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Cloud – capturing the silver lining for Europe

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1. Executive summary

The Draghi report noted that "*the productivity gap between the EU and the US is largely explained by the tech sector.*"

A growing element of the tech sector is cloud computing, which is a key building block for digitalisation.

Cloud encompasses thousands of applications including artificial intelligence (AI), which is expected to contribute to future productivity growth and the competitiveness of businesses throughout the economy.

The growth of public cloud started with the launch of Amazon Web Services (AWS) in 2006. Cloud revenues for the sector have grown at around 20% per annum whilst prices have declined at around 10% per annum; implying volume growth of around 30% per annum.

Growth in cloud has been driven by efficiencies, including gains in energy efficiency for workloads transferred to the cloud, by an expansion of services and an expansion of sectors serviced. Cloud also reduces cross country frictions for enterprise, whilst the pay as you go model and scalable nature of cloud benefits start-ups and scale ups.

Cloud is currently undergoing a transformation driven by demand for training of, and inference by, AI models. This involves massive investment to expand capacity.

The availability, rather than source, of high-quality cloud services at scale is key to achieving higher productivity growth in Europe. Local ownership is neither necessary, nor sufficient, to achieve good outcomes and specific policy goals.

Whilst the Draghi report recognises that global cloud providers are an important source of cloud services in Europe, it is proposed that the EU should ensure that it has a domestic industry that can meet the demand for "sovereign cloud" solutions.

There is a risk that policies focussed on local cloud provision could discriminate against global supply at a time when rapid growth in demand – growth that could not conceivably be met in the near term without global supplier participation – would further widen the productivity gap between the EU and the US.

The flexibility to utilise the best available cloud and AI services is essential if digitalisation is to proceed at the pace required to support productivity growth, innovation and the global competitiveness of European industry.

Compute will be distributed with global cloud clusters for latency insensitive tasks such as AI model training and extended inference, local compute for latency sensitive tasks such as chat or search and device embedded compute where low latency is critical, for example, in autonomous vehicles.

Europe's Digital Decade targets for 2030 include a target for the location of cloud computing, namely that there should be 10,000 edge nodes by 2030. It is envisaged that these would be embedded in networks close to users.

Whilst some compute may be embedded in networks, there is no basis for a numerical target, and such intermediate compute may neither deliver the low latency and dependability of device-based compute nor the efficiency of larger compute clusters.

There has also been consideration of a charge based on data flows to help fund network investment. However, such a charge would depress flows of data, reducing the incentive

for investment in cloud solutions and in connectivity.

Further, whilst cloud and networks are complementarity, this does not imply that the services are in some sense converging and should be subject to the same regulation.

To support cloud and AI the market for inputs, including electricity, needs to be flexible and responsive. The energy required for computing should not be viewed as in tension with environment goals, rather the opportunity for cloud providers to stimulate demand at scale for carbon free electricity should be recognised.

Cloud providers have not only committed to purchases of established sources of green energy but have also invested in bringing forward solutions ranging from geothermal to small modular reactors. Cloud and the development of carbon free energy sources are complementary.

To capture the silver lining from cloud the EU needs to remain open to a diversity of suppliers of cloud services, allow the market to determine the optimal location of compute, not impose unjustified regulation or data charges and permit flexible provision of required inputs including energy.

By doing so the EU can ensure that cloud, connectivity and green energy develop in a complementary manner, thereby supporting the competitiveness of European enterprise and helping close the productivity gap.

2. Digital transformation of everything

'Digital' - connected computing, software, cloud and AI are transforming everything.

One measure of that transformation is productivity growth, the value of output in value added terms for a given input, say per hour worked. And productivity matters, as Paul Krugman put it in 1994:

"*Productivity isn't everything, but, in the long run, it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker.*"

The Draghi report[1] identified a growing productivity gap over the past two decades between the EU and the US as the key driver of income divergence.

And it's not just income, but leisure too, that depends on productivity. Health and longevity may not automatically follow, but over the past century or so gains in longevity have been correlated with gains in income per capita.

Underpinning productivity growth is innovation over the ways we do things, and 'tech' in the broad sense is integral to that.

