making others dependent on Europe. The supply chain node's European membership – Czechia, Estonia and Poland – are all production and infrastructure hubs for critical technologies or for technology inputs.[21] Consequently, creating or reinforcing technological chokepoints should be the central aim of this prioritization package. European countries within the cluster provide examples of how Europe can integrate more deeply into global tech production networks and transform highly specialized firms into indispensable supply chain nodes.[22] Companies outside the cluster, such as Germany's industrial "hidden champions,"[23] illustrate that doing so is possible for non-cluster countries as well.

OVERARCHING OBJECTIVE

Building upon existing industrial strengths and regional technology ecosystems to make Europe a global tech supply chain node and improve its geopolitical leverage.

POLICY PRIORITIES

First, Europe should consolidate and expand its existing supply chain strengths rather than attempting to reshore entire value chains. Public investment and industrial policy should focus on strengthening proven industrial clusters and technology ecosystems to support sectors which are expected to remain critical over the next 15-20 years. These include:

- Semiconductor manufacturing and production equipment;
- Industrial automation and advanced manufacturing;
- Digital logistics;
- Software and cybersecurity for industrial control systems;
- Telecommunications equipment;
- Cloud and data center infrastructure; and
- Open source-based, application-oriented AI (especially for industrial production).

Ideally, Europe would control at least one element of the new technological stack, preferably several, to secure its position and generate financial returns that can feed back into supply chain node-relevant innovations.

Second, innovation policy should increasingly focus on converting industrial capabilities into technological leadership and future chokepoints (see Box 1). Securing stronger ICT patent portfolios is key to rising in global value chains and will require a more supportive ecosystem. Critical elements include explicit political incentives for ICT patenting, enhanced tech investment, and applied research and commercialization. These efforts can help lock firms into strategically more valuable and profitable positions within global value chains. They may also generate political advantages by boosting Europe's capacity to engage in global standard-setting and enhancing its resilience against supply chain-related coercion.[24]

21 OECD, "Special Focus: Semiconductor Value Chains," in Economic Security in a Changing World (Paris: OECD Publishing, 2025), www.doi.org/10.1787/4eac89c7-en; International Trade Administration, "Estonia Advanced Manufacturing," Estonia Country Commercial Guide, February 5, 2026, www.trade.gov/country-commercial-guides/estonia-advanced-manufacturing.

22 Magdalena Kapela, "Poland in International Supply Chains in 1995–2020: Global Value Chains and Shift-Share Analysis," European Research Studies Journal 27, no. 4 (2024): 1102–1121, www.doi.org/10.35808/ersj/3560; Viktor Květoň and Petr Horák, "Firms' Supply Chain Integration, R&D Collaboration, and Impact on Competitiveness: Evidence from Czechia," Journal of the Knowledge Economy 15, no. 2 (2024): 5817–5840, www.doi.org/10.1007/s13132-023-01242-8; OECD, "SME Internationalisation," in SME Policy in Czechia (Paris: OECD Publishing, 2026), www.doi.org/10.1787/73cde8ec-en.

23 Hermann Simon, Hidden Champions of the Twenty-First Century: The Success Strategies of Unknown World Market Leaders (New York: Springer, 2009)

24 Mahrenbach et al., "Digital Patent Decline."

Third, Europe should selectively deepen partnerships with trusted tech middle powers. Cooperation with countries such as Japan, South Korea, Taiwan and Israel would strengthen complementary capabilities in semiconductors, manufacturing equipment, cybersecurity and advanced industrial technologies while reducing excessive dependence on the US and China.[25] It also provides an opportunity to collectively shape global governance – or at a minimum transnational – rules to solidify Europe's position in global supply chains. Targeted friend-shoring and near-shoring measures could additionally encourage relocation of strategically selected production capacities to Europe.

Fourth, despite expanding domestic capabilities, Europe should continue participating in both US- and Chinese-centered supply chains wherever strategically beneficial. Complete decoupling would impose substantial economic costs and reduce opportunities for technological learning. Venture capital and public investment should therefore continue supporting emerging tech firms operating within global markets. Doing so via US- or China-led initiatives like Pax Silica[26] could help secure partnerships with non-technopole supply chain nodes as well, further boosting opportunities for technological learning and market expansion.

EXPECTED OUTCOMES AND TRADE-OFFS

This strategy is unlikely to produce a dramatic reduction in Europe's digital dependence in the short- or medium-term. On the contrary, dependence may initially increase because expanding advanced manufacturing requires imported equipment, specialized components and foreign technological inputs.[27] Its primary contribution lies in strengthening Europe's leverage rather than eliminating dependence. Controlling at least one element of the new stack (e.g., a production stage or manufacturing input) and avoiding further deindustrialization can help Europe enhance its economic resilience and political bargaining power despite continued digital dependence.

Several important trade-offs accompany this approach:

- **INCREASED COSTS**
  Innovation policy and industrial policy necessary to secure and expand supply chain strengths require substantial public investment. Europe already trails China and the US significantly in industrial subsidies.[28] Increasing these may prove a political and, if the European Chips Act is any indication,[29] also an economic hurdle. Friend-shoring may also increase production costs and negatively impact GDP. For example, the International Monetary Fund (IMF) estimates returning to the level of integration exhibited 25 years ago by disentangling from China "translates into long-term global GDP losses of 4.5 percent under reshoring and as much as 1.8 percent under friend-shoring."[30]

25 Maximilian Mayer, Gedaliah Afterman, Narayanappa Janardhan, and Laura Mahrenbach, eds., Workarounding: Tech Middle Power Cooperation in a Turbulent World (Singapore: Palgrave Macmillan, 2026), www.doi.org/10.1007/978-981-95-7629-6.

26 Pax Silica is the US Department of State's "flagship effort on AI and supply chain security." As of August 2026, it included 26 signatory and non-signatory participants and has begun to invest in joint projects to diversify AI, and especially semiconductor, supply chains. More information available here: www.state.gov/pax-silica#signatories.

27 Mayer et al., "A Wake-Up Call."

28 See OECD, "Industrial Subsidies Hit USD 108 Billion and Reshape Global Competition," June 1, 2026, www.oecd.org/en/blogs/2026/06/industrial-subsidies-hit-usd-108-billion-and-reshape-global-competition.html.

29 Niclas Poitiers and Tillman Schenk, "Revamping Europe's Chips Strategy: Indispensability, Not Self-Sufficiency," Bruegel Analysis, May 13, 2026, www.bruegel.org/analysis/revamping-europes-chips-strategy-indispensability-not-self-sufficiency; Oliver Falck, Clemens Fuest and Daniel Gros, "Rethinking the EU Chips Act: Europe Should Strengthen Its Strategic Assets Instead of Subsidizing National Champions," ifo Institute, February 13, 2026, www.ifo.de/en/econpol/opinion/2026-02-13/rethinking-the-eu-chips-act.

30 Diego A. Cerdeiro, Parisa Kamali, Siddharth Kothari, and Dirk Muir, "The Price of De-Risking: Reshoring, Friend-Shoring, and Quality Downgrading," IMF Working Paper 2024/122 (2024), www.doi.org/10.5089/9798400269646.001.

- **INCREASED RISK**
  Concentrating resources on selected technologies entails significant uncertainty and risk, as governments effectively bet on sectors expected to remain strategically relevant over the next two decades. Given the rapid pace of technological development, some of these bets could be wrong – with immense consequences.

- **INCREASED CHANCE OF GEOPOLITICAL COERCION**
  Firms occupying technological chokepoints are likely to face growing geopolitical and legal pressure and competition from technopoles. This could take the form of export controls, investment screening and standards enforcement as technopoles seek to prevent advanced semiconductor manufacturing in Europe.[31] While European chokepoints should be better placed to withstand such pressure under this scenario than is currently the case, Chinese expansion in the realm of ICT patenting[32] suggests maintaining those chokepoints may nonetheless be a significant challenge.

APPLICABILITY ACROSS EUROPEAN CLUSTERS

The package is particularly well-suited to countries in the supply chain node and transitional clusters, whose manufacturing capabilities can serve as foundations for chokepoint development. Their primary challenge is upgrading from production to innovation-intensive activities, including generating more patents, acquiring and keeping human talent and securing necessary investment levels and partners. Post-industrial countries can help on several of these fronts, leveraging their advanced services, engineering capabilities and research institutions to support and develop selected industries in supply chain node and transitional countries. Specifically, post-industrial countries should provide high-value design, software, standards development and industrial R&D in collaboration with manufacturing hubs across Europe.

