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# The Global 5G/6G Race

## REGULATION, MARKETS, AND INNOVATION DYNAMICS

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## Abstract

This report examines the global race for 5G and 6G leadership through a comparative analysis of regulation, R&D investment, patenting, and the rollout of next-generation networks and services across Europe, the United States, and Asia. The United States leads in digital services and semiconductors, while Asia dominates telecommunications infrastructure and hardware. Europe's strengths lie in telecom equipment and specific semiconductor niches but remain too narrow to offset weaknesses in digital platforms and data-driven services. Patent data highlight Asia's stronger position in 5G technologies, while R&D spending confirms U.S. leadership in areas less visible in patent counts yet vital for long-term innovation and value creation. Europe performs relatively well in 5G network deployment and services in some member states but lacks the scale in digital services and innovation ecosystems needed for global leadership.

The EU's comprehensive digital regulation has particularly strengthened privacy protection but risks constraining innovation. To remain a meaningful player in the 6G era, Europe must align its regulatory ambitions with its production and innovation capacities and its investment incentives. Without such recalibration, well-intentioned regulation may ultimately erode the competitiveness it seeks to protect.

# Tiivistelmä

## Globaali 5G/6G-kilpailu: sääntely, markkinat ja innovaatiot

Raportti tarkastelee globaalia 5G- ja 6G-kilpailua vertailemalla sääntelyä, t&k-investointeja, patentointia sekä uuden sukupolven verkkojen ja palvelujen käyttöönottoa Euroopassa, Yhdysvalloissa ja Aasiassa. Yhdysvallat johtaa digipalveluissa ja puolijohteissa, kun taas Aasia hallitsee televiestintäinfrastruktuuria ja laitteistoja. Euroopan vahvuudet painottuvat televiestintälaitteisiin ja puolijohteiden erikoisalueisiin, mutta nämä ovat liian kapeita kompensoimaan heikkouksia digialustoissa ja datavetoisissa palveluissa. Patenttidata vahvistaa Aasian aseman 5G-teknologioissa, kun taas t&k-panostukset korostavat Yhdysvaltojen johtajuutta aloilla, jotka eivät näy patenteissa mutta ovat keskeisiä pitkän aikavälin innovoinnille ja arvonluonnille. Eurooppa menestyy kohtuullisesti 5G-verkkojen käyttöönotossa ja palveluissa, mutta siltä puuttuu digitaalisten palvelujen ja innovaatioekosysteemien mittakaava, joka on edellytys globaalille johtajuudelle.

EU:n digitaalinen sääntelykehys on vahvistanut erityisesti yksityisyydensuojaa, mutta voi myös rajoittaa innovaatioita. Säilyttääkseen merkittävän aseman 6G-aikakaudella Euroopan on sovitettava sääntelynsä paremmin yhteen tuotanto- ja innovaatiokyvykkyyksien sekä investointikannustimien kanssa. Ilman tätä sääntely voi lopulta heikentää juuri sitä kilpailukykyä, jota se pyrkii suojaamaan.

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**Keywords:** 5G, 6G, Global markets, Regulation, Innovation capabilities, Patents, R&D

**Avainsanat:** 5G, 6G, Globaalit markkinat, Sääntely, Innovaatiokyvykkyydet, Patentit, T&k

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# Contents

# 1 Introduction

The emergence of 5G and the anticipated transition to 6G mark a new phase in global digital transformation. These technologies require large-scale infrastructure, integration of data-intensive services, and robust frameworks for security and trust. As Bauer & Bohlin (2022) demonstrates, policy choices in licensing, market design and obligations profoundly influence the pace and direction of innovation in 5G markets. Consequently, regulation has become a defining feature of the 5G/6G landscape, influencing competition, investment decisions, and innovation, while also reflecting broader societal objectives such as security, sovereignty, and consumer protection.

This report provides a comparative examination of regulatory approaches across domains central to next-generation networks. It considers briefly infrastructure and security regulation, rules governing digital services trade, and the broader set of digital regulations addressing data, platforms, and artificial intelligence. The focus is on the European Union, the United States, and Asia, with particular attention to China. Rather than offering causal explanations, the report maps the diversity of regulatory frameworks and situates them in the context of mobile ecosystem development. By highlighting similarities and divergences across regions, it shows how different governance models reflect varying priorities — from openness and competition to sovereignty and trust — and how these choices shape the environments in which 5G and 6G technologies are being deployed.

Beyond regulatory frameworks, the report examines technological leadership as a defining factor in the global race for 5G and 6G. In this report, the global 5G/6G race and related notions of leadership are understood broadly. They refer not only to the rollout of network infrastructure but also to the competition over the technologies, standards, and services that these networks enable. Leadership in 5G/6G therefore encompasses the ability to shape and capture value across the entire connectivity-driven ecosystem.

We use research and development (R&D) investments and standard essential patenting data to assess technological advantage across four regions: the European Union, the United States, China, and other parts of Asia. R&D data complements SEP counts by capturing the scale of resources committed to technological development, whereas SEPs indicate which innovations become embedded in global standards. While SEP counts are imperfect indicators of technological leadership and have been critiqued as noisy and prone to bias (Teece, 2021), when considered together with R&D investments they remain among the best available metrics for assessing contributions to the development of foundational technologies. Recent research further shows that 5G technology development rests not only on patents but also on scientific publications and standard contributions, with front-runner firms typically active across all three domains (Buggenhagen & Blind, 2022).

In contrast to earlier studies, which typically identified both the United States and Asia as leading centers of 5G patenting (Noble et al., 2019; Pohlmann et al., 2020; Parcu et al., 2022), our updated analysis highlights an even stronger dominance of Asia in the SEP landscape. As of October 2024, nearly 70% of the top 50 SEP-owning firms were located in China and other parts of Asia. The United States, by contrast, appears weaker in SEP-based measures, reflecting the fact that its global leadership in digital services, clearly visible in R&D investments, translates only marginally into 5G patenting, since software and platform innovations generate relatively fewer SEPs. By combining SEP and R&D indicators across four technology domains (i.e., telecom infrastructure, digital services, hardware and components, and semiconductors) our approach provides a more granular and timelier picture of technological leadership. It highlights how U.S. strengths are concentrated in digital services and semiconductors, Asia dominates patenting in infrastructure and hardware, and Europe remains broadly represented across domains but lacks a clear specialization capable of sustaining global leadership.

Taken together, the report offers an integrated view of how governance models, innovation trajectories, and industrial capabilities interact to shape Europe's comparative position vis-à-vis the United States and Asia in the emerging 6G era.

# 2 Regulation

Regulation may affect competition, resource allocation, and market efficiency either positively or negatively. In the context of 5G and 6G, these dynamics are particularly important because the technologies rely on large-scale infrastructure investments and the intensive use of both personal and industrial data. Strict regulations may slow the market entry of new firms, reduce competitive pressure, and hinder innovation, potentially delaying network deployment and the growth of data-driven markets. Conversely, pro-competition regulation can encourage companies to optimize their operations, invest in advanced technologies, and develop innovative applications, thereby fostering the expansion of digital markets and the efficient use of data across the economy.

## 2.1 Infrastructure regulation and security

Infrastructure regulation and security form the foundation for 5G and 6G deployment. Choices in spectrum policy, competition rules, and interoperability have historically determined how robust and competitive infrastructures evolve. While these dimensions are crucial, they have already been examined extensively in contemporary comparative studies (Bauer & Bohlin, 2022; Ali-Vehmas, 2025). This section therefore provides only a brief overview, focusing on key regulatory contrasts across the EU, the United States, and China.

Table 1 summarizes these differences. Spectrum management illustrates the contrast between market-led and state-led models: in the EU, spectrum bands are harmonized at the European level, but auctions are organized by national regulators, often with coverage obligations to ensure balanced deployment. The United States relies on FCC-led auctions, where spectrum is allocated to the highest bidders with fewer coverage obligations, resulting in faster rollouts but uneven rural access. China, by contrast, allocates frequencies directly to state-owned operators, enabling rapid deployment but limiting competition and market entry.