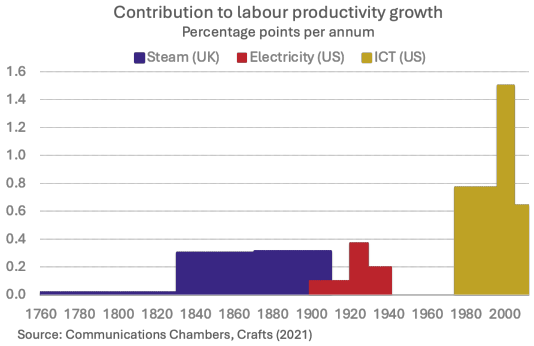
Yet Robert Solow quipped in 1987 that *"You can see computers everywhere but in the productivity statistics"*

But we did see computers, more correctly connected computers, in the productivity statistics from the mid-1990s.

General purpose technologies

Technologies subject to continuous improvement and widespread application are referred to as general purpose technologies. They are particularly impactful, with the contribution of steam, electricity and computing (ICT) shown in Figure 1.[2]

Figure 1: Productivity growth contributions of previous general-purpose technologies



In each case complementary innovation was necessary to spur productivity growth; the combination of steam and rail; centralised electricity generation coupled with distributed motors and connected computing including cloud computing.

Connected computing and software

The benefits of the 'ICT revolution' are readily seen in labour productivity statistics for the US, but a similar acceleration of productivity growth was less evident in Europe.[3]

During the 2000's the importance of software and cloud services rose but took time to reach

[1] Report for European Commission (The Draghi report), September 2024, The future of European competitiveness. *https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en*

[2] Crafts, September 2011, Artificial intelligence as a general-purpose technology: an historical perspective, Oxford Review of Economic Policy, Volume 37, Number 3. *https://academic.oup.com/oxrep/article/37/3/521/6374675*

[3] Sayed and Gordon, August 2020, Transatlantic technologies: Why did the ICT revolution fail to boost European productivity growth? *https://cepr.org/voxeu/columns/transatlantic-technologies-why-did-ict-revolution-fail-boost-european-productivity*

sufficient scale for transformative change. The centrality of software (including AI) is now clear, with everything from business communications to autonomous vehicles, re-usable rockets and health care dependent on software.

Evidence regarding digital transformation

Labour productivity, assessed on a per-hour basis (i.e. controlling for differences in hours worked), has grown 73% for American workers since 1990 versus 39% in the euro area.[4] This difference is associated with greater dynamism in terms of the churn of workers and corporations, coupled with higher R&D, in the US.

Focusing on technology firms, the IMF estimate that labour productivity for US technology firms has surged by nearly 40 per cent since 2005, whilst it has remained almost constant for European technology firms.[5]

The Draghi report pointed to digital in relation to the overall EU-US productivity divergence:[6]

"The main reason EU productivity diverged from the US in the mid-1990s was Europe's failure to capitalise on the first digital revolution led by the internet – both in terms of generating new tech companies and diffusing digital tech into the economy."

Focussing on investment, Draghi found that:

"In 2021, EU companies spent about half as much on [Research and Innovation] R&I as share of GDP as US companies – around EUR 270 billion – a gap driven by much higher investment rates in the US tech sector. This innovation gap also translates into a gap in overall productive investment between the two economies, which is driven mainly by lower investment in tangible ICT assets and in software, databases and intellectual property."

Whilst Draghi was right to call out the EU gap in tech, he attributed a lack of EU dynamism, in part, to companies:

"*...specialised in mature technologies where the potential for breakthroughs is limited*."

This perspective underestimates the importance of tech, since industries considered mature were in fact ripe for disruption via tech. This is now painfully clear in the EU automotive (electrification and autonomy) and space launch industries (re-use).

Digital really is transforming everything, and it is critical to enable this transformation in Europe.