FEASIBILITY

This prioritization package appears relatively feasible because it builds upon existing European industrial capabilities rather than attempting to create entirely new technological sectors. Current initiatives – including the European Chips Act and broader industrial policy – already move in this direction.[33] In the short-term, an enhanced focus on IP/patents would suffice, making initial implementation costs and institutional barriers lower than for more transformational strategies. Yet achieving meaningful results would still require sustained and substantial private investment and public funding over a period of 15–20 years, which could be politically and economically challenging for many states.

31 Aurelio Insisa, "Beyond the European Chips Act: EU Supply Chain Dependencies on China, Taiwan and the United States," Istituto Affari Internazionali Brief, April 6, 2026, www.iai.it/en/publications/c41/beyond-european-chips-act-eu-supply-chain-dependencies-china-taiwan-and-united.

32 Mahrenbach et al., "Digital Patent Decline."

33 European Commission, "Commission Presents New Package to Boost European Semiconductor Ecosystem," June 23, 2026, www.ec.europa.eu/commission/presscorner/detail/en/ip_26_1585.

Technopole imitation

US and Chinese dominance in tech markets, innovation and supply chains, as well as their more independent performance on most DDI dimensions, suggests copying the technopoles may be an alternative path towards a more resilient future for Europe. Unlike the supply chain node replication package, which accepts higher levels of digital dependence in exchange for increasing European leverage over selected chokepoints, the technopole imitation package aims to reshape the entire digital stack, substantially expand Europe's technological capabilities, and ultimately achieve a high degree of technological and strategic autonomy. Its ambition is not merely to manage dependence, but to fundamentally reduce it. In practical terms, this would amount to a significantly more ambitious version of the EuroStack vision: not simply strengthening selected layers of the digital ecosystem, but building a comprehensive, globally competitive European technological stack.[34]

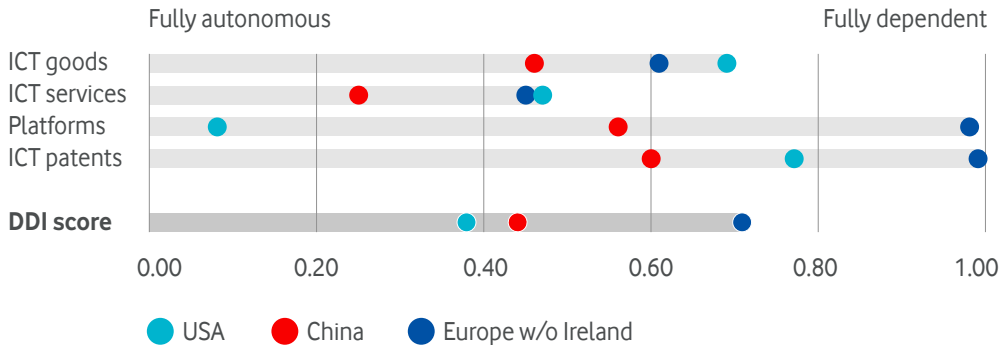


FIGURE 13
Gaps in DDI dimensions: China and the United States vs. Europe without Ireland (Average scores, 2020-2023)

While both the US and China provide examples of successful technopoles, their different political systems, industrial structures, and approaches to technological development are distinct – as are their digital dependence profiles. Pursuing either pathway would require Europe to close its largest dimension gaps, most notably in digital patents and platforms (Figure 13). Doing so would not only require a long-term strategy but also sustained political commitment, strengthened institutional coordination, and massive public and private investment. This package consequently moves far beyond the business-as-usual approach at the national and regional levels.

OVERARCHING OBJECTIVE

Transform the EU into a full-fledged technopole by building and adopting a European digital stack in which all critical layers are predominantly controlled by European firms and technologies.

34 Francesca Bria, Paul Timmers, and Fausto Gernone, "EuroStack - A European Alternative for Digital Sovereignty," February 13, 2025, accessed online September 1, 2026, www.euro-stack.info/.

POLICY PRIORITIES

First, dramatically accelerate innovation across Europe's digital technologies and ecosystems by amplifying the availability and impact of human and financial resources. Significantly increasing the Horizon Europe budget would be an important first step, but greater regulatory flexibility, faster commercialization pathways, and policies that mobilize European private capital while attracting investment from trusted international partners are equally essential.[35] Completing and amending the Digital Single Market,[36] strengthening European supply chains, and providing a harmonized regulatory environment for start-ups and innovative firms via the proposed "EU Inc." framework[37] can also help facilitate financial resource availability and investment. Prioritizing STEM education from primary school onwards to grow Europe's long-term talent base for innovating frontier digital technologies is crucial as well. So too is incentivizing partnerships between European research institutions and firms to ensure stack innovation and accrued human and financial resources translate into long-term market power for European firms.

Second, design and govern the European digital stack around a distinct European vision of digital sovereignty. Rather than replicating the US's proprietary platform model or China's state-centric approach, Europe should develop an interoperable, open-source stack built around European technologies and standards. These actions should be integrated into a core public digital infrastructure (DPI) that includes both digital identity and payment systems and which can be used to secure and provide foundational government services. Europe should not build this DPI from scratch but rather draw lessons from and adapt tech middle power models, such as the India Stack, which have already been tested both inside and outside Europe.[38]

Third, establish a European Sovereign Technology Fund to co-invest in material infrastructure, including AI compute, cloud infrastructure, and hyperscale data centers capable of competing with US and Chinese providers.[39] The fund should also support industrial scale-up, advanced manufacturing, semiconductor foundries, and other technological and economic capabilities required to establish Europe as a genuine technopole.

Fourth, promote the European stack and European capabilities via strategic technological partnerships. Cooperation with tech middle power partners such as India, Japan, South Korea, and Israel should focus on jointly developing critical technologies, sharing best practices, pooling capital and know-how, securing access to raw materials, and collaborating on frontier AI and other emerging technologies. Cooperation with the technopoles should combine FDI, local content requirements, and managed market access to develop European capabilities via technology transfer, learning, emulation and localization.

35 EuroStack Initiative, Deploying the EuroStack: What's Needed Now, May 19, 2025, www.eurostack.eu/wp-content/uploads/2025/08/eurostack-white-paper-final-19-05-25-3.pdf.

36 Eurostat, "What Is the Digital Single Market About?," European Commission, www.ec.europa.eu/eurostat/cache/infographs/ict/bloc-4.html.

37 European Commission, "EU Inc.: A New Harmonised Corporate Legal Regime," March 18, 2026, www.commission.europa.eu/topics/business-and-industry/doing-business-eu/company-law-and-corporate-governance/eu-inc-new-harmonised-corporate-legal-regime_en.

38 Press Information Bureau, Government of India, "India's Digital Public Infrastructure: Setting a Global Benchmark for Population-Scale DPI," PIB Backgrounder, March 6, 2026, accessed July 27, 2026, www.pib.gov.in/PressReleasePage.aspx?PRID=2235812&reg=3&lang=2; Laura C. Mahrenbach and Jürgen Pfeffer, "Measuring Political Legitimacy with Twitter: Insights from India's Aadhaar Program," New Media & Society 25, no. 10 (2023): 2704–2723; Vivek Raghavan, Sanjay Jain, and Pramod Varma, "India Stack—Digital Infrastructure as Public Good," Communications of the ACM 62, no. 11 (2019): 76–81, www.doi.org/10.1145/3355625; Institut Montaigne, "India's Digital Public Infrastructure: A Success Story for the World?," accessed September 3, 2026, www.institutmontaigne.org/en/expressions/indias-digital-public-infrastructure-success-story-world.

39 The European Sovereign Technology Fund rule is one suggested policy priority based on the DDI evidence and its application in this scenario.

EXPECTED OUTCOMES AND TRADE-OFFS

If successful, this approach would substantially increase Europe's technological autonomy and dramatically reduce its digital dependence over the medium to long term. In the short term, however, it would require exceptionally ambitious and politically risky decisions, including a fundamental reprioritization of public spending. While the likelihood of fully realizing this vision remains highly uncertain (see below), the strategy could still produce significant benefits. Europe would likely become considerably less dependent on foreign digital ecosystems. It would acquire new technological capabilities and innovation dynamics. And, as a new infrastructural power, it would secure greater control over the technologies underpinning its economy and security.

Nonetheless, the strategy entails substantial trade-offs:

- **INCREASED COSTS**
  Public investment costs would be enormous, requiring difficult fiscal choices and potentially crowding out other public priorities in defense, social welfare, and agriculture. Replacing or complementing existing ICT products and services within the European market would also impose transitional costs on businesses and consumers, potentially generating resistance from users unwilling to bear higher costs and from policymakers concerned about the fiscal burden.