Security regulation has become increasingly geopolitical. The EU has adopted the *5G Toolbox*, which sets common principles for risk assessment and vendor diversi-

**Table 1 5G infrastructure regulation in EU, United States and China**

| Category | EU | China | USA |
|---|---|---|---|
| Spectrum Policy | National auctions, EU-level coordination of frequency bands | Centrally managed, state-led allocation | FCC-led market-based auctions |
| Security | 5G Cybersecurity Toolbox, restrictions on high-risk vendors (no uniform Huawei ban) | Strong government oversight, restrictions on foreign vendors | Legislative and regulatory bans on Chinese vendors (Huawei, ZTE) |
| Network Deployment | Coverage obligations, Slower due to regulation and permit processes | Accelerated rollout with government support and coordination | Fast private rollout in dense areas; uneven coverage in rural regions |
| Net Neutrality | Strict rules, strong data protection | No net neutrality; extensive content filtering and censorship | Net neutrality repealed |
| Competition | Pro-competition framework, yet markets remain concentrated | State-led operators, limited competition | Competitive but highly concentrated market dominated by a few large players |

**Source:** Authors' own compilation.

fication, resulting in partial restrictions on Huawei and other high-risk vendors (European Commission, 2020). Implementation, however, varies across member states. Finland has taken a relatively moderate approach, focusing on risk management and multi-vendor strategies rather than outright bans. By contrast, Sweden has adopted one of the strictest interpretations, imposing a full ban on Huawei and ZTE equipment in both core and radio networks. The United States has gone further with a nationwide ban on Chinese vendors. China, in turn, maintains comprehensive state oversight of operators and infrastructure, embedding security regulation within broader industrial and political control. These differences highlight how infrastructure regulation is no longer just a technical matter but part of a wider contest over trust, sovereignty, and technological leadership.

Differences are also evident in the regulation concerning network deployment. The EU combines coverage obligations, which ensures more balanced access across regions but slows down rollout speed. The United States has seen rapid private deployment driven by market incentives, but this has resulted in uneven coverage and persistent rural–urban gaps. China's state-led model, with substantial government support, has enabled one of the fastest and most comprehensive 5G rollouts worldwide.

Finally, net neutrality rules affect how infrastructures are used once deployed. The EU enforces strict non-discrimination in traffic management, combined with strong data protection rules under the GDPR. The United States repealed federal net neutrality obligations in 2017, allowing operators more freedom to manage traffic. China, in turn, does not enforce net neutrality and maintains extensive state control over online content. These divergent approaches shape the openness and perceived trustworthiness of digital infrastructures in each region.

Competition policy forms a core dimension of infrastructure regulation. In the EU, the regulatory framework promotes competition through network access and sharing rules, ensuring that smaller operators can use incumbent infrastructure. However, national markets remain concentrated, typically dominated by three major operators. In the United States, competition is market-driven and dynamic but structurally concentrated among a few nationwide carriers. In China, the state controls all major operators, and market entry is limited. These variations illustrate how infrastructure competition depends not only on market forces but also on regulatory design.

While competition is an integral part of infrastructure regulation, broader market structures and regulatory conditions affecting digital trade and data flows are examined in Section 2.2 using the OECD Digital STRI indicators.

## 2.2 Digital services trade regulation

Differences in mobile infrastructure and digital trade regulations across Finland, the EU, the United States, and China in 2024 were analyzed using the OECD Digital Services Trade Restrictiveness Index (Digital STRI). These indices are designed to identify and measure trade barriers in a comparable manner across countries, providing insights, for instance, into regulatory constraints affecting mobile infrastructure development, digital services and cross-border data flows. These indicators are highly relevant for 5G and 6G, since mobile infrastructure deployment, competition conditions, and restrictions on the use of personal data directly affect the cost, speed, and scope of next-generation network rollouts and services.

We formulated various composite indicators to measure different aspects of digital regulation, including Mobile Infrastructure Regulation, Mobile Market Concentration, Restricted Personal Data Transfer, Market Entry Regulation, Digital Trade Support Gaps, Payment Regulation, and IPR Regulation. Each of these indices captures a specific regulatory dimension: some reflect the presence or absence of specific regulatory measures (e.g. data transfer restrictions, payment regulation), while others capture market structures shaped by regulation (e.g. market concentration).

The composite indicators were constructed from binary (1/0) sub-indicators, reflecting whether a given regulatory measure or condition is present. Depending on the number of sub-indicators, values ranged from 0 to 6 before normalization. To ensure meaningful comparison across dimensions, all indices were normalized to a [0,1] scale by dividing each composite indicator value by its maximum possible score. Higher index values therefore indicate more restrictive regulatory environments, while lower values reflect more open or less reg-

ulated conditions. Annex 1 provides the detailed structure of the Digital Regulation Composite Indicators and their component sub-indicators.

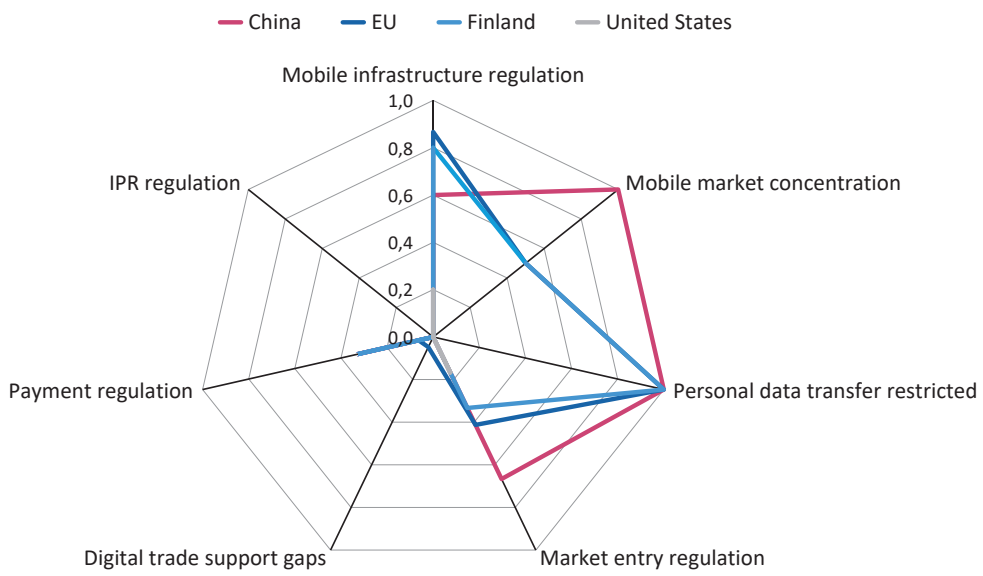
The radar chart (Figure 1) presents a comparative analysis of digital regulation across the EU, Finland, the United States, and China, emphasizing key differences in policy approaches. The EU and Finland impose the strictest regulations on mobile infrastructure, with scores ranging from 0.8 to 0.87, while China maintains a moderate level at 0.6, and the United States has the least regulated market at 0.2. A key distinction is the United States' more liberal approach to mobile interconnection prices and conditions, which are subject to regulation in the other regions. Additionally, the EU enforces net neutrality, ensuring non-discriminatory Internet traffic management, whereas neither the United States nor China has such a mandate.

The Mobile Market Concentration composite indicator measures the extent of market consolidation by assessing the presence of dominant firms in mobile termination and mobile origin. Mobile termination refers to receiving calls on a mobile network, where a dominant operator can impose high interconnection fees, restricting competition. Mobile origin refers to initiating calls, where a single firm's control can translate into significant pricing power. A higher index score indicates a less competitive market with dominant firms shaping prices and access; a lower score reflects a more competitive environment with multiple operators and fewer distortions.

The United States has no dominant firms in termination or origination, reflecting a competitive interconnection market. In Finland and most EU countries, mobile origination is competitive, but termination remains concentrated, allowing some operators to influence interconnection fees. In China, dominant firms exist in both termination and origination, reinforcing market power and limiting competition. While the EU regulates interconnection through competition-based rules requiring cost-oriented and non-discriminatory access, China relies on state control and administrative coordination, reflecting a more centralized model.

Regarding restrictions on personal data transfer, only the United States scores 0, reflecting its open cross-border data policies, while China, the EU, and Finland score 1, indicating stricter personal data regulations. This aligns with the EU's GDPR framework and China's data localization requirements, both of which impose significant restrictions on international flows of personal data. Un-

**Figure 1 Digital service trade regulation comparison in 2024**




**Source:** Authors' own calculations based on data from the OECD Digital Services Trade Restrictiveness Index.

der GDPR, personal data may freely flow within the EU/EEA and to countries with an EU "adequacy decision" (e.g. Japan, South Korea, the UK), while transfers to other jurisdictions require additional safeguards such as standard contractual clauses.