ICT-use versus production

Evidence shows that productivity gains via the use of ICT are becoming relatively more important compared to gain from the production of ICT: [7]

"*The gains from ICT adoption across the world economy may soon (or may already) outpace*

[4] The Economist, 14 October 2024, American productivity still leads the world. https://www.economist.com/special-report/2024/10/14/american-productivity-still-leads-the-world
[5] IMF, September 2024, How to Awaken Europe's Private Sector and Boost Economic Growth. https://www.imf.org/en/Blogs/Articles/2024/09/11/how-to-awaken-europes-private-sector-and-boost-economic-growth
[6] European Commission (The Draghi report), September 2024, The future of European competitiveness: Part A - A competitiveness strategy for Europe.
[7] Ho, Nomura and Samuels, June 2024, Growing adoption rates of ICT have counterbalanced the productivity slowdown in advanced economies. https://cepr.org/voxeu/columns/growing-adoption-rates-ict-have-counterbalanced-productivity-slowdown-advanced

the standard measured contribution of ICT to aggregate productivity growth."

For Europe, a study found that:[8]

"In 1997-2017 EU's labour productivity (LP) growth was strongly connected with the indirect channel of ICT impact, i.e., with TFP [total factor productivity] dynamics in ICT-using sectors. In the pre-crisis period, TFP growth in these sectors had a positive impact on productivity in the EU (except Italy). In the old EU members its contribution was on average 0.4 pp. of 1.6% [per annum] growth in LP ..."

The availability, rather than source, of high-quality ICT services at scale is key to achieving higher productivity growth in Europe.

Cloud computing

Cloud provides accessible compute, storage and applications which businesses and consumers can utilise without incurring up-front costs and with less investment in skills.

Cloud computing has undergone rapid growth coupled with declining prices. Cloud computing supports digitalisation of the economy including enterprise, government and science and technology – it is a building block and enabler.

Whilst cloud services pre-date the current pivot to AI, the potential of AI and its dependence on cloud services illustrates the role of cloud in helping innovation to diffuse and be widely adopted.

Cloud and AI

AI is undergoing rapid improvement, with a wide range of applications, and is itself a method of invention[9]. Cloud computing infrastructure is a critical input to the production and use of AI.

We already see significant gains in some areas, and a clear path to substantial gains in others. The following examples serve to illustrate the opportunity and the role of cloud computing.

The development of large language models would not have been possible without cloud computing at scale, and a significant amount of inference is cloud based. Early beneficiaries of these models include knowledge workers, including software developers.

Multimodal models are a natural extension of language models, and their ability to learn from video and make inferences about the world has been utilised for robotics and autonomous vehicles.

Further, the Nobel prize in Chemistry in 2024 for the development of protein structure prediction tool AlphaFold in 2024 highlighted the role of cloud and AI as a method of invention. Proteins are building blocks of life, and understanding protein structure is key to advances in medicine.

Alpha-Fold has hugely compressed the time it takes to establish the structure of a protein, and the number of proteins for which the structure is known. AlphaFold has predicted over 200 million protein structures, whereas

[8] Izabela Mlynarzewska-Borowiec, 2021, Direct and Indirect Impact of ICT on EU's Productivity Growth. European Research Studies Journal, Volume XXIV, Special Issue 4. https://ersj.eu/journal/2689

[9] Google DeepMind, November 2024, A new golden age of discovery. https://deepmind.google/public-policy/ai-for-science/

prior to AlphaFold around 170,000 structures had been determined experimentally.[10]

These examples illustrate early gains from AI, underpinned by cloud. Other changes may take longer, since they require a more fundamental reorganisation of business and government.

The potential, if not all the details, are now clear; and cloud-AI is an essential part of the solution. It is important that policy facilitates rather than curtails the contribution of cloud in the near and longer-term.

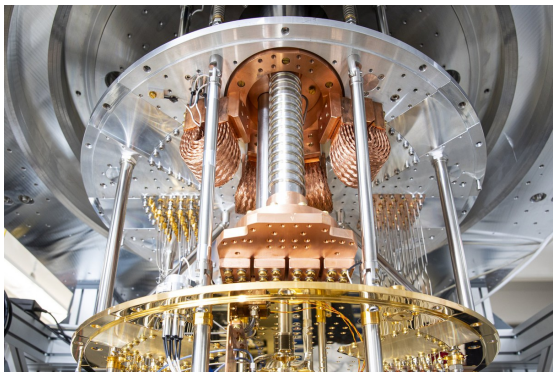
Cloud and quantum computing

Quantum computing is a frontier technology which promises to increase the scope to perform certain computing tasks beyond the reach of 'classical' computers.