- **INCREASED RISK**
  Large-scale investments could become sunk costs if major projects fail: compared with the scale of this agenda, the shortcomings of GAIA-X would appear modest.[40] Failures could also quickly erode public and political support.

- **NATURAL RESOURCE STRESS AND PUBLIC PUSHBACK**
  Constructing a European technopole would require significant additional energy, water, land, and other natural resources, particularly for compute infrastructure and AI data centers. If experience in other countries is indicative, this could encourage public resistance, particularly if tech expansion negatively impacts public services, including water and electricity provision, or affects quality of life.

- **POLICY AND INFRASTRUCTURAL REBALANCING**
  The strategy requires the EU to tilt its innovation-regulation balance toward a strategy centered on technological construction and innovation despite related risks. After all, one cannot regulate a digital stack into existence; one has to build it.

- **ARCHITECTURAL AND COORDINATION CHALLENGES**
  Europe would need to determine the appropriate balance between publicly governed digital infrastructure, commercial platforms, and open-source ecosystems. This implies greater coordination challenges as well in balancing numerous stakeholders, including national tech champions, smaller firms, public infrastructure providers, foundations, research institutions, and other non-commercial organizations.

40 Calcara, "European Cloud Computing Policy."

- **GEOPOLITICAL PUSHBACK**
  Building a European technopole would require the EU to balk existing policy,[41] reject Pax Silica and related technopole-led initiatives and pursue a far more assertive strategy aimed at progressively reducing dependence on dominant US and Chinese technology ecosystems. Given the economic and geopolitical advantages the US and China accrue from their current dominance, Washington and Beijing would have strong incentives to resist such an effort. At worst, they could even pursue parallel or complementary policies that make the emergence of a European-controlled digital stack significantly less likely.

APPLICABILITY ACROSS EUROPEAN CLUSTERS

The division of labor in building a European technopole should capitalize on the comparative strengths of different clusters. Post-industrial countries could take the lead in developing digital ecosystems, generating patents, scaling unicorns, and advancing frontier innovation, while supply chain node countries could specialize in hardware manufacturing, critical raw materials, advanced industrial production, and technical education. Although the capacity to provide large-scale industrial subsidies and mobilize venture capital is concentrated in Europe's five largest economies, the creation of a genuinely European digital stack would require national champions to evolve into "continental tech champions" capable of competing at global scale.[42] At the same time, this transformative process could reshape Europe's economic geography, creating new technological core-periphery dynamics as some regions emerge as key nodes of the European technopole while others risk falling behind.

FEASIBILITY

This prioritization package requires the most far-reaching changes and represents a fundamental break with current European policies, levels of public investment, and approaches to long-term strategic planning. It also demands the greatest shift in public and political imagination: to develop a European technopole, Europe must develop a new vision of the future that foregrounds technological patriotism and improves public awareness of European technologies and products. Given its scale of ambition, substantial financial costs, and expected geopolitical pushback from the US and China, this is the least feasible of the prioritization packages. Nevertheless, its closest real-world manifestation – the EuroStack initiative – has already attracted a growing and increasingly influential community of supporters.

41 Théophane Hartmann, "EU Signs US 'Pax Silica' Initiative Singling-Out China on AI Chips," Euractiv, June 24, 2026, accessed September 3, 2026, www.euractiv.com/news/eu-signs-us-pax-silica-initiative-singling-out-china-on-ai-chips/.

42 Developing continental technology champions are one suggested policy priority based on the DDI evidence and its application in this scenario.

Vulnerability minimization

Concerns about digital dependence often interpret dependence primarily as a vulnerability. Hence a third alternative could be to identify and minimize Europe's most threatening digital dependencies, including key chokepoints and critical "kill-switches." In essence, this is an emergency approach, addressing Europe's most significant weaknesses as quickly as possible. Such an approach aligns with the growing sense of urgency reflected in the European Commission's characterization of AI as a "geopolitical weapon" as well as decisionmakers' fears that currency digitalization could make the Eurozone "lose control of its own money" to non-European financial technology providers.[43] It is also underlined by recent events, such as the suspected sabotage of undersea communication cables in the Baltic Sea,[44] which demonstrate the vulnerability of Europe's digital infrastructure and that vulnerability's implications for connectivity and national security.

The DDI dimensions most likely to feature in vulnerability minimization assessments include ICT patents and digital platforms, that is, the dimensions in which Europe has consistently been most dependent on foreign suppliers (Table 5). Securing more ICT patents is critical to establish European businesses as supply chain nodes, creating future economic opportunities and protecting against foreign economic, technological and even extrajudicial interference in Europe.[45] Similarly, decreasing and managing dependence on foreign platforms enhances current resilience in the face of kill switch activation and decreases vulnerability to kill switches in the medium and long terms.

	2010	2015	2019	2023
ICT patents	**0.993**	**0.993**	**0.994**	**0.996**
Platforms	**0.952**	**0.975**	**0.982**	**0.981**
ICT goods	**0.579**	**0.599**	**0.597**	**0.599**
ICT services	**0.428**	**0.420**	**0.418**	**0.422**

TABLE 5
Average DDI dimension scores for European countries, selected years
Heatmap colors range from dark red (most dependent) to dark blue (least dependent).

OVERARCHING OBJECTIVE

Identify and alleviate the digital dependencies that make Europe most vulnerable as much and as quickly as possible.

POLICY PRIORITIES

First, establish "Program 30" to map Europe's strategic vulnerabilities.[46] Program 30 should identify kill switches and chokepoints and prepare responses to these vulnerabilities by 2030. The goal is to eliminate or substantially mitigate each vulnerability over the medium term by acting as quickly as possible.[47] The

43 Barbara Moens and Henry Foy, "AI Is Becoming a Geopolitical Weapon, Warns EU Digital Chief," Financial Times, July 21, 2026, accessed September 3, 2026, www.ft.com/content/ccaf6c42-f94b-4afc-a063-7243b4fb78ed; Olaf Storbeck, "Digital Euro 'Only Defence' against Deepening US Control of Money, Economists Warn," Financial Times, January 10, 2026, accessed September 3, 2026, www.ft.com/content/b0602271-cd43-4a6e-a96d-c8166a05d040.

44 Rafał Miętkiewicz, "Hybrid Threats in the Baltic Sea: The Results of Analysis of Countermeasure Options," Terroryzm—studia, analizy, prewencja, special issue (2025): 35–70, www.doi.org/10.4467/27204383TER.25.014.21517.

45 Mahrenbach et al., "Digital Patent Decline."

46 Program 30 is one suggested policy priority based on the DDI evidence and its application in this scenario.

47 Because the DDI operates at the macro level, it cannot capture all sector-specific dependencies, individual technologies, or discrete technological chokepoints.

EU's 5G Toolbox illustrates how potential chokepoints controlled by China, such as those related to critical raw material exports, are being addressed in Brussels and European capitals.[48] But Program 30 must also include US chokepoints, such as Europe's dependence on US-based cloud infrastructure and software providers for storing and managing critical data.[49]

Kill switch vulnerabilities vis-à-vis both technopoles exist as well and must be considered. For instance, Chinese companies control solar inverters in many of Europe's power grids which have been shown to contain undocumented communication devices and which can be switched off remotely.[50] Similarly, the US government already demonstrated its willingness to employ a kill switch in June 2026, restricting foreign nationals' access to Anthropic's most advanced large language models.[51]

Second, in the short term, prioritize addressing chokepoints and kill switches linked to core state functions and national security. The goal is not technological self-sufficiency but improving Europe's capacity to detect and respond to physical, cyber and economic security vulnerabilities, including those related to espionage and trade secrets. Doing so in the short term will be challenging and the chances of complete success are poor. To boost those chances, governments should be prepared to spend rapidly and heavily in select areas such as defense, satellites or intelligence. A first step would be scaling up existing European kill switch initiatives, such as the French public sector's rejection of Microsoft and the Swiss government's decision not to adopt Palantir's services. A second step would focus on easing platform-related chokepoints, as in the proposal to develop new European financial and monetary infrastructure around the digital Euro.[52]

Third, pursue long-term chokepoint solutions by investing in next-generation and emerging technologies. The focus should be on areas such as semiconductors, batteries, quantum, critical raw materials and smart green grids, where Europe can compete in new technological waves rather than trying to catch up to mature markets. This measure requires increased, mission-driven European science funding and targeted industrial subsidies for innovation and IP generation to correct Europe's digital patent gap. Japan provides an especially important lesson: as its digital patent leadership declined, its DDI score also deteriorated significantly. Europe's industrial policy should therefore place much greater emphasis on creating and retaining patents in emerging digital technologies.[53]

Fourth, decrease Europe's exposure to US technology giants. Ireland's position provides US Big Tech with low-tax access to the EU market and turns the Irish economy into a chokepoint (Box 3). This arrangement reinforces Europe's structural dependence on US digital platforms while leaving both the EU and the Irish economies highly vulnerable to tech companies' strategic, investment, and location decisions. Governments and regulation could aim to disperse the concentration of US Big Tech firm headquarters in Europe. Doing so would distribute benefits from

48 Tero Poutala, Elina Sinkkonen, and Mikael Mattlin, "EU Strategic Autonomy and the Perceived Challenge of China: Can Critical Hubs Be De-weaponized?," European Foreign Affairs Review 27, no. 2 (2022): 79–98, www.doi.org/10.54648/EERR2022015; European Commission, "The EU Toolbox for 5G Security," factsheet, January 29, 2020, accessed September 1, 2026, www.digital-strategy.ec.europa.eu/en/library/eu-toolbox-5g-security.