The Market Entry Regulation composite indicator measures barriers to entering digital markets based on six binary (0/1) sub-indicators: discriminatory conditions for e-commerce, the requirement for an e-commerce license, mandatory online tax registration, deviations from standard contract rules, the obligation for commercial presence (physical business operations), and the requirement for local presence (legal or representative office).

Market entry is most restricted in China (0.67), where foreign businesses face high barriers, while the EU (0.41) and Finland (0.33) impose moderate restrictions. The United States (0.17) remains the most open market. In China, foreign firms in certain sectors (e.g., telecom, finance, e-commerce) often face licensing, local registration and in some cases commercial presence or local partner requirements. By contrast, the EU typically focuses on designating a local representative or legal entity for cross-border digital services rather than mandating operational presence, although national rules and sector-specific regulations may vary. This reflects the EU's focus on regulatory oversight, while China enforces stricter market control, and the US maintains the most open entry conditions for digital businesses.

The Digital Trade Support Gaps composite indicator evaluates whether countries lack key frameworks facilitating digital trade, based on three binary sub-indicators: absence of legal protection for confidential information, lack of legal recognition of electronic signatures as equivalent to handwritten ones, and no dispute settlement mechanism for cross-border digital transactions. The Digital Trade Support Gaps composite indicator differs from the others in interpretation: here, higher scores denote the absence of enabling frameworks for digital business. Scores were nearly identical across countries: China, Finland, and the United States all scored 0, while the EU scored 0.05. In other words, all regions have strong regulatory frameworks that support digital trade.

The IPR Regulation composite indicator assesses whether trademark and copyright protections discriminate against foreign firms, and whether judicial, administrative, and criminal enforcement mechanisms are available. Since all jurisdictions largely adhere to international norms, all countries scored 0, indicating strong IPR protection and enforcement.

The Payment Regulation composite indicator is constructed from three binary (0/1) sub-indicators, each measuring restrictions in digital payment systems. These include discriminatory access to payment settlement methods, deviations from international payment security standards, and restrictions on internet banking or insurance. Payment regulation is most restrictive in China and Finland, both scoring 0.33, whereas the EU has fewer restrictions at 0.06, and the United States has none, scoring 0.

For 5G/6G ecosystems, these regulatory differences imply diverging trajectories: Europe emphasizes controlled market access and user trust, China prioritizes sovereignty and state control, while the US relies on openness and competition. These choices may shape not only the pace of infrastructure deployment but also the global competitiveness of data-intensive 5G/6G services.

## 2.3 Digital regulation

The rollout of 5G and 6G infrastructures coincides with a period of massive regulatory activity in the European Union. Over the past decade, the EU has created a dense framework that defines how personal data may be collected, combined, and repurposed; how dominant digital platforms must interact with users and competitors; and how artificial intelligence can be deployed particularly in high-risk applications (see, e.g., Harakka (2023) for a comprehensive discussion). By contrast, the United States lacks a comprehensive federal law regulating the collection, use, and sale of personal information by private companies and imposes no general restrictions on cross-border personal data transfers. China's Personal Information Protection Law (PIPL) is comprehensive but embedded in a state-led, security-centric governance model, where the role of the government in overseeing and controlling data flows differs materially from the EU's market- and rights-based regime. Against this backdrop, this section focuses on the European approach, which emphasizes end-user rights, transparency, and accountability.

For 5G/6G ecosystems, such regulations are consequential. Services such as connected vehicles, industrial IoT, and personalized healthcare depend on large-scale, real-time data processing, and much of this further involves personal data. EU regulation places strict limits on the lawful basis for the processing of personal data, the purposes for which personal data can be used, and the extent to which it can be shared across platforms or combined with external sources. These constraints not only affect cross-border transfers but also the broader design of business models, innovation strategies, and competitive dynamics in data-intensive markets.

### GDPR

The General Data Protection Regulation (GDPR; Regulation (EU) 2016/679) has been applied across the EU since May 2018. The GDPR sets out core principles for processing personal data comprising lawfulness, fairness and transparency, purpose limitation, data minimization, accuracy, storage limitation, integrity and confidentiality, and accountability. It grants data subjects strong rights for their personal data, including the right to data portability and the right to be forgotten. Compliance requires measures such as encryption, access controls, breach notifications, Data Protection Impact Assessments (DPIAs), and in many cases the appointment of Data Protection Officers (DPOs). Penalties for non-compliance are significant, up to €20 million or 4% of global turnover.

In the 5G and 6G context, GDPR shapes several interrelated dimensions from data flows and extraterritorial scope to compliance costs and competition dynamics.

**Data flows and extraterritorial scope:** 5G/6G services rely on large-scale, often real-time data flows spanning everything from connected vehicles to industrial IoT and health applications. GDPR affects not only whether data can be transferred, but also how it can be collected, combined, and reused. Core principles such as data minimization and purpose limitation require that only the data strictly necessary for a given service is processed, while profiling and automated decision-making are subject to strict safeguards. These requirements may complicate the design of AI-driven 5G/6G applications and limit the use of broad, data-intensive business models. In addition, GDPR's restrictions on cross-border transfers of personal data outside the EU may constrain international services and make global integration more complex compared with jurisdictions with more permissive data regimes, while also raising the cost and complexity of innovation activities that depend on personal data (Lalova-Spinks et al., 2024; Koski, 2025).

**Compliance costs and barriers to entry:** Meeting GDPR requirements has proven costly for companies. For instance, in the first year alone, the EU-wide hiring of DPOs was estimated to add €40 billion in costs (Koski and Valmari, 2020). Beyond the direct compliance costs, empirical research shows that GDPR reduced EU firms' ability to process and store personal data, leading to a 26% decline in data storage and a 15% drop in computation relative to U.S. firms, while raising information production costs by around 4% (Demirer et al., 2024). These burdens fall disproportionately on smaller firms and those in data-intensive sectors, including potential entrants in 5G/6G markets that depend on IoT devices, real-time analytics, and cross-platform data integration.

**Competition and consumer trust:** By enhancing user rights and transparency, the GDPR may strengthen trust in personal data use in digital markets, a critical factor for the adoption of data-intensive 5G/6G applications. At the same time, empirical research highlights that privacy regulation interacts closely with firm performance and competition dynamics. The GDPR compliance has been associated with declines in profitability, investment, and venture capital funding, particularly for smaller and data-intensive firms (Goldberg et al., 2019; Koski and Valmari, 2020; Jia et al., 2025).

Further evidence shows that broader market dynamics compound these challenges. Acquisitions by large technology firms have been found to reduce market entry and venture capital availability, creating "kill zone" effects that discourage new start-ups. These effects have been documented in both the United States and Europe, indicating that the phenomenon is not region-specific but reflects the global market power of dominant technology firms (Koski et al., 2025). When combined with high compliance costs under GDPR, such dynamics risk reinforcing concentration in data-intensive markets, making it harder for smaller firms to enter and scale within the emerging 5G/6G ecosystem.

The European model thus combines strong consumer rights with a high degree of regulatory oversight. This approach contrasts with the United States, where data-use practices and cross-border flows are more permissive, but competition is shaped by consolidation, and with China, where data localization and state control dominate. While all three regimes coexist with advanced 5G rollout, the EU framework places greater emphasis on trust and accountability. This emphasis can enhance user acceptance of new 5G/6G services, but it simultaneously adds compliance burdens and interacts with global market concentration in ways that shape the competitive balance and innovation pathways of the ecosystem.

### Other key EU digital regulation

**Digital Markets Act** (**DMA**), in force since November 2022, targets very large online platforms, so-called *gatekeepers*, that act as critical intermediaries between businesses and end-users. To qualify as a gatekeeper, a firm must operate in at least three Member States and meet thresholds of €7.5 billion annual EU revenue (or €75 billion global market capitalization) alongside at least 45 million active monthly end-users or 10,000 yearly business users. These criteria make clear that the regulation is aimed at the handful of dominant firms whose market position enables them to shape competition and user choice across Europe.