Quantum computers are complex machines which, whilst beyond the reach of most, are accessible as cloud services.

Figure 2 shows the complexity of part of the OpenSuperQ quantum computer, a project funded by the EU.[11]

Figure 2: Cryostat of the OpenSuperQ quantum computer



Potential applications include logistics, financial portfolio optimisation, cryptography, drug discovery, materials science and AI model training. These applications will require quantum systems at greater scale, with greater stability and improved error correction. Useful systems will combine classical and quantum computers.

Quantum computers utilise specialised infrastructure and skills that almost all users will access as a service. Several companies and research institutes provide cloud-based access to quantum processors and emulators for experimentation.

This enables researchers, and prospective users, to build capacity and identify problems where quantum computing might help in future.

[10] Demis Hassabis, July 2022, AlphaFold reveals the structure of the protein universe. https://deepmind.google/discover/blog/alphafold-reveals-the-structure-of-the-protein-universe/

[11] Forschungszentrum Jülich, March 2023, The European Quantum Computer Project OpenSuperQ Is Extended. https://www.fz-juelich.de/en/news/archive/press-release/2023/the-european-quantum-computer-project-opensuperq-is-extended

3. Cloud as a building block for digital transformation

Cloud computing is the on-demand and flexible availability of data storage, computing and applications. Cloud computing involves the separation of computing workloads from hardware, and the provision of a wide range of services on demand. Given its nature: [12]

"cloud computing is a key driver for digital transformation, as it can improve access to advanced IT solutions, boosting innovation and productivity across a wide range of sectors."

Drivers of cloud computing

The potential to deliver applications as a service via the cloud lowers barriers to adoption and use, allowing users and startups to innovate and focus on their core business.

Public cloud computing is also typically more efficient than self-provision of computing. In addition to economies of scale, capacity is utilised efficiently whilst redundancy and back up can be delivered at lower cost.

Cloud computing is also more energy efficient, with a study finding that whilst the gains depend on the application, energy savings were around 50% for the average workload transferred to the cloud.[13]

Cyber security may also be more effectively addressed via public cloud services. According to the UK National Cyber Security Commission:[14]

"The scale of public cloud services can bring many security advantages..." and "Managed services tend to be configured, designed, operated, and monitored more effectively than any customer designing their own service could achieve."

AI tools included with cloud services are also strengthening security.[15]

Barriers to cross-border business operations are also reduced by cloud providers via services including payments and translation. Cloud services contribute to a more seamless European market.

The evolution of the market

Public cloud revenue more than doubled between 2019 and 2023 to $496bn.[16]

Continued growth will be driven by an expansion of cloud services and the migration of existing workloads to the public cloud. A survey by Goldman Sachs Research in 2024 estimated that about 30% of companies surveyed workloads had migrated to the public cloud. [17]

Private in-house provision competes with public cloud services. Industrial companies may prefer on-premises computing for reasons of low latency and to ensure that their

[12] Biglaiser, Crémer and Mantovani, March 2024, The Economics of the Cloud. https://www.tse-fr.eu/sites/default/files/TSE/documents/doc/wp/2024/wp_tse_1520.pdf
[13] Park, Han and Lee, June 2022, Green Cloud? An Empirical Analysis of Cloud Computing and Energy Efficiency. Management Science, Volume 69(3). https://pubsonline.informs.org/doi/10.1287/mnsc.2022.4442
[14] National Cyber Security Centre, November 2020, Security benefits of a good cloud service. https://www.ncsc.gov.uk/whitepaper/security-benefits-of-a-good-cloud-service#section_16
[15] Google, February 2024, How AI can strengthen digital security. https://blog.google/technology/safety-security/google-ai-cyber-defense-initiative/
[16] Goldman Sachs, September 2024, Cloud revenues poised to reach $2 trillion by 2030 amid AI rollout. https://www.goldmansachs.com/insights/articles/cloud-revenues-poised-to-reach-2-trillion-by-2030-amid-ai-rollout
[17] Goldman Sachs, September 2024, Cloud revenues poised to reach $2 trillion by 2030 amid AI rollout. https://www.goldmansachs.com/insights/articles/cloud-revenues-poised-to-reach-2-trillion-by-2030-amid-ai-rollout

data remains private. Firms typically utilise a mixture of private and public cloud.