49 Madalena Barata da Rocha, Antoine Mathieu Collin, and Camille Reverdy, "Competing for Inputs: How the European Union Can Improve Critical Raw Materials Supply Security," Bruegel Policy Brief, July 9, 2026, accessed September 3, 2026, www.bruegel.org/policy-brief/competing-inputs-how-european-union-can-improve-critical-raw-materials-supply-security; "Beijing's Export Control Counterpunch: 14 EU Entities Added to China's Controlled List," Geopolitechs, July 24, 2026, accessed September 3, 2026, www.substack.com/home/post/p-208306640; JS Tan and Kathleen Thelen, "Cloud Capitalism and the AI Transition," Politics & Society 54, no. 2 (2026): 184–214, www.doi.org/10.1177/00323292251396395.

50 Erika Langerová, "China Holds a Kill Switch to European Power Grids," China Observers in Central and Eastern Europe (CHOICE), May 6, 2025, accessed September 3, 2026, www.chinaobservers.eu/china-holds-a-kill-switch-to-european-power-grids/; Sarah McFarlane, "Rogue Communication Devices Found in Chinese Solar Power Inverters," Reuters, May 14, 2025, accessed September 3, 2026, www.reuters.com/sustainability/climate-energy/ghost-machine-rogue-communication-devices-found-chinese-inverters-2025-05-14/.

51 Théophane Hartmann, "Commission Official Points to US 'Kill Switch' on Anthropic AI Models," Euractiv, June 23, 2026, accessed September 3, 2026, www.euractiv.com/news/commission-official-points-to-us-kill-switch-on-anthropic-ai-models/.

52 See Philip R. Lane, "The Digital Euro: Maintaining the Autonomy of the Monetary System," SUERF Policy Note, no. 369 (April 2025), accessed September 3, 2026, www.suerf.org/publications/suerf-policy-notes-and-briefs/the-digital-euro-maintaining-the-autonomy-of-the-monetary-system/.

53 Mahrenbach et al., "Digital Patent Decline."

these firms' presence across the continent, strengthen Ireland's economic autonomy, and make it harder to coerce European policymakers.

Fifth, financially and rhetorically commit to sustaining national and European tech champions and innovation ecosystems in the long-term. Several Scandinavian countries – notably Finland, Sweden, and Norway – illustrate how quickly technological leadership can erode and the high costs of that erosion (Figure 6). In Finland, for example, the decline of Nokia as a global technology leader weakened the country's digital innovation ecosystem, harmed the economy and substantially increased European dependence on foreign technology providers.[54] Minimizing vulnerabilities requires immediate action, such as financial incentives encouraging private capital to invest in European startups. But it will only be possible if governments also commit to sustaining national tech champions, renewing innovation capacity and training and securing human digital resources in the long-term.

EXPECTED OUTCOMES AND TRADE-OFFS

Although the primary objective is mitigating strategic dependencies rather than becoming fully independent, this prioritization package should reduce Europe's overall level of digital dependence. Addressing chokepoints and kill switches in the short term while committing to developing European alternatives in the long term would enhance Europe's strategic autonomy and reduce its exposure to coercive tactics associated with weaponized interdependence.[55] This should limit Europe's exposure to the most severe risks arising from the technopoles' tech rivalry.

Yet these measures also involve important trade-offs:

- **HIGHER COSTS AND POORER TECHNOLOGICAL PERFORMANCE**
  Eliminating specific chokepoints may require Europe to adopt technological solutions that are more costly or less capable than existing alternatives. This could complicate governance in the short term, as Europe addresses rapidly evolving societal and technological contexts with less efficient, more expensive and poorer performing technologies. It must also be accepted as a medium- and long-term trade-off as European firms and research institutions develop their next gen technology niches – itself an initiative with potentially spiraling costs.

- **DECREASED STRATEGIC AUTONOMY AND CHANGING DEPENDENCE RELATIONSHIPS**
  Reducing exposure to specific vulnerabilities may require European governments to make long-term geopolitical choices in an increasingly bipolar technological order. Bandwagoning with one of the technopoles is a quick means of mitigating selected kill switch and/or chokepoint vulnerabilities, but comes at the cost of also limiting Europe's access to the other technopole's technologies and markets.[56] This would not necessarily increase dependence, but it would shift it. It could also potentially narrow Europe's technological, economic and political choices more broadly.

54 International Monetary Fund, Finland: Selected Issues, IMF Staff Country Report 2001, no. 215 (Washington, DC: International Monetary Fund, 2001), www.doi.org/10.5089/9781451813227.002; Edwin Lane, "Nokia: Life after the Fall of a Mobile Phone Giant," BBC News, March 18, 2016, accessed September 3, 2026, www.bbc.com/news/business-35807556; Ian Wylie, "Europe Lost Nokia. Finland Doesn't Want to Lose AI," Euractiv, June 11, 2026, accessed September 3, 2026, www.euractiv.com/news/europe-lost-nokia-finland-doesnt-want-to-lose-ai/.

55 Farrell and Newman, "Weaponized Interdependence."

56 Thorsten Benner and Jakob Hensing, "Das Paradox europäischer KI-Souveränität: Es gibt keinen realistischen Weg ohne die USA," Neue Zürcher Zeitung, July 21, 2026, accessed September 3, 2026, www.nzz.ch/meinung/das-paradox-europaeischer-ki-souveraenitaet-es-gibt-keinen-realistischen-weg-ohne-die-usa-ld.10013864.

APPLICABILITY ACROSS EUROPEAN CLUSTERS

As in the other prioritization packages, implementing this package will build on the strengths of the individual clusters. Post-industrial countries' research institutions and universities should develop the analytical and technological capabilities required to identify which kill switches and chokepoints to prioritize in the short term and to develop Europe's own chokepoints around next generation technologies in the long-term. Post-industrial countries must also use industrial policy to encourage corporate technology and investment decisions to focus on select areas, especially technologies that support state function and national security. Supply chain node governments should focus industrial policy measures on developing applications for European next generation and emerging technologies to secure economic and geopolitical advantages from future European chokepoints. They should also improve public-private sector coordination to ensure sufficient funding and rapid implementation of policy decisions.

Given the greater need for coordination in this package, particularly in identifying Europe's vulnerabilities, EU institutions also play a crucial role. Primary tasks include prioritizing strategic targets and missions, such as European Central Bank action to create and operate a digital Euro and the implementation of Program 30; ensuring financial and technical assistance is available to support each cluster achieving its targets; and coordinating existing measures to ensure national policies and implementation support the shared European goal of minimizing vulnerabilities.

FEASIBILITY

With the exception of decreasing European exposure via the Ireland effect, which is highly unlikely, this emergency approach is broadly consistent with measures that the EU has already adopted or is currently considering. The prioritization process would therefore be easier to implement because it could build on existing policies and instruments. Programs such as Horizon Europe, for example, could be directly linked to addressing strategic chokepoints and kill switches. However, Europe must significantly increase cross-European coordination to be successful. Some measures, such as establishing and implementing Program 30, will require centralized and consistent management at the European level. Quick action, which has sometimes proven challenging for European tech, will also be required.