The DMA prohibits practices such as self-preferencing, blocking external links, and preventing users from uninstalling software. Gatekeepers must also enable interoperability in some services, provide business users access to data, allow advertisers to measure performance independently, and make unsubscribing as easy as subscribing. Furthermore, platforms cannot combine or repurpose user data across services without explicit consent, aligning with GDPR's principle of data minimization. Non-compliance can result in fines of up to 10% of global annual turnover, rising to 20% for repeat infringements, and the European Commission may impose structural remedies in severe cases.

For 5G/6G markets, the DMA matters because many future services from IoT applications to edge-based platforms will depend on access to ecosystems controlled by gatekeepers. By lowering barriers to switching and forcing dominant players to open data and interfaces, the DMA seeks to level the playing field for smaller firms and new entrants. This could foster greater diversity of services built on top of 5G/6G infrastructures.

**Digital Services Act** (**DSA**), effective since November 2022, complements the DMA but has a broader scope. It applies to almost all providers of digital services, from hosting services to online platforms, with obligations that scale according to the type and size of provider. The central aim is to create a safer and more accountable online environment by regulating content moderation, advertising transparency, and systemic risk management. Smaller providers benefit from lighter obligations, while very large platforms (i.e., those with more than 45 million users in the EU) are subject to stricter rules.

All providers must ensure the traceability of traders, transparency in recommender systems, restrictions on personalized advertising to minors, and clear crisis mechanisms in events such as war or pandemics. Very large platforms must undergo annual audits, allow vetted researchers to study systemic risks, and provide the Commission with access to data to monitor compliance. Enforcement includes fines up to six percent of global turnover.

For 5G/6G, the DSA's relevance lies less in infrastructure and more in user trust. As immersive and data-intensive services proliferate (e.g., extended reality (XR), real-time content sharing) the credibility of these platforms will depend on compliance with DSA standards. By setting European benchmarks for transparency, accountability, and user protection, the DSA strengthens the legitimacy of new digital services that will increasingly rely on 5G/6G connectivity.

**The Data Act**, adopted in November 2023 and applicable from September 2025, represents a major step in Europe's data governance framework. Its central objective is to increase access to and use of data to spur innovation, growth, and consumer rights. It grants users, both individuals and businesses, the right to access data generated by connected devices and associated services and, upon request, to share it with third parties. The regulation applies broadly to IoT products such as vehicles, industrial equipment, consumer devices, and virtual assistants, while exempting micro and small enterprises from the most demanding obligations.

The Act also targets cloud, edge, and other data processing services. Providers must ensure interoperability and portability, allowing customers to switch between providers or combine services without undue restrictions or excessive switching costs. Providers must also remove artificial lock-in mechanisms and, over time, enable free transfer of data, applications, and digital assets. These rules aim to foster competition in cloud and edge services that will form the backbone of time-critical 5G/6G applications.

For 5G/6G ecosystems, the Data Act may be the most consequential of the newer regulations. By mandating access to IoT data and limiting vendor lock-in in cloud and edge services, it directly shapes who can capture value from connected devices and infrastructures. It opens opportunities for aftermarkets, service innovation, and data-driven competition, while also raising compliance costs and legal complexity. Nonetheless, the Data Act represents a decisive attempt to make data, the essential input of 5G/6G economies, more widely accessible and usable across Europe.

**The Artificial Intelligence Act (AI Act),** adopted in 2024, introduces the world's first comprehensive regulatory framework for AI, with obligations phased in from 2025 onwards. It applies a risk-based approach: 'unacceptable-risk' uses (e.g. social scoring) are banned; 'high-risk' systems used in areas like critical infrastructures, healthcare, transport, education, and employment face strict requirements; 'limited-risk' systems (e.g. chatbots) must meet transparency obligations, while 'minimal-risk' AI remains largely unregulated. For high-risk AI, providers must ensure robust risk management, high-quality training data, documentation, human oversight, and post-market monitoring, alongside registration in an EU database and conformity assessment before market entry.

In 5G/6G contexts, the AI Act is particularly relevant because many emerging services from autonomous mobility and smart manufacturing to personalized healthcare and real-time biometric applications rely on AI. By setting strict obligations, the AI Act increases compliance costs and complexity, especially for high-risk systems, though some provisions ease the burden on SMEs. While such regulation aims to reinforce transparency, accountability, and trust, its effect on the adoption of AI-enabled services in Europe's 5G/6G ecosystem is likely to be mixed.

Combined with the GDPR and the Data Act, the AI Act consolidates the EU's role as a global reference point in data and AI governance, though this approach may also entail risks of reduced innovation and slower commercialization compared to less regulated jurisdictions.

Taken together, the EU's digital regulation enhances privacy and trust but also raises compliance barriers. While related initiatives such as the NIS2 Directive and the Cybersecurity Act reinforce the cybersecurity dimension of Europe's digital governance, this analysis focuses on frameworks that directly shape data governance and AI deployment. For SMEs in particular, the cumulative compliance burden may prove disproportionately heavy, potentially widening the gap between frontrunner firms that fully leverage digitalization and those struggling to adapt.

# 3 Global R&D dynamics related to the development of 5G/6G markets

This chapter explores how global R&D expenditures are distributed across key technology domains that underpin the development of 5G and 6G technologies and related markets, and how the balance of technological strength has shifted over the past decade. The focus is on identifying which countries and regions – particularly the European Union, the United States, and China, with the rest of Asia also considered – have emerged as the strongest R&D investors, and how their relative positions have evolved between 2013 and 2023. Understanding these dynamics is crucial not only for assessing how technological leadership has shifted in the past, but also for evaluating future trajectories of innovation and competitiveness in mobile networks and the broader digital economy. The trends observed provide early signals of where the global race for 5G/6G leadership may be heading, and what this implies for Europe's position.

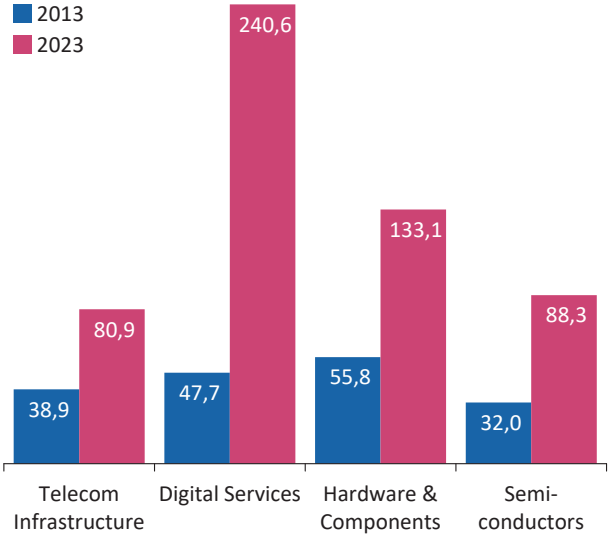
To capture these dynamics, firms are grouped into four technology domains that reflect the structure of the mobile technology ecosystem: telecom infrastructure (mobile and fixed-line telecommunications and telecommunications equipment), digital services (software and

computer services), hardware and components (computer hardware, electronic equipment, and electrical components), and semiconductors.[1] This level of detail is possible because the EU Industrial R&D Investment Scoreboard classifies firms according to the ICB4 system, which allows a more fine-grained mapping of sectoral R&D expenditures than broader industry codes such as NACE. Covering the world's 2,000 largest corporate R&D investors, and together responsible for more than 85 percent of global business-funded R&D in 2023, the Scoreboard provides consistent firm-level data and thus a highly representative basis for comparative analysis across regions and technology domains.

The distribution of leading corporate R&D investors across technology domains directly linked to the development of 5G and 6G infrastructure and services shows a clear shift in the structure of the mobile technology ecosystem between 2013 and 2023. The number of firms investing heavily in digital services increased, while both semiconductor and telecom infrastructure firms became less numerous among the world's largest R&D spenders. In semiconductors, this likely reflects industry consolidation and the growing dominance of a handful of very large players. In telecom infrastructure, by contrast, the reduced presence among top R&D investors appears to stem from a relative slowdown in research intensity among traditional network equipment providers. Importantly, the overall number of leading firms captured in these domains remained broadly stable between 2013 and 2023, which supports the comparability of R&D investment trends over time.