Private cloud solutions can be purchased on a modular basis from companies such as Vertiv and Schneider Electric.[18] Users can also build their own data centres but rent the servers and outsource day-to-day management or they can lease space in a data centre owned and managed by someone else.

The public cloud industry is comparatively young, with AWS kick starting the industry in 2006. Google Cloud Compute entered the industry 2 years later, followed by Microsoft Azure in 2010.

Public cloud providers may build their own facilities or be hosted by others such as Equinox (who also host services).

Adoption of cloud computing

Cloud supports digitalisation by easing software development, supporting scaling of online business and by speeding up scientific and technological innovation.

Illustrative of software development gains is coding companion Amazon CodeWhisperer, a cloud-based tool for coding. CodeWhisperer is used by enterprises including telco BT to increase coding productivity.[19]

Illustrative of scaling of online businesses is second-hand fashion site Vinted – a European start-up - plans to expand beyond clothes into electronics, books, toys and video games as the start-up seeks to capture more of the booming market for used goods.[20] Vinted utilises a range of cloud services including Okta.[21]

Illustrative of the role of both public and private cloud in supporting scientific and technological innovation is CERN (Conseil Européen pour la Recherche Nucléaire). The Large Hardon Collider (LHC) Computing Grid – a distributed computing infrastructure arranged in tiers – gives a community of thousands of physicists near real-time access to LHC data.

Digital transformation

The scale of the digital transformation potential of cloud isn't simply a reflection of cloud expenditure, but what the investment in cloud services delivers across the whole economy and price declines in relation to cloud services.

Investment – future potential

Investment by tech companies has skyrocketed, with around 80 per cent of the total driven by data centers.

Microsoft, Alphabet, Amazon and Meta have reported combined capital expenditure of $246bn in 2024, up 63% from $151bn in 2023. They forecast spending could exceed $320bn in 2025.[22]

However, whilst cloud computing is rising rapidly in importance, cloud computing and the growth contribution of cloud computing is not necessarily reflected fully in national accounting data.

[18] The Economist, October 2023, Why companies still want in-house data centres. *https://www.economist.com/business/2023/10/05/why-companies-still-want-in-house-data-centres*
[19] BT Group, February 2024. BT Group advances AI-enhanced product development with Amazon CodeWhisperer. *https://newsroom.bt.com/bt-group-advances-ai-enhanced-product-development-with-amazon-codewhisperer/*
[20] FT, October 2024, Second-hand success story Vinted plans to expand beyond clothing. *https://www.ft.com/content/89240b0c-8921-4ba3-a3ea-128711eeae93*
[21] Okta, Vinted: Quickly setting up new employees for success with an Okta-powered infrastructure. *https://www.okta.com/uk/customers/vinted/*
[22] FT, February 2025, Big Tech lines up over $300bn in AI spending for 2025. *https://www.ft.com/content/634b7ec5-10c3-44d3-ae49-2a5b9ad566fa*

Historical research highlights the difference fully capturing the contribution of cloud computing could make. Capital expenditures at hyperscale cloud service providers in the US rose at an annual rate of 21 percent during 2010 to 2015, but not all of this is necessarily captured in the US national accounts.[23]

Nominal IT equipment and software investment may have been $58 billion higher in 2015 than in the official estimates, implying additional growth in investment of 2 percent per annum during the period 2007-2015. Allowing for this would add 0.3 percent per annum to GDP growth during the period.

Price decline – more volume for spend

For AWS the price for compute fell at an average rate of about 7 percent per annum during 2000-2016, for their database product, prices fell at an average rate of more than 11 percent per annum during 2009-16; and for storage by 17 percent per annum during 2009-2016.[24]

Ongoing unit price declines drive cloud adoption and imply more rapid volume growth than revenue growth. This reinforces the conclusion that cloud is, and will, have a substantial impact in terms of digital transformation.

Growth has accelerated with the growth of AI underpinned by cloud. These shifts are also not fully reflected in national accounting.[25] [26] The AI driven transformation of cloud is considered further in the following section.