Diversification

A final approach starts from the premise that Europe's long-term, structural dependence on both technopoles is a significant geopolitical risk (Figure 14). So too is Europe's excessive reliance on either China or the US for specific technologies and in specific sectors. For example, the DDI reveals a pronounced one-sided dependence on US digital platforms – which is now extending to AI foundation models – as well as on US cybersecurity expertise.[57] At the same time, the bilateral trade in ICT goods of most European countries remains heavily skewed towards China, even where their overall DDI score for ICT goods dependence is relatively low.[58]

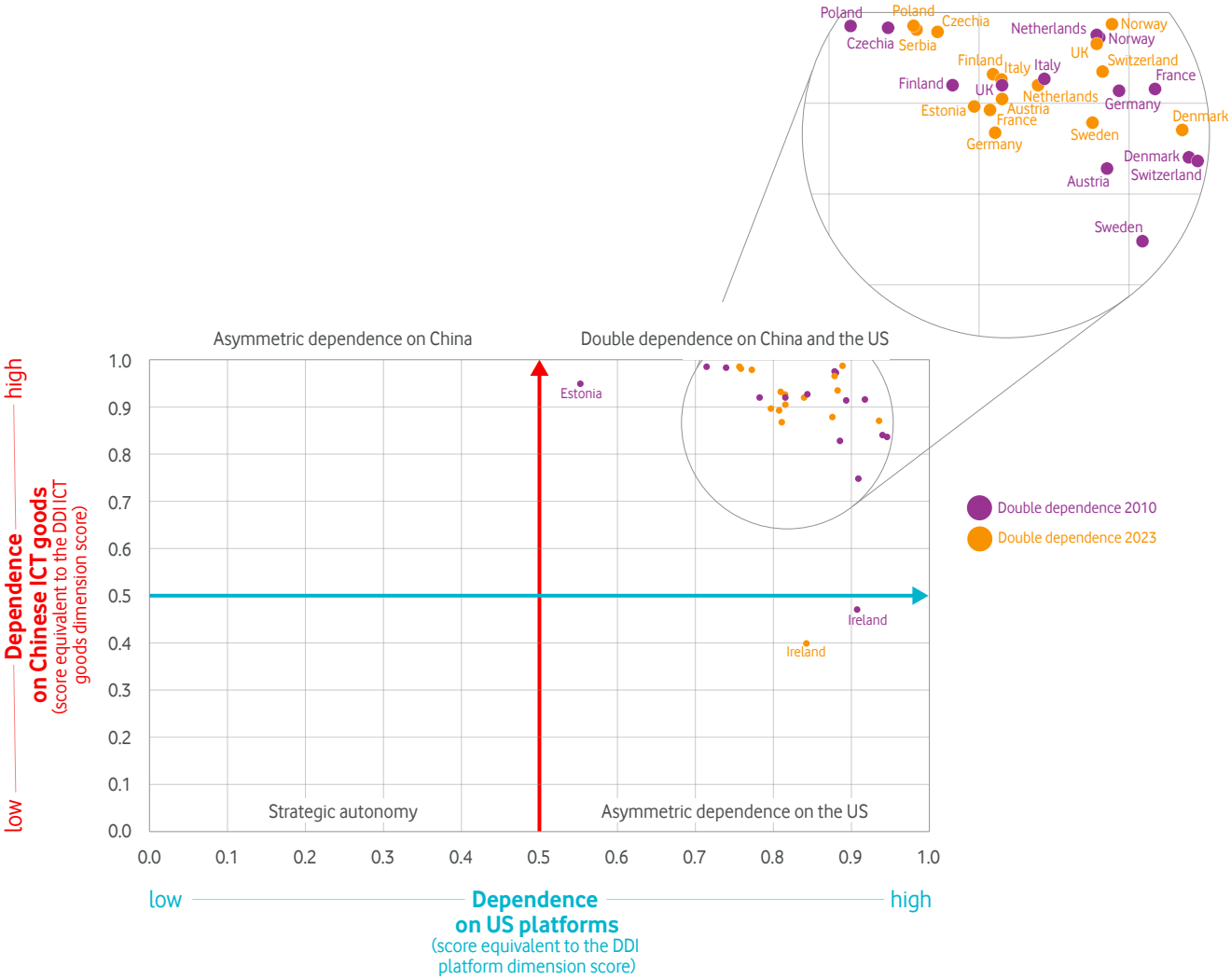


FIGURE 14

Double dependence structure of European countries over time

Illustrating dependence on Chinese ICT goods and US platforms. Bilateral dependence on Chinese ICT goods indicates trade relations between China and a selected country. Bilateral dependence on US platforms indicates the market shares of US platforms in a selected country. Both calculated using DDI formulas (see Appendix 1) based on the UNCTAD 2025, "ICT goods: Bilateral trade by category – Annual" and StatCounter datasets, respectively. Source: DDI

57 Vili Lehdonvirta, Boxi Wú, and Zoe Hawkins, "Weaponised Interdependence in a Bipolar World: How Economic Forces and Security Interests Shape the Global Reach of US and Chinese Cloud Data Centres," Review of International Political Economy 32, no. 5 (2025): 1442–1467, www.doi.org/10.1080/09692290.2025.2489077; Maximilian Mayer and Yen-Chi Lu, "Global Structures of Digital Dependence and the Rise of Technopoles," New Political Economy 30, no. 5 (2025): 755–774, www.doi.org/10.1080/13563467.2025.2497766; Karen Hao, Empire of AI: Inside the Reckless Race for Total Domination (London: Allen Lane, 2025).

58 Mayer et al., "Digital Trade Trap?"

Hence this prioritization package aims to achieve a more balanced distribution of technology partners while reducing asymmetric dependencies on a small number of suppliers wherever possible. Doing so could reshape Europe's digital dependence pattern in a way that strengthens European choice and strategic autonomy while mitigating bilateral asymmetries.

OVERARCHING OBJECTIVE

Combine trade, investment and anti-trust regulatory measures to partially replace existing sectoral and dimensional dependencies with ones better suited to preserving European digital autonomy and resilience.

POLICY PRIORITIES:

First, create new technology partnerships wherever possible. One strategy, known as "workarounding", uses small group, informal cooperations with other middle powers but without technopoles to develop independent technological capabilities and reduce dependence on Chinese ICT goods and US platforms.[59] Europe could workaround with East Asian countries such as Japan and Taiwan on semiconductors,[60] India on digital public infrastructure and e-governance systems, African partners on digital payment ecosystems, and South Korea and the Gulf states on developing alternative AI capabilities.[61] Doing so can help Europe achieve strategic goals with long-term implications for European sovereignty, such as an independent global payment network connecting the digital Euro and other national digital currencies which could not be disrupted, constrained, or instrumentalized by external powers. Workarounds additionally facilitate partnership and production networks that create economic opportunities for European businesses, enable European governments to co-shape governance and norms in emerging tech areas and help ensure the European workforce stays cutting-edge in key technological fields.[62]

Second, implement a "33% rule" as a new tenet of EU digital regulation to target technopole dependencies: non-technopole, preferably European, countries should control at least one-third of any strategically important market and critical infrastructure.[63] Symbolically, in a digital world dominated by two technopoles, the 33% rule preserves a third of the digital sphere for non-technopoles in line with diversification package priorities. Functionally, it requires Europe to reduce excessive reliance on dominant US platforms and infrastructure while facilitating the emergence of alternative providers. These alternatives should include both European solutions and trusted non-European providers, such as Asian or African platforms like Line, Kakao, Shopee and M-Pesa or AI models developed outside the US and Chinese ecosystems. It also requires European countries with high levels of dependence on high-risk vendors' 5G infrastructure to diversify their supplier base, transitioning toward a more balanced and resilient telecommunications ecosystem.

Third, significantly scale up Europe's existing but largely untapped potential in open-source software and open-source models across all layers of the digital ecosystem, drawing on recent French initiatives as practical examples.[64] Although this would not eliminate the outsized role major commercial technology companies

59 Mayer et al., eds., Workarounding.

60 Insisa, "Beyond the European Chips Act."

61 Mayer et al., eds., Workarounding.

62 Laura Mahrenbach, Gedaliah Afterman, Maximilian Mayer, and Narayanappa Janardhan, "Workarounding While the International Order Fractures," Quincy Institute for Responsible Statecraft, June 9, 2026, accessed September 3, 2026, www.quincyinst.org/research/workarounding-while-the-international-order-fractures/.

63 The 33% rule is one suggested policy priority based on the DDI evidence and its application in this scenario.

64 United Nations Office of Information and Communications Technology, "France Becomes First Government to Endorse UN Open Source Principles," May 6, 2025, accessed September 3, 2026, www.unite.un.org/en/news/france-becomes-first-government-endorse-un-open-source-principles.

play in Europe's digital ecosystem, it would strengthen the role of non-commercial technology providers, foundations, and open-source communities alongside them, integrating alternative viewpoints as ecosystems develop. This diversification, for instance in the form of public or non-commercial ownership of critical software ecosystems, would also be a key step in promoting digital autonomy.