Between 2013 and 2023, total R&D expenditures of leading companies in 5G/6G-relevant technology domains more than tripled, rising from €174 billion to €543 billion. The most dramatic growth occurred in digital services, where investments increased more than five-fold, reflecting the central role of platform-based and data-driven innovation. Semiconductor R&D also expanded strongly, growing by 176%, alongside hardware and components, which rose by 139%. This highlights the strategic importance of advanced chips and devices for next-generation networks. By contrast, telecom infrastructure R&D grew more modestly, increasing by 108%, compared to the explosive expansion of data- and service-driven markets.

**Figure 2 R&D expenditures of firms among the top 2000 global R&D investors by technology domain, 2013 vs. 2023, bill. eur**




**Source:** Authors' own calculations based on data from the EU Industrial R&D Investment Scoreboard.

**Table 2 Number of companies among top global R&D investors by technology domain, 2013 vs 2023**

| Cluster | Freq. 2013 | Share, %, 2013 | Freq. 2023 | Share, %, 2023 |
|---|---|---|---|---|
| Telecom Infrastructure | 99 | 14,80 | 77 | 11,42 |
| Digital Services | 206 | 30,79 | 274 | 40,65 |
| Hardware & Components | 231 | 34,53 | 232 | 34,42 |
| Semiconductors | 133 | 19,88 | 91 | 13,50 |
| **Total** | **669** | **100,00** | **674** | **100,00** |

**Source:** Source: Authors' own calculations based on data from the EU Industrial R&D Investment Scoreboard.

The distribution of R&D expenditures across regions underwent a marked transformation between 2013 and 2023. In 2013, the United States already accounted for a majority share (i.e., about 51%) of corporate R&D spending in 5G/6G-related domains among the world's top 2,000 investors, followed by Asia excluding China (22%) and the European Union (17.4%). China's role remained relatively modest at 5.5%. By 2023, however, the picture had shifted: the United States further strengthened its dominance to 56.4%, while China expanded its share more than threefold, reaching 17.4%. In contrast, the European Union's share declined to 9.4%, and Asia excluding China fell to around 14%, reflecting the rising concentration of corporate R&D in the U.S. and China.

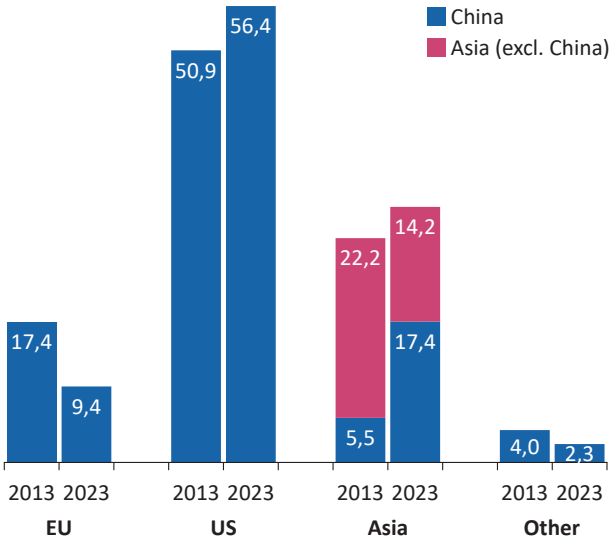
Looking across technology domains (see Figure 4), the U.S. lead is most pronounced in digital services, where American tech giants such as Alphabet, Microsoft, and Meta account for the bulk of global R&D expenditures. But the United States is also a major force in semiconductors, with companies like Intel, Nvidia and AMD among the world's largest corporate R&D investors. This reflects a broader trend of many U.S. firms moving toward a fabless business model, in which semiconductor companies concentrate on R&D and design while outsourcing fabrication to external, mostly East Asian, foundries (Congressional Research Service, 2020). This shift has reinforced the concentration of global chip production in Taiwan, South Korea, and Japan, even as U.S. firms capture a large share of the R&D value.

Asia, by contrast, has built its position mainly in telecommunications infrastructure and hardware, with China's state-driven R&D fueling firms like Huawei and South Korea's Samsung emerging as another leading player in the field. In semiconductors, China remains relatively weak in terms of R&D investment despite strong policy support. Europe's R&D expenditure share is more evenly distributed across all four domains, but this breadth comes at the cost of global dominance in any single technology domain.

Out of the top 40 R&D firms across technology domains, fully half are U.S.-based, reflecting the overwhelming dominance of American companies. China accounts for seven of the 40, concentrated in telecom infrastructure and hardware. European firms appear across domains but contribute only six entries in total (Germany, France, Finland, Sweden, and the Netherlands combined), highlighting their fragmented and less prominent position. The remaining firms are largely from Asia – Taiwan, South Korea, and Japan – underscoring their continued strength in semiconductors and hardware. Looking only at the overall top 10 R&D investors across all domains, the U.S. presence is even more striking: seven of the ten are American, alongside two from China and one from South Korea.

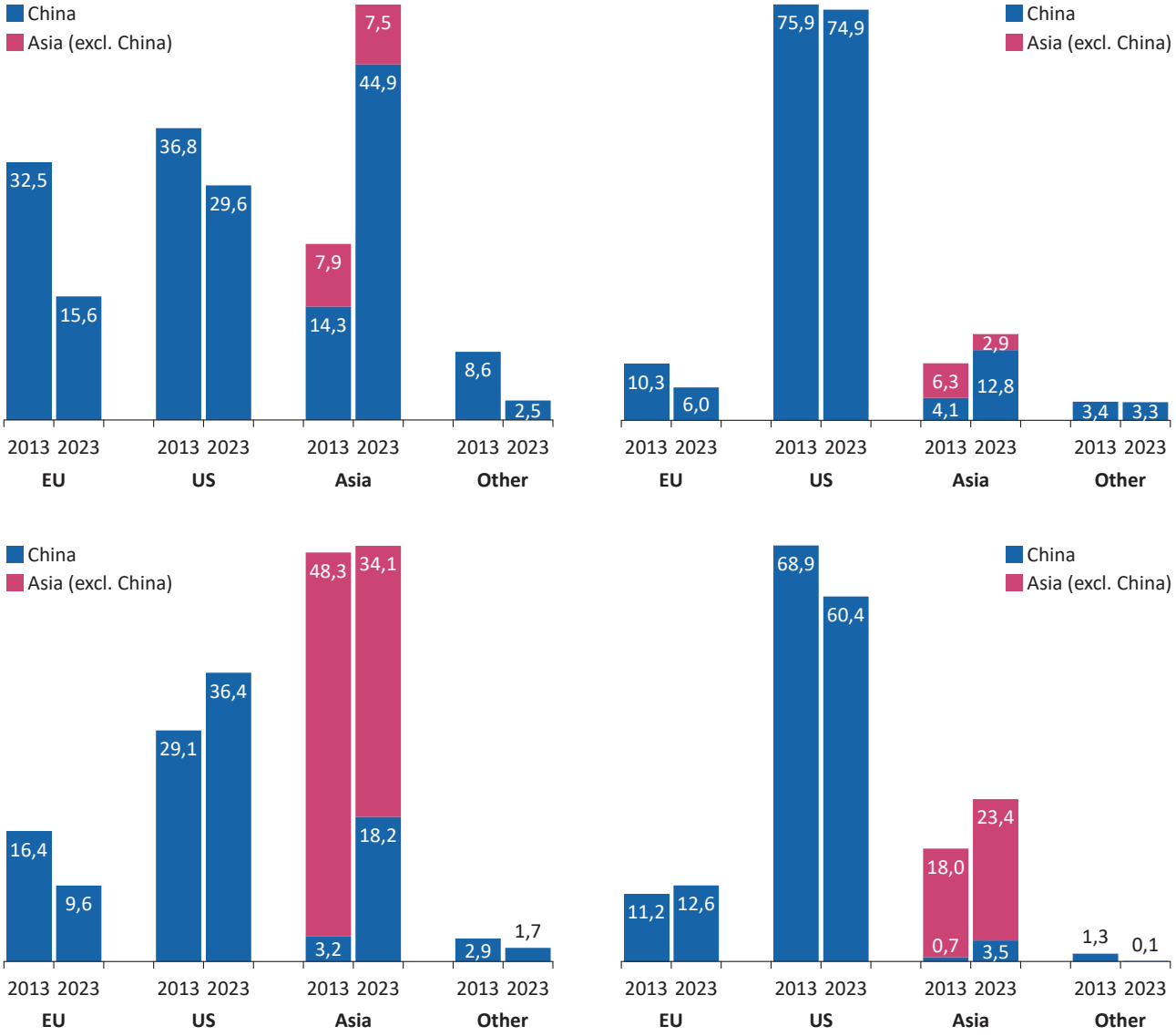
Taken together, the evidence indicates three broad trends. The United States has reinforced its leading position in R&D for digital services and semiconductors. China has expanded its investment rapidly in telecommunications infrastructure and hardware, while the rest of Asia maintains a strong position in hardware and components. Europe, by contrast, risks being positioned between these poles, lacking a distinct technological specialization that could sustain global leadership into the 5G and emerging 6G era.