[23] Bryne, Corrado and Sichel, 2018, The rise of cloud computing: minding your P's, Q's and K's. *https://www.nber.org/system/files/working_papers/w25188/w25188.pdf*

[24] Bryne, Corrado and Sichel, 2018, The rise of cloud computing: minding your P's, Q's and K's. *https://www.nber.org/system/files/working_papers/w25188/w25188.pdf*

[25] Byrne, 2022, The Digital Economy and Productivity. *https://www.federalreserve.gov/econres/feds/files/2022038pap.pdf*

[26] Corrado, Haskel and Jona-Lasinio, 2021, Artificial intelligence and productivity: an intangible assets approach. Oxford Review of Economic Policy, Volume 37, Number 3. *https://academic.oup.com/oxrep/article/37/3/435/6374681*

4. Cloud market transformation

The demand for AI model training and inference is both stimulating and changing the cloud market.

There are several considerations at play. The scale of investment in AI related compute, the type of compute required, shifts in the market and uncertainty over the role of cloud versus edge computing.

One thing is clear, the future cloud market will look different to the existing market, and current cloud revenues, market shares and growth rates are likely to prove poor predictors for the near-term future.

Scale

Aschenbrenner (2024)[27] projects AI data centre compute increasing by an order of magnitude (OOM) every two years and AI capability scaling with successive orders of magnitude of compute.

Further, gains in model 'intelligence' are continuing via expanded run-time compute, whilst agentic models may require multiple calls on compute. The range of applications and number of user queries can also be expected to grow.

Inference is expected to overtake training as the main driver of compute requirements for AI; and a substantial amount, but not all, of inference will be cloud based. Cloud is a key building block for AI, and AI is changing the cloud market.

Jevons paradox

An argument has been made that the claimed low compute cost of AI model DeepSeek signalled lower demand for computing power. DeepSeek may not in fact have been an outlier in terms of efficiency trends[28], however the broader question regarding the impact of improvements in model performance and efficiency deserves consideration.

In relation to efficiency gains, a counterargument is that efficiency gains will stimulate demand by lowering costs. The fact that efficiency gains may see increased use is known as Jevons paradox (based on the historical observation that as steam engines became more efficient demand for coal grew rather than declined).

The demand stimulus from efficiency gains for existing uses of cloud and AI would not necessarily be sufficient to grow overall use of compute. However, AI models are becoming more capable as well as more efficient, opening new use cases.

Expect demand for compute to continue to scale driven both by efficiency gains and cost declines and the expansion of use cases.[29]

Compute pivot

With the growth of AI, a different computing mix is required, more oriented towards graphics (and tensor) processing units (GPU's and TPU's) than general purpose central processing units (CPU's).

[27] Leopold Aschenbrenner, June 2024, SITUATIONAL AWARENESS: The Decade Ahead. *https://www.forourposterity.com/situational-awareness-the-decade-ahead/*

[28] Semianalysis, January 2025, DeepSeek Debates: Chinese Leadership On Cost, True Training Cost, Closed Model Margin Impacts. *https://semianalysis.com/2025/01/31/deepseek-debates/*

[29] The Economist, February 2025, The data-centre investment spree shows no signs of stopping. *https://www.economist.com/business/2025/02/05/the-data-centre-investment-spree-shows-no-signs-of-stopping*

NVIDIA, building on its experience in the gaming market (which is graphics intensive), developed specialised AI related processing units and is a near near-term beneficiary of this shift. Hyperscalers have also developed their own specialised chip and server designs.

Entry and transformation

Whilst the investment by hyperscalers related to AI and associated compute is vast[30], they are not the only participants in this rapidly expanding market.

Oracle have pivoted into cloud infrastructure provision for AI[31], Tesla have built a large AI compute facility; whilst Coreweave, who specialise in high-performance computing, are expanding rapidly.