Fourth, establish a new European Technology Evaluation and Cybersecurity Hub (E-TECH).[65] This center should operationalize expert assessments of emerging digital technologies, applications and standards, including quantum technologies and AI, to develop Europe-specific digital safety and security procedures that facilitate cyber resilience and defense. E-TECH should operate fully independently of both China and the US and should serve as a public resource for Europe and the wider global community. Doing so would not only improve European resilience. It would also promote Europe's reputation as a digital leader, provide a platform for identifying workarounding opportunities in the realm of cybersecurity and reinforce European support for digital technologies that support transparency and the common good.

EXPECTED OUTCOMES AND TRADE-OFFS

This approach would not reduce Europe's overall digital dependence but it would rebalance Europe's digital dependencies over time by creating new partnerships, developing European capabilities and facilitating alternatives to technopole platforms, services and infrastructure. Doing so should increase European resilience and help shape economic and technological ecosystems to prioritize long-term European gains over short-term functionality.

As with the other prioritization packages, diversification also entails trade-offs:

- **MORE COMPLICATED TECHNOPOLE MANAGEMENT**
  The 33% rule would constitute a significant market intervention and would almost certainly provoke strong pushback from both China and the US. Nevertheless, as in the supply chain node package, cooperation with both countries would and must continue. Managing these contrasting impulses could prove complicated.

- **DIFFICULTY ADDRESSING SOME DEPENDENCE CHALLENGES**
  Reshoring production from China does not address hidden dependencies on Chinese firms operating through third countries, meaning that apparent diversification does not necessarily translate into genuine strategic autonomy. Similarly, ecosystem diversification and a push for open source does not address Europe's declining digital patent activity, meaning European firms will remain dependent on digital IP developed in East Asia and the US and face higher costs, rather than reaping higher profits, in the long term.[66]

- **INCREASED FINANCIAL AND COORDINATION COSTS**
  Workarounding offers great potential but also requires a relatively greater investment of human and financial resources in diplomatic and governance coordination. The lack of certainty implicit in flexible cooperation may limit governments' willingness to invest these resources.[67] And those costs may be both geopolitical and financial if workarounding fails, not only failing to reach targeted goals but also alienating technopole partners in the process.

65 The European Technology Evaluation and Cybersecurity Hub is one suggested policy priority based on the DDI evidence and its application in this scenario.

66 Mahrenbach et al., "Digital Patent Decline."

67 Kernaghan Webb, "Do Middle Powers Need a Room of Their Own?", Centre for International Governance Innovation, August 2026, accessed online September 3, 2026, www.cigionline.org/articles/do-middle-powers-need-a-room-of-their-own/.

APPLICABILITY ACROSS EUROPEAN CLUSTERS

Overall, there are no major differences in how this policy would apply across European clusters. Countries in all clusters must comply with the 33% rule and avoid creating new asymmetric dependencies – particularly with technopoles – as they diversify supply chains. However, the post-industrial cluster faces a comparatively greater challenge because of its higher dependence on ICT imports and its extensive reliance on Chinese components. As a result, diversification will require more substantial adjustments in these countries.

FEASIBILITY

This approach would require a fundamental shift in the EU's regulatory framework and underlying governance logic as well as a substantial reconfiguration of its relationships with both China and the US, convincing both sides that Europe is capable of and committed to a more independent strategic course. As in the technopole imitation package, diversification also necessitates Europe develop a new public vision for its technological future. This is not only necessary to cultivate public support for the transition to open source and non-technopole technologies, itself a significant disruption to the digital status quo. It is also necessary to encourage people to adopt non-technopole and especially European technologies and promote achieving a more technologically sovereign status for Europe. Strong political leadership and a compelling strategic narrative must be advanced aggressively by national governments and in Brussels to achieve these goals.

Conclusions and policy recommendations for Europe

Europe can no longer avoid making several critical strategic choices about digital resilience, economic development, and its technopolitical positioning. Those decisions will shape European economic, technological and geopolitical opportunities for years to come. To make informed decisions and get Europe's strategic priorities right, a better understanding of Europe's digital dependencies and related trade-offs is critical.

The Digital Dependence Index steps into this gap, providing systematic, nuanced, comparable evidence for 51 countries over the past 14 years, including for 16 European countries. Building on analysis of this data, we have developed four prioritization packages aimed at reducing either digital dependencies or the vulnerabilities associated with them. All prioritization packages require multiple, coordinated actions over the short-, medium- and long-term time frames. All four also aim to build on the divergent strengths of different European countries.

To begin, European policymakers must recognize that Europe's levels of digital dependence are already higher than many world regions – and in many countries digital dependence is increasing. Simultaneously, European states present evolving and distinct digital dependence profiles, with most clustered in the post-industrial and supply chain node clusters as of 2023. This demonstrates that neither levels nor patterns of digital dependence are fixed. As a result, policy choices can significantly shape digital trajectories.

Yet this nuanced analysis also shows that there is no one-size-fits-all strategy for reducing digital dependencies. Different dependence clusters illustrate distinct strengths and weaknesses and may require different approaches to alleviate related vulnerabilities. As state actions diverge, Europe-wide coordination mechanisms will be essential for ensuring national and regional policies support one another and are aligned to achieve Europe's shared strategic priorities.

Choosing shared strategic priorities is a key first step in moving beyond the current business-as-usual approach, which undermines Europe's geopolitical leverage while doing little to improve Europe's technological and economic opportunities. The four prioritization packages presented here provide data-driven alternatives to sidestep such hazards. Technopole imitation is the most ambitious package, requiring the greatest levels of investment, sustained political commitment, and far-reaching institutional reform. Supply chain node replication is more feasible, building on existing European policies and platforms, but it is also ambitious in its financial basis and required time commitments. Vulnerability minimiza-

tion is an emergency approach: while it also builds on existing digital policies and platforms and is less transformative than other packages, it nonetheless requires a substantial increase in coordination and quick action, both of which could prove challenging. Finally, the diversification package is more incremental but requires unity of both purpose and narrative to ensure sufficient public support and mediate technopole backlash.

Importantly, the prioritization packages are not mutually exclusive. Some packages are complementary and could be pursued in combination. For example, the supply chain node replication package could easily be paired with either the diversification or vulnerability minimization packages.

To chart a new course, Europe must refine its technocratic statecraft, combining strong political commitment, a culture of learning, and strategic direction at the highest levels of decision-making with a bureaucracy capable of maintaining long-term focus, coordination, and implementation. The importance of coordination is, notwithstanding insights of the Draghi Report,[68] still consistently underestimated for securing Europe's future opportunities. Yet it is crucial for ensuring digital dependence policy responses are sequenced in a way that facilitates success.

Another central component should be the creation of more flexible and effective government–industry partnerships within a renewed – and flexible – framework for technology governance. Doing so can help Europe secure the international technology partnerships it needs in all prioritization packages. Managing and deepening partnerships via concrete joint missions can contribute directly to reducing Europe's digital dependencies while also strengthening long-term trust. This will be especially important in implementing the diversification and the supply chain node replication packages.

Finally, each prioritization package requires a different vision of Europe's technological future and its place in the global innovation system and geopolitical constellations. Improved digital resilience relies not only on technocratic implementation but also on public debate and political imagination. Europe needs a compelling, forward-looking narrative that articulates the kind of innovative and autonomous society it wants to become. Such a narrative must be communicated effectively to mobilize support among citizens, communities, businesses and researchers for a digital trajectory that reduces Europe's digital dependencies while reshaping its societal and political future.

68 Mario Draghi, The Future of European Competitiveness: A Competitiveness Strategy for Europe (European Commission, September 9, 2024), www.commission.europa.eu/topics/competitiveness/draghi-report_en.

Appendix 1: DDI index construction

The Digital Dependence Index (DDI) offers a comprehensive, evidence-based, and comparative quantitative assessment for measuring and comparing the degree of digital dependencies across 51 countries between 2010 and 2023. It encompasses a broad range of digital technologies that serve as the backbone of the global digital economy, including digital hardware, software, platforms, and ICT patents. This technical note explains how we calculated the DDI.

In this study, digital dependence refers to the extent to which actors in a particular country must rely on foreign-supplied digital technologies to perform digital activities. The DDI understands digital dependence as a multidimensional phenomenon reflecting the extent to which national economies rely on digital inputs from abroad. DDI values reflect changes in national policies, strategies, and economic choices that increase or reduce a country's digital dependence.[69] The index can consequently be used to systematically and quantitatively assess how digital dependence evolves over time for countries at all levels of economic and technological development.