**Figure 3** **Regional R&D shares, 5G/6G-related domains among the top 2000 global R&D investors, 2013 vs. 2023, %**




**Source:** Authors' own calculations based on data from the EU Industrial R&D Investment Scoreboard.

**Figure 4** **Regional R&D shares by technology domain among the top 2000 global R&D investors, 2013 vs. 2023, %**




**Source:** Authors' own calculations based on data from the EU Industrial R&D Investment Scoreboard.

# 4 Leading companies in the 5G patent landscape

Whereas the previous chapter examined broader patterns of R&D investment across the main technology domains underpinning 5G and 6G, this chapter narrows the focus on patents, and specifically those declared as essential to 5G standards. While R&D expenditures indicate the scale and direction of technological effort, they do not reveal how innovations shape global markets. Standard-essential patents (SEPs) provide this complementary perspective. Because any company implementing global communication standards must use SEPs, they represent both strategic influence over technology deployment and substantial licensing power. SEPs are therefore one critical indicator of technological leadership and economic value in the 5G ecosystem.

While 5G patents are most directly associated with the telecom infrastructure domain, the leading patent own-

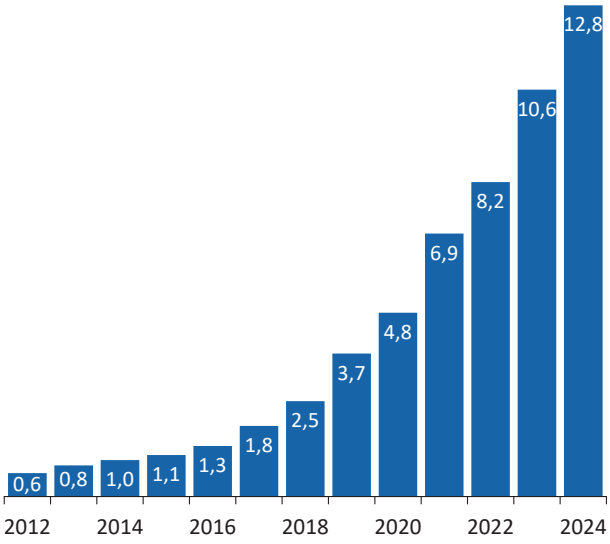
ers include firms whose activities extend into semiconductors and hardware. Companies such as Huawei, Ericsson, and Nokia are primarily infrastructure-focused, whereas Qualcomm, Samsung, and to some extent Huawei also operate at the intersection of semiconductors and devices.

According to LexisNexis (2025), drawing on the ETSI database, as of October 31, 2024, more than 57,000 active 5G patent families had been granted in at least one jurisdiction worldwide. A patent family refers to a set of related patents filed in multiple jurisdictions to protect the same invention, thus avoiding double counting when measuring global patenting activity. Figure 5 illustrates the steady annual increase in 5G patents, showing that the number of granted patents has grown over tenfold between 2014 and 2024. This sharp rise underscores the rapid pace of innovation and the intense competition driving the evolution of the 5G industry.

We next shed light on the top 50 5G patent-owning companies using the Patent Asset Index, a value-based metric developed by LexisNexis PatentSight. The index evaluates the innovative impact and quality of patents by considering how extensively other innovations build upon them and the breadth of their legal protection, thereby going beyond simple counts of declared SEPs. Figure 6 illustrates the regional distribution of these companies based on their headquarters. Asia dominates the 5G patent landscape: more than two-thirds of the top 50 patent owner companies are located in Asia, with 30% based in China. Meanwhile, 18% of the companies are headquartered in the United States, and 14% in Europe.

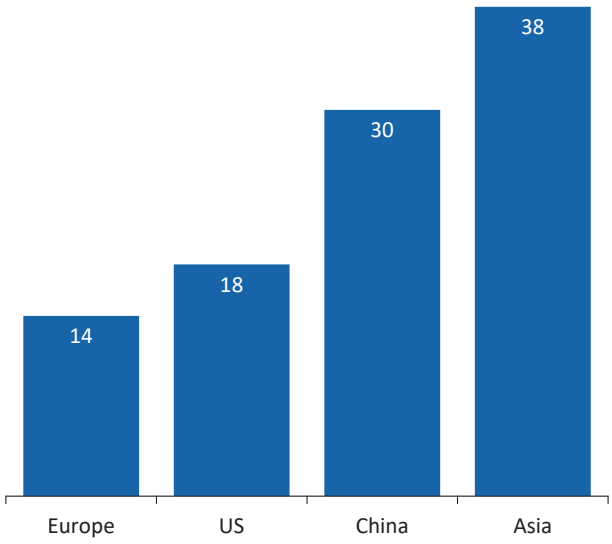
The top three companies in the Patent Asset Index ranking were Huawei (China), Qualcomm (US), and Ericsson (Sweden), leading in the ownership of patented network and mobile innovations. Nokia (Finland) ranked 7th, establishing it as another of Europe's key players in 5G technology. Importantly, however, the group of top 50 patent owners extends well beyond traditional telecom equipment providers. It also includes device manufacturers such as Apple and Xiaomi; semiconductor companies such as Intel and MediaTek; research organizations and IP-focused entities such as Fraunhofer and ITRI; and digital service and platform companies such as Alphabet. This diversity underlines how 5G technologies span a wide industrial base, embedding not only network infrastructure but also consumer electronics, semiconductors, digital platforms, and software technologies. Nevertheless, patenting activity remains concentrated in a few core domains, as illustrated in Figure 7.