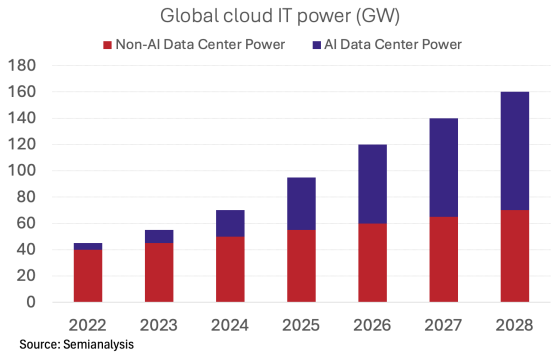
Coreweave plan to invest $2.2bn to build data centres in Norway, Sweden and Spain by the end of 2025, and have committed $1.3bn for two facilities in the UK.[32]

Others are also investing in cloud infrastructure, to support AI-related startup and scale-ups, including the EU which has made high performance computing infrastructure available for AI developers.[33]

Cloud revenues do not yet fully reflect these developments, since investment in AI has been made ahead of anticipated revenues. One approach to gauging the scale of the transformation underway is to look at projections of IT power needs of AI-related versus non-AI related data centre workloads.

Data centre IT power demand will double from about 49 GW in 2023 to 96 GW by 2026, with 90 per cent of the growth coming from AI-related demand (Figure 3).[34]

Figure 3: Data centre IT power consumption



AI will flip the industry from dominance by non-AI compute to around two-thirds AI related computing by 2028. Realignment of the market can be expected, including opportunities for entrants.

Edge versus cloud

For training purposes compute need not necessarily be close to end users. The opportunity to build quickly, and availability of electricity at scale, are key considerations.

For inference, latency, and therefore proximity to users, may matter. It matters for a voice chat, much less so for an agentic or long inference task delegated to AI.

Large models can also be distilled into smaller models that run locally, and some inference will happen at the device.

[30] FT, October 2024, Corporate wizards out-magic the muggles. *https://www.ft.com/content/3962f1f1-b669-4945-92d5-c2fdc107c0fb*
[31] FT, September 2024, The $200bn man: Larry Ellison's wealth rebounds as Oracle joins AI boom. *https://www.ft.com/content/a2834bdd-0ed5-45ef-9708-d9b7195a57ee*
[32] FT, June 2024, How an upstart is using its Nvidia ties to challenge cloud computing giants.
[33] EU, November 2023, Commission opens access to EU supercomputers to speed up artificial intelligence development. *https://digital-strategy.ec.europa.eu/en/news/commission-opens-access-eu-supercomputers-speed-artificial-intelligence-development*
[34] Semianalysis, March 2024, AI Datacenter Energy Dilemma – Race for AI Datacenter Space. *https://semianalysis.com/2024/03/13/ai-datacenter-energy-dilemma-race/*

For a round-trip latency requirement of 50 ms for 'real-time' consumer applications, a server placement within 2000-4000 km of the user is likely adequate. A modest number of data centres would be needed to meet this requirement across the EU.

Local device-based inference at the 'edge' reduces dependency on connectivity, reduces latency and may assure privacy. However local inference may be less efficient, general or capable, which matters for some applications but not others.

Some users will also run AI inference on local dedicated hardware. For example, protein structure prediction tool Alpha-Fold2 is available via the cloud or locally utilising a powerful workstation.

For very low latency applications such as autonomous vehicles, inference is likely to be on-board the vehicle (continuous connectivity may also be viewed as a security risk[35]).

Compute will therefore be distributed globally for non-latency critical applications including training and long inference time tasks, nationally for responsive consumer applications and at the device for applications, such as autonomous vehicles, that depend on very low latency and secure and continuous inference (a requirement mobile networks are unable to meet).

[35] FT, January 2017, Google keeps self-driving cars offline to hinder hackers. *https://www.ft.com/content/8eff8fbe-d6f0-11e6-944b-e7eb37a6aa8e*

5. Cloud as a catalyst for input market dynamism

Cloud computing utilises inputs including connectivity, chips and electricity.

Whilst some view growth in demand for inputs with concern, it is stimulating investment in areas that may not only be of strategic value nationally and EU-wide, but which are also likely to help the green transition.

The complementary nature of demand from cloud providers and their willingness to make long-term commitments with suppliers are driving positive changes in adjacent markets.

Connectivity

Connectivity is a strategic priority in the EU, with targets for fixed and mobile connectivity. Substantial progress has been made, though it is now recognised that adoption rather than supply may constrain investment.