Key advantages include:

- **MULTIDIMENSIONAL COVERAGE**
  The DDI captures key factors shaping national digital ecosystems, including digital goods and services trade, platforms and patents.

- **CLEAR AND TRANSPARENT METHODOLOGY**
  The DDI uses clearly defined indicators and standardized data from well-established, publicly available sources.

- **CONSISTENT MONITORING OVER TIME**
  The DDI tracks changes in the same digital dependence dimensions annually over fourteen years.

- **CROSS-COUNTRY COMPARISON**
  The DDI provides a systematic framework for comparing digital dependence across countries.

69 See Mayer, M., & Lu, Y. C. (2025). Global structures of digital dependence and the rise of technopoles. New Political Economy, 30(5), 755–774. www.doi.org/10.1080/13563467.2025.2497766

DDI structure, components and data sources

The DDI measures dependence on a scale from 0 (total independence) to 1 (total dependence). It comprises four complementary dimensions and 23 related indicators:

- **TRADE IN ICT GOODS**
  - Indicators: Computers and peripheral equipment; communication equipment; consumer electronic equipment; electronic components; miscellaneous
  - Data source: UNCTAD Data Centre

- **TRADE IN ICT SERVICES**
  - Indicators: Telecommunications services; computer software; computer services; computer software licenses
  - Data source: UNCTAD Data Centre

- **PLATFORMS**
  - Indicators: Browsers; search engines; desktop operating systems (OS); mobile OS; social media; smartphones; tablets
  - Data source: Statcounter GlobalStats

- **ICT PATENTS**
  - Indicators: Audio-visual technology; telecommunications; digital communication; basic communication processes; computer technology; IT management methods; semiconductors
  - Data source: WIPO IP Statistics Data Center

This complexity adds nuance to existing understandings of digital dependence. For instance, the DDI shows countries may be highly dependent on different dimensions, and that high dependence on a single channel does not necessarily imply deep or systemic digital dependence overall.

Limitations

Like all indices, the DDI also has certain limitations:

- **AGGREGATE NATURE OF THE INDEX**
  The DDI measures a country's reliance on the global digital economy rather than its economic performance, competitiveness, or vulnerability. As a result, it does not cover all areas of the economy nor does it cover disparities in sectors, companies, and industries within a country.

- **EQUAL WEIGHTING**
  The index assumes all four dimensions are weighted equally.

- **DATA LIMITATIONS**
  Some relevant factors cannot currently be included as comparable and publicly available data are limited. Some examples include data centers, cloud services, large language models (LLM), and cybersecurity capabilities.

These limitations mean that the index is best used alongside complementary quantitative and qualitative approaches, such as bilateral trade, supply chain analysis, and sector-specific assessments. The DDI can also be combined with other methodologies, such as stack, supply chain and sectoral analysis, to gain a more comprehensive understanding of dependencies, interconnections and dynamics.

Calculation

Digital dependence was calculated in three steps.

STEP 1: ESTIMATING DIGITAL DEPENDENCE ALONG THE DDI DIMENSIONS

The DDI dimension scores reflect a country's amount of foreign-supplied digital hardware, software, platform, or ICT patents relative to that state's total demand for digital technologies (see equations below). Digital dependence for each dimension was calculated as the arithmetic mean of all indicators within that dimension. Calculating the arithmetic mean aggregates the indicators by assigning an equal weight to each indicator. This ensures that no individual indicator distorts the dimension-level measure.

The calculations were performed as follows:

ICT goods indicators, measured in millions USD at current prices for each year in the period 2010-2023:

$$\text{Indicator score in ICT goods} = \frac{\text{Total ICT goods imports}}{\text{Sum of total ICT goods exports and imports}}$$

Platform indicators, measured in market share calculated by Statcounter based on website page views:[70]

$$\text{Indicator score in platforms} = \frac{\text{Total market share of foreign platform companies}}{\text{Total market share of foreign and domestic platform companies}}$$

ICT patent indicators:[71]

$$\text{Indicator score in ICT patents} = 1 - \frac{\text{Total number of granted ICT patents owned by domestic entities globally}}{\text{Total number of granted ICT patents globally}}$$

Modifications were necessary when calculating the ICT services dimension score due to the nature of the ICT services data. While that data does represent all ICT services indicators, it does not provide export and import data by indicator. As a result, we calculated a dimension score rather than an indicator score, with values measured in millions USD at current prices for each year in the period 2010-2023:

$$\text{Indicator score in ICT services} = \frac{\text{Total ICT services imports}}{\text{Sum of total ICT services exports and imports}}$$

MISSING DATA IMPUTATION

Missing observations for ICT goods and services trade were replaced using three methods. First, gaps of up to three consecutive years were estimated using Holt–Winters exponential smoothing based on available historical country data. Second, where data gaps exceed three consecutive years, missing values are imputed using the average trade value of comparable countries in the same geographic region. Finally, no ICT services data was available from the UNCTAD

70 Statcounter GlobalStats, "What methodology is used to calculate Statcounter Global Stats?", 2026, www.gs.statcounter.com/faq" \l"methodology.

71 This calculation includes patents granted by any patent office included in the WIPO dataset

dataset for Qatar, Saudi Arabia, South Africa, and Switzerland. After researching available proxy datasets, we proxied these values from UNCTAD's Digitally Deliverable Services data to avoid excessive imputation. Full comparability can consequently not be assured, so please understand these values as indicators of trends rather than precise quantitative measures aligned with the other DDI scores.

STEP 2: CREATING THE DIMENSION INDICES

The value of digital dependence in a given dimension was normalized using minimum and maximum values, or goalposts, that reflect historical evidence for each dimension.[72] These goalposts represent "the natural zero" and maximum value of digital dependence, corresponding to conditions of autarky (i.e. complete digital independence) and absolute digital dependence, respectively, and map onto DDI values of 0 and 1. Historically, absolute digital dependence has occurred in all four dimensions.[73] However, countries have never achieved complete digital independence in the dimensions of ICT goods and ICT patents. Rather, the historical minimum values of digital independence were 0.10 for ICT goods and 0.05 for ICT patents.[74] These minimum values were therefore set as the new zero points in the normalized digital indices for these two dimensions, as shown in Table 1.

Dimension indicators	Minimum	Maximum
Trade in ICT goods	0.10 (as the new zero)	1
Trade in ICT services	0	1
Platforms	0	1
ICT patents	0.05 (as the new zero)	1

TABLE A.1
DDI GOALPOSTS

Having defined these minimum and maximum values, the DDI dimension indices were calculated using the following equation:

$$\text{Dimension index} = \frac{\text{Actual value of dimension indicator in a given year} - \text{Indicator minimum value}}{\text{Indicator maximum value} - \text{Indicator minimum value}}$$

STEP 3: AGGREGATING THE DIMENSIONS

The overall DDI score for a given year is calculated as the geometric mean of the four dimension indices for that year:

$$\text{DDI} = (I_{ICT\ goods} \cdot I_{ICT\ services} \cdot I_{ICT\ platforms} \cdot I_{ICT\ patents})^{1/4}$$

The DDI uses the geometric mean to limit substitutability between its dimensions, with each dimension receiving the same weight in the overall index. Unlike the arithmetic mean, the geometric mean limits the extent to which a very high value in one dimension can compensate for a very low value in another. This is particularly important for measuring digital dependence, as low dependence in one dimension should not fully offset substantial dependence in another. Using the geometric mean consequently ensures a more balanced and meaningful representation of a country's overall digital dependence.

72 The historical context is necessary to ensure the index reflects real-world values for digital dependence. The historical data was collected from the same sources which provided the DDI index data.

73 Historical data for goods and services taken from UNCTADstat, 2026, www.unctadstat.unctad.org/EN/Index.html. Historical data for patents retrieved from Claude Diebolt and Karine Pellier, "Patents in the Long Run: Theory, History and Statistics", 2018, Association Francaise de Cliométrie Working Paper Number 3; and Claude Diebolt and Karine Pellier, La Cliométrie du brevet, Rapport de recherche: Projet Exploratoire / Premier Soutien (PEPS) du CNRS, 2010. Historical data for platforms taken from Statcounter GlobalStats, 2026, www.gs.statcounter.com/.

74 UNCTADstat, 2026 and Diebolt and Pellier, 2018.

Cutoff points for levels of digital dependence

Based on the digital dependence trends identified in the data, we identified three natural thresholds of digital dependence:

- **LOW DEPENDENCE** DDI value between 0.35 and 0.57
- **MEDIUM DEPENDENCE** DDI value between 0.57 and 0.83
- **HIGH DEPENDENCE** DDI value between 0.83 and 1.00

As is evident in the policy study (see Figure 5), most countries fall into the medium dependence category.