**Figure 5** **Number of worldwide granted 5G declared patent families (1 000) by year of first publication**



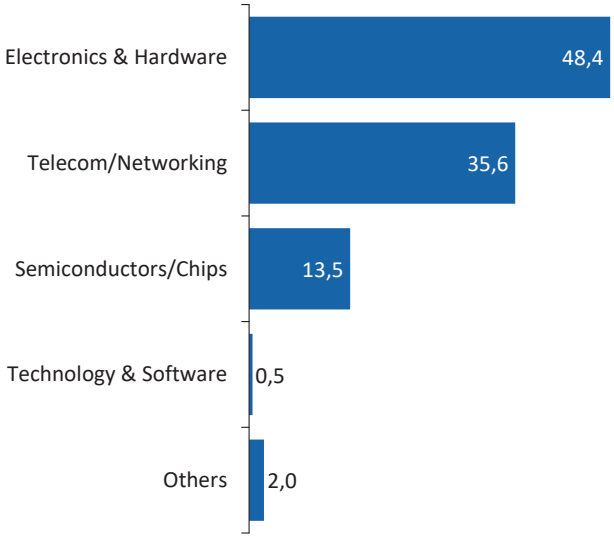

**Source:** NexisLexis (2025).

**Figure 6** **Regional distribution of top 50 5G patent owners based on Patent Asset Index, %**




**Source:** NexisLexis (2025).

**Figure 7 Shares of 5G standard essential patents by industry, %**



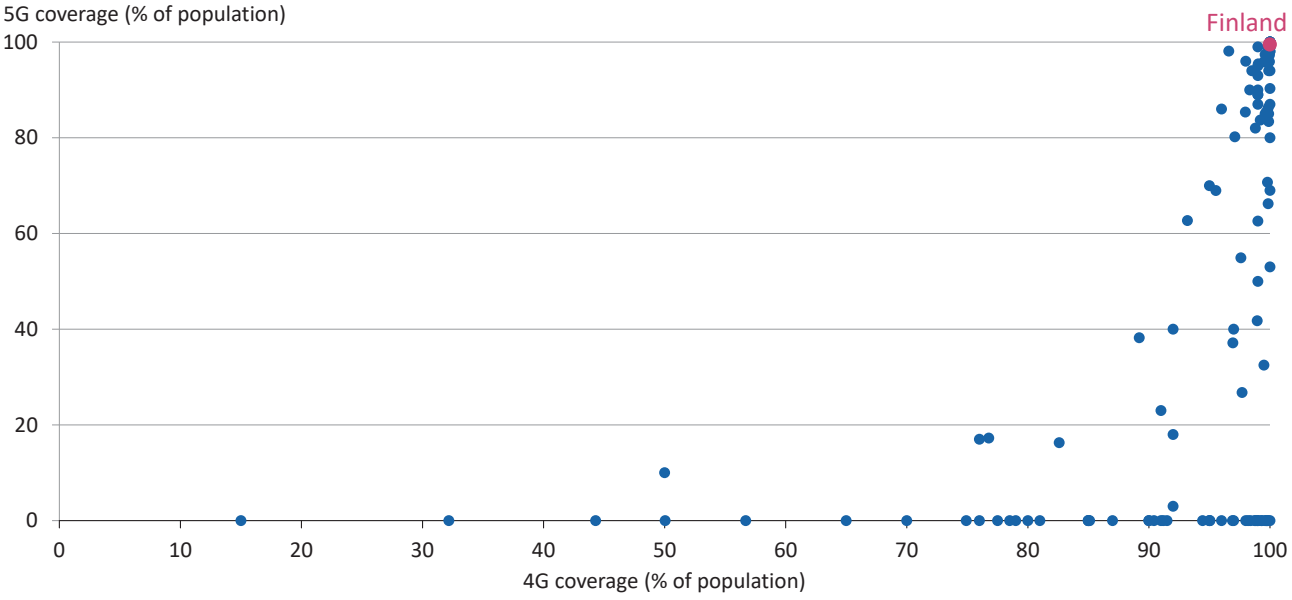

**Source:** NexisLexis (2025).

According to NexixLexis data, nearly half of all SEPs are concentrated on electronics and hardware, followed by telecom and networking (36%) and semiconductors (14%). By contrast, software and digital service firms account for only a marginal share (about 0,5%). This distribution highlights the divergence between R&D and patent-based measures of leadership: the United States dominates in digital services, yet these activities less often than in other 5G relevant domains. Conversely, Asia's strengths in infrastructure, hardware, and semiconductors correspond directly to the domains most intensively captured by SEPs, reinforcing its patent-based leadership.

# 5 Leading countries in the 5G infrastructure and service development

Next, we explore how leading countries have advanced in deploying 5G infrastructures and developing related services. We begin by examining 5G infrastructure deployment, focusing on the extent of coverage provided. Figure 8 presents a scatter plot illustrating the percentage of inhabitants within range of 4G and 5G mobile-cellular signals across a sample of 124 countries in 2023, regardless of their subscription status. Among the 50 countries where 5G coverage reached at least 80%, the vast

**Figure 8 The percentages of inhabitants that were within range of 4G and 5G mobile-cellular signal in 2023**




**Source:** ITU.

majority had at least 99% 4G coverage, with the lowest recorded 4G coverage being 96%. These findings suggest that the rapid deployment of 5G networks cannot be explained by bypassing 4G infrastructure (i.e., a 4G leapfrogging strategy was not a factor). Instead, it appears that the strong foundation of existing 4G networks has facilitated the transition to 5G, enabling a faster rollout and broader coverage.

Furthermore, we use indicators developed by GSMA Intelligence[2] to evaluate 5G connectivity across different markets. The 5G Connectivity Index measures the performance of 39 markets[3] based on key 5G infrastructure and service outcomes, with scores ranging from 0 to 100, where higher scores indicate stronger 5G capabilities. Our analysis includes China but does not separately distinguish Mainland China and Hong Kong.

The 5G infrastructure composite indicator is structured around three pillars: spectrum availability, network deployment, and user experience. It assesses the allocation of frequency bands, the deployment of 5G infrastructure, including base stations and standalone networks, and the quality of service, considering speed, latency, and video performance. The 5G services composite indicator focuses on affordability, adoption, and market development. It evaluates the cost of 5G data and devices, the penetration of 5G subscriptions and device shipments, and market expansion based on data traffic and revenue growth.

Table 3 categorizes countries according to their 5G infrastructure and service composite indicators. Interestingly, every country with a 5G infrastructure composite indicator above 60 had at least 99.9% of its inhabitants within range of at least a 4G/LTE mobile-cellular signal in 2023, irrespective of whether they were subscribers.

When looking at the service composite indicator, some divergence is evident. The United States, for example, ranks only in the mid-range for infrastructure (40–50) but achieves one of the highest scores for services (above 60), reflecting rapid market adoption and affordability. Finland performs strongly across both dimensions, while Sweden demonstrates higher service scores (50–60) relative to its infrastructure position (40–50), suggesting advanced uptake despite more moderate network deployment. Conversely, countries such as Italy and Bulgaria show relatively stronger infrastructure than services, indicating that available networks have not yet translated into widespread adoption.

The findings suggest that different regulatory approaches can coexist with strong 5G development, as China, Finland, and the United States all rank among the top countries in 5G services, despite significant regulatory

**Table 3 5G infrastructure and service composite indicators in Q3 2024**

| Score | 5G infrastructure | 5G services |
|---|---|---|
| Above 60 | United Arab Emirates, Kuwait, Qatar, Norway, Denmark | USA, Kuwait, Finland, China, Qatar, Singapore |
| 50–60 | South Korea, Finland, Switzerland, China, Singapore, Australia, Netherlands, Greece | Saudi Arabia, United Arab Emirates, Denmark, Australia, South Korea, Switzerland, Japan, Austria, Norway, UK, Sweden |
| 40–50 | Bulgaria, Germany, USA, Japan, Thailand, Czechia, Canada, Austria, France, Brazil, Saudi Arabia, Spain, Sweden, UK | Germany, Netherlands, Israel, France, Italy, Canada, Bulgaria |
| 30–40 | Italy, Malaysia, Israel, India, New Zealand, Philippines | Malaysia, New Zealand, Spain, Chile, Czechia, Greece, Thailand, India |
| Below 30 | Chile, South Africa, Mexico, Nigeria, Indonesia | Mexico, Brazil, Indonesia, Philippines, South Africa, Nigeria |

**Source:** GSMA Intelligence.

differences. The United States follows a market-driven approach, promoting open competition, flexible data policies, and minimal restrictions on digital transactions. In contrast, China imposes strict market entry regulations and strong state control while still achieving a high level of 5G deployment. The EU and Finland emphasize regulatory governance and controlled market access, yet Finland remains at the forefront of 5G services.

These results indicate that both liberal and interventionist regulatory frameworks can support advanced 5G ecosystems, provided that key factors such as infrastructure investment, spectrum allocation, and innovation incentives are effectively managed. Rather than a single optimal regulatory model, policy effectiveness depends on how regulations interact with industry dynamics, investment environments, and technological capabilities.

# 6 EU policy responses and geopolitical context

The European Union enters the 5G/6G era facing a double challenge. On the one hand, global R&D dynamics show a sharp concentration of technological leadership in the United States, which dominates digital services and semiconductors, and in Asia, where China has rapidly expanded in telecom infrastructure and South Korea, Taiwan, and Japan retain strong positions in semiconductors and hardware. Europe's share of corporate R&D investment in 5G/6G-related domains has declined markedly over the past decade, leaving it without clear global leadership in any single technology domain.

As illustrated in Figure 2, the growth of R&D in digital services and semiconductors has been strong worldwide, but European firms have captured only a small fraction of this expansion. By contrast, Europe's relative strength in telecom infrastructure has not been enough to offset its declining position in the domains that increasingly capture the value of connectivity. This imbalance underscores the structural challenge: while Europe retains important assets in network equipment, it risks marginalization in the higher-value layers of the 5G/6G ecosystem. On the other hand, the EU has adopted the world's most comprehensive regulatory framework for digital markets. This combination of relatively weaker R&D specialization and a heavily regulated environment raise questions about Europe's competitiveness. Empirical evidence suggests that high compliance costs and regulatory uncertainty may slow market entry, discourage venture capital investment, and weaken innovation incentives, particularly for smaller firms. At the same time, the concentration of R&D power in the United States and Asia illustrates Europe's continued reliance on foreign platforms, chips, and services in the emerging 6G economy.

Europe's regulatory approach may also confer certain strategic advantages. By embedding principles of privacy, security, and accountability into its digital regulatory framework, the European Union has become a global reference point in digital governance, shaping policy debates well beyond its borders. While this normative influence is most visible in areas such as personal data protection and competition policy, its relevance for emerging technologies like 6G remains uncertain, as industrial capacity and technological leadership affect the direction of global standardization. Nonetheless, trust-based regulation could still provide a comparative advantage in sensitive domains such as critical infrastructure, healthcare, and mobility, where data protection and security are important.

Europe's competitiveness ultimately depends on its ability to translate regulatory credibility and existing industrial assets into technological and market outcomes. Although Europe retains notable telecom infrastructure players such as Ericsson and Nokia, its overall industrial base in network equipment and related technologies has eroded over the past decade. Future leadership will therefore depend less on legacy strengths and more on the capacity to drive innovation, scale new service ecosystems, and capture value in the global 5G/6G marketplace.

Semiconductors present a distinct challenge. Leading-edge foundries require massive investment and rely on an ecosystem that Europe currently lacks. Complete independence is unrealistic, but Europe retains unique strengths in lithography (ASML), power electronics (Infineon, STMicroelectronics), and automotive and industrial chips. Leveraging these niches, while developing strategic partnerships with global leaders, offers a pragmatic path to mitigate supply chain vulnerabilities without overstretching industrial policy.

Digital services remain a relative weakness for Europe. While the United States and China have built global platform ecosystems, Europe lags far behind in scaling data-driven innovation. This disadvantage is visible in R&D dynamics: EU firms have steadily lost ground in digital services over the past decade, leaving Europe without major global players in a domain that increasingly captures the value of 5G/6G connectivity. Strict privacy regulation under the GDPR, while enhancing consumer privacy, has also added compliance burdens and limited firms' access to and use of personal data for innovation and data-driven activities. The Data Act and the Digital Markets Act may help improve access to data, lower barriers to data sharing and market entry, and foster fairer competition. Yet regulatory measures alone cannot replace the scale, investment, and ecosystem depth needed to build globally competitive platforms.

European firms need to compete in high-value segments of the 5G/6G economy, particularly in services and applications where most new value will be created. Europe's ability to influence technological standards will depend not on regulatory leverage alone, but on its capacity to innovate and to participate credibly in global technology ecosystems. Without such capabilities, the EU risks being squeezed between the scale advantages of the United States and the state-driven momentum of China.

# 7 Synthesis and policy implications

This report has examined the global race for 5G and 6G leadership through three interlinked dimensions: regulatory regimes, technological capabilities, and market dynamics. Technological capabilities were assessed through both R&D investments and patents, capturing the scale of innovation effort and its codification into global standards. The United States has consolidated its dominance in digital services and semiconductors, while China has rapidly expanded its role in telecom infrastructure and hardware. Europe, by contrast, has seen its share of global R&D decline and lacks clear technological leadership in any single domain. Its remaining strength lies in telecom infrastructure, through firms such as Ericsson and Nokia, and in semiconductors, notably ASML in lithography, Infineon in power electronics, and STMicroelectronics in embedded systems. Yet these capabilities are concentrated in narrow segments and remain too limited to offset structural weaknesses in digital platforms, large-scale chip manufacturing, and data-driven services.

Patent data confirm Asia's stronger position in 5G technologies, with nearly 70% of leading standard essential patent holders based in China and other Asian economies. The United States appears smaller in patent counts but dominates R&D in digital services and semiconductors, in other words, areas less visible in patent metrics yet central to long-term technological progress and value creation. Europe's industrial base, meanwhile, is concentrated in sectors of declining global relevance and has not developed comparable strength in the domains shaping the future of 5G and 6G.

While Europe lags behind in R&D investment and patent intensity, the picture is more positive in 5G network deployment and service performance. In 5G infrastructure, countries such as Denmark, Norway, Switzerland, and the Netherlands rank among global leaders, while Finland, Sweden, and Denmark perform strongly in 5G services. These cases suggest that certain European countries have leveraged regulatory choices, competitive market structures, and long-standing technological capabilities to achieve strong 5G deployment, even if this has not translated into global leadership in foundational technologies.

The EU has built the world's most comprehensive digital regulatory framework. These measures reflect Europe's distinctive governance model centered in trust, accountability, and consumer rights. Yet the cumulative effect has proven double-edged. Empirical evidence indicates that GDPR compliance alone reduced data storage and computation among European firms relative to their U.S. counterparts, while also discouraging venture capital investment and new market entry. With successive layers of regulation, these burdens risk deepening. What began as a strategy to ensure responsible innovation may in practice have constrained European firms' ability to scale data-driven services and compete globally, reinforcing existing structural imbalances.

Europe's central dilemma is therefore clear. Regulatory leadership enhances normative power but cannot substitute for industrial and innovation capacity and may

even constrain it if compliance demands become excessive. To remain a meaningful player, Europe must recalibrate. Rather than expanding legal obligations, it should simplify compliance, ensure proportional rules for smaller firms, and foster conditions that allow innovation to scale across markets. Data governance should evolve from a focus on restriction to responsible enablement, maintaining trust while providing the scale and flexibility that next-generation ecosystems demand.

Ultimately, Europe's position in the global 5G/6G race will depend on whether it can strike a better balance between its regulatory ambitions and the industrial and technological capacities needed to strengthen its role in next-generation networks. Without such balance, well-intentioned regulation risks undermining the very competitiveness it seeks to protect.

# Annex 1

## Composition of Digital Regulation Composite Indicators

| Composite Indicator* | Sub-indicators (each get value 1 if condition is met, 0 otherwise) |
|---|---|
| Mobile Infrastructure Regulation | Interconnection is mandated (mobile), Interconnection prices and conditions are regulated (mobile), Interconnection reference offers are made public (mobile), Vertical separation is required (mobile), Non-discriminatory Internet traffic management is mandated |
| Mobile Market Concentration | Dominant firm in mobile termination, dominant firm in mobile origin |
| Personal Data Transfer Restricted | Restrictions on cross-border transfer of personal data |
| Market Entry Regulation | Discriminatory conditions for licenses to engage in e-commerce, License or authorisation required for e-commerce, Online tax registration is not available for foreign providers, National contract rules deviate from international standards, Commercial presence required for cross-border services, Local presence required for cross-border services |
| Digital Trade Support Gaps | No laws protect confidential information, Electronic signatures are not legally equivalent to handwritten, Dispute settlement mechanism do not exists for cross-border digital trade |
| Payment Regulation | Discriminatory access to payment settlement methods, National payment security standards deviate from international standards, Restrictions on internet banking or insurance |
| IPR Regulation | Foreign firms discriminated in trademark protection, Discriminatory treatment of foreigners in copyright protection, Exceptions to copyright protection are not limited in accord with international rules, Judicial enforcement of intellectual property rights are not unavailable, Provisional enforcement measures are not unavailable, Criminal enforcement measures are not unavailable |

* The composite indicator is the sum of binary sub-indicators, divided by their total number for normalization.

**Source:** The OECD Digital Services Trade Restrictiveness Index Database.

# Endnotes

1 While semiconductors underpin multiple other domains, they are treated here as a distinct cluster given their unique R&D intensity and strategic role in global value chains. Some overlap between categories is inevitable, but this classification provides a consistent basis for comparative analysis across regions and technologies.

2 For further information, see, https://data.gsmaintelligence.com.

3 The countries included are: **Europe** (Norway, Denmark, Finland, Switzerland, Netherlands, Greece, Bulgaria, Germany, Czechia, Austria, France, Spain, Sweden, United Kingdom, Italy), **North America** (United States of America, Canada, Mexico), **South America** (Brazil, Chile), **Oceania** (Australia, New Zealand), **Asia** (Mainland China, South Korea, Hong Kong SAR (China), Singapore, Japan, Thailand, Malaysia, Israel, India, Indonesia, United Arab Emirates, Kuwait, Qatar, Saudi Arabia), and **Africa** (South Africa, Nigeria).

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