Appendix 2: Principal component and cluster analyses

There are various ways to classify countries according to their economic and technological features.[75] Our analysis combines two widely used multivariate analysis techniques – principal component analysis (PCA) and cluster analysis – with the multidimensional DDI variables. Doing so provides complementary perspectives on digital dependence, helping to capture aspects of this phenomenon that may not be fully reflected by any single method. Specifically, PCA helps reduce the information contained in several indicators into a smaller number of dimensions while cluster analysis groups countries with similar characteristics.

This appendix provides a brief overview of how we employed both methodological approaches to identify the clusters discussed in this study. The clusters reflect interrelationships among the multidimensional DDI variables across technological domains and can consequently be used to examine how these relationships differ across distinct groups of countries and over time.

Principal component analysis

PCA is a statistical method that reduces the number of variables in a large dataset by identifying a (smaller) number of principal components, that collectively preserve most of the information contained in the original variables.[76] PCA produces a rotated component-loading matrix, which reorganizes the component structure into a simple structure. Component loadings indicate the strength and direction of the association between each original variable and each component. They range from -1 to +1. Higher loading values indicate a stronger association, whereas values close to zero indicate a weaker association. Higher absolute loading values therefore help identify the variables that are most relevant to the interpretation of each component.[77]

DATA SELECTION

The analysis includes 20 indicators covering four dimensions – ICT goods, ICT services, platforms and ICT patents – for a sample of 51 countries across four periods (2010, 2015, 2019 and 2023). Although the selection of the periods is partly arbitrary, it generally aims to assess the long-term stability of the system while taking into account key economic and geopolitical turning points. These include:

75 Other multivariate methods, such as network analysis and regression models, can also be used to study relationships between countries and variables. However, they are not primarily designated to classify countries into groups according to their similarities and were therefore less useful for this study.

76 Ian T. Jolliffe and Jorge Cadima, Principal Component Analysis: A Review and Recent Developments, Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 374 , no. 2065(2016): 1-16.

77 Joseph F. Hair, William C. Black, Barry J. Babin, and Rolph E. Anderson, Multivariate Data Analysis. 8th Edition, 2018, Cengage Learning, London.

- **2010** The year following the 2008-09 global financial crisis
- **2015** A turning point associated with the end of the 2000s commodity super-cycle[78]
- **2019** The year when the US formally designated China a strategic competitor[79]
- **2023** The most recent year for which information is available as well as one reflecting the post-pandemic global economy

KAISER–MEYER–OLKIN (KMO) TEST

Our sample selection aims to maximize data availability while avoiding redundant information, particularly since the data were previously standardized. The test of Kaiser–Meyer–Olkin (KMO) assesses whether a sample size is adequate for dimension reduction, such as PCA. The KMO statistic ranges from 0 to 1, with values above 0.5 considered generally acceptable.[80] In our selected years, KMO values are between 0.7 and 0.8, indicating good sampling adequacy.

BARTLETT'S TEST OF SPHERICITY

This test assesses whether the correlations between our variables are sufficiently large to justify applying a dimension-reduction technique. A statically significant result of ($p < 0.05$) indicates that the correlation matrix differs significantly from an identity matrix, meaning that the variables are sufficiently correlated to proceed with the analysis.[81] For all selected years in our sample, Bartlett's test is highly statistically significant ($p < 0.001$). This confirms the existence of sufficient correlations among the variables and the feasibility of using data reduction techniques.

COMPONENT IDENTIFICATION AND EXTRACTION

A principal component analysis with varimax orthogonal rotation was performed to identify underlying components. The number of components retained was determined by their contribution to the total variance explained.

- **2010** Four main components were extracted, jointly explaining 81% of the cumulative variance. These components included variables from all four original dimensions: ICT goods, ICT services, ICT patents and platforms.

- **2015** Four main components were extracted. These include ICT goods, ICT patents, and two platform-related components (smartphones, remaining platform indicators).

- **2019** Four main components were extracted. These include ICT patents, platforms and two ICT goods groups (electric components, remaining ICT goods).

- **2023** Three components were identified. These broadly correspond to ICT goods, platforms and ICT patents.

78 The Commodities Supercycle's End and Political Risk, Strategic Comments 22, no. 2(2016): i–ii.

79 Suisheng Zhao, The Rise and Fall of a New Cold War: The US–China Great Power Rivalry from President Trump I to II, Journal of Contemporary China, Latest articles (2026): 1–18.

80 Hair et al., Multivariate Data Analysis

81 Hair et al., Multivariate Data Analysis

As is evident, starting in 2015, ICT services were no longer retained as part of the reduced set of variables. This does not necessarily imply that ICT services are unimportant. Rather, PCA selects the linear combinations of the original indicators which account for the greatest share of the variance in the data. An indicator may therefore make a relatively limited contribution to the retained components when its information overlaps with that provided by other indicators.

Cluster analysis

The cluster analysis groups countries according to similarities across the main dimensions identified in the data (see PCA above), while reducing the influence of highly correlated individual indicators. The resulting clusters should therefore be understood as empirical groupings based on reduced components rather than as fixed or exhaustive classification of countries. The cluster analysis was conducted using the k-means method, a non-hierarchical (partitional) clustering algorithm.

INPUTTING THE TARGET NUMBER OF CLUSTERS

Originally developed by James MacQueen in 1967, k-means partitions a given data set (x_i, i=1...n) into a prespecified number (k) of clusters.[82] A key feature of the k-means method is that the number of clusters must be specified in advance. This means the method is sensitive to the choice of initial cluster centroids. To address this issue, our analysis tested different initializations and solutions to identify groupings that were both interpretable and stable over time. We subsequently selected the six-cluster solution as the most appropriate, given its greater stability over time and its ability to produce balanced country groupings.

IDENTIFYING CLUSTERS

We use k-means clustering to group countries with similar characteristics. The algorithm first selects a set of initial cluster centers (centroids). Each country is then assigned to the cluster whose center is closest to it. The center of each cluster subsequently recalculated based on the countries assigned to it. These two steps (assigning countries to clusters and recalculating the cluster centers) are repeated until the cluster assignments become stable.

The objective of k-means clustering is to create groups in which countries are as similar as possible to one another and as different as possible from countries in another groups. More formally, the algorithm minimizes the sum of squared Euclidean distances between each observation and the centroid of the cluster to which it belongs:

$$f(K) = \sum_k \sum_{m \in k}^{n} \sum_j (x_{mj} - \mu_{kj})^2 \rightarrow \min.$$

In simple terms, the algorithm searches for the configuration of clusters in which countries are, on average, as close as possible to the center of their respective cluster.

82 James MacQueen, "Some Methods for Classification and Analysis of Multivariate Observations", Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability, Volume 1: Statistics, University of California Press, 1967, 281-297.

Because Euclidean distance is sensitive to differences in scale, all variables are standardized prior to clustering. This prevents variables measured on different scales from having a disproportionate influence on the resulting cluster assignments.

ADVANTAGES AND LIMITATIONS OF K-MEANS CLUSTERING

Compared with conventional hierarchical clustering techniques, non-hierarchical clustering using k-means has several advantages. These include that k-means clustering is better suited to working with relatively large data sets when compared to other techniques and that it allows the degree of clustering observed in the actual data to be compared with that obtained from comparable randomized data.

However, it also possesses certain limitations. K-means can be sensitive to outliers and to the initial specification of cluster centers. Different initial settings may therefore produce different cluster solutions. To address this issue, we tested several cluster configurations and compared the results to identify the solution that was most appropriate for the objectives and characteristics of our study.

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PUBLISHER
University of Bonn
Regina-Pacis-Weg 3
53113 Bonn, Germany
Executing entity: Institute for Political Science, CASSIS

IN COOPERATION WITH
Vodafone Institute for Society and Communications

EXECUTING ENTITY
Center for Advanced Security
Strategic and Integration Studies (CASSIS)

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The authors would like to thank the additional members of the University of Bonn/CASSIS team for their assistance in preparing this brief, especially Johannes Doerfert and Liang Geng. We would also like to thank Simona Autolitano, Cindy Cheng, Nina Frahm, Kunhan Li, Hendrik Ohnesorge, Caja Thimm, Paul Timmers and the Vodafone Institute team for their valuable input and interesting discussions while preparing the brief.

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October 2026

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Vodafone Institute for Society and Communications