Cloud based applications are complementary to investment in connectivity, since they stimulate demand and willingness to pay, thereby improving the case for network investment.

Chips

Production of state of the art chips requires enormous up-front investment and is therefore only feasible at scale in a limited number of locations globally.

The demand for chips from growth in cloud infrastructure and AI is encouraging the development of competing processors[36], and investment in new chip fabrication facilities.

Following the EU Chips Act, a new chip fabrication facility is under construction by TSMC in Dresden in collaboration with Bosch, Infineon and NXP.

Green transition

We are accustomed to viewing energy demand as part of the challenge of de-carbonisation. However, there are two reasons to flip this logic on its head.

First, data centres are seeking carbon-free electricity at scale and can enter commitments that help bring forward the innovation and financing needed.[37] [38] [39]

Second, data centres and AI are helping the green transition by accelerating progress around energy efficiency optimisation and innovation in relation to carbon free energy production[40] and storage[41].

[36] FT, November 2024, Amazon steps up effort to build AI chips that can rival Nvidia. *https://www.ft.com/content/3d9b5c6d-f1ae-4f6f-adc3-51e5f1dfb008*

[37] The Economist, January 2024, *https://www.economist.com/technology-quarterly/2024/01/29/data-centres-improved-greatly-in-energy-efficiency-as-they-grew-massively-larger*. *https://www.economist.com/technology-quarterly/2024/01/29/data-centres-improved-greatly-in-energy-efficiency-as-they-grew-massively-larger*

[38] Reuters, March 2023, Microsoft signs power purchase deal with nuclear fusion company Helion. *https://www.reuters.com/technology/microsoft-buy-power-nuclear-fusion-company-helion-2023-05-10/*

[39] Reuters, November 2024, France's EDF in talks on deals to power three 1GW data centres. *https://www.reuters.com/business/energy/frances-edf-talks-deals-power-three-1gw-data-centres-2024-11-07/*

[40] Meftahi *et al*, October 2023, Machine Learning Enhanced High-Throughput Fabrication and Optimization of Quasi-2D Ruddlesden–Popper Perovskite Solar Cells, Advanced Energy Materials, Volume 13 (38). *https://onlinelibrary.wiley.com/doi/10.1002/aenm.202203859*

[41] Chen *et al*, January 2024, Accelerating computational materials discovery with artificial intelligence and cloud high-performance computing: from large-scale screening to experimental validation. *https://arxiv.org/abs/2401.04070*

6. Policy

The focus here is on policy in relation to cloud, and clouds benefits and its enablers. Linkage to the Draghi report and Europe's Digital Decade targets is made.

The Draghi report

The Draghi report argues that "*the productivity gap between the EU and the US is largely explained by the tech sector.*"

Further the report argues that to digitise and decarbonise the economy and increase the EU's defence capacity an increase in investment of around 5 percentage points of GDP is required.

To meet these challenges the report proposes more support for innovation and investment, more single market and reduced barriers to scaling (though more regulation is proposed in some areas of digital).

The emphasis tends towards production of ICT, rather than use of ICT services, and towards improving returns to telecoms, but potentially at the expense of the rest of the tech industry.

In relation to cloud the focus is on the EU's competitive disadvantage in the provision of cloud, and a weak cloud sector hindering innovation in adjacent fields, such as pharma, energy, materials and defence.

Whilst it is seen as too late to develop a systematic challenge to US cloud providers, the report argues that the EU should ensure that it has a competitive domestic industry that can meet the demand for "sovereign cloud" solutions.

The linkage between cloud and AI is highlighted, and the report argues for cross-industry coordination and data sharing to accelerate the integration of AI into European industry.

Europe's Digital Decade targets for 2030

Europe's Digital Decade targets for 2030 include two sets of targets that are particularly relevant to this study, namely those for infrastructure and digital transformation of business:[42]

Secure and sustainable digital infrastructures

- Connectivity: Gigabit for everyone
- Cutting edge Semiconductors: double EU share in global production
- Data - Edge & Cloud: 10,000 climate-neutral highly secure edge nodes
- Computing: first computer with quantum acceleration

Digital transformation of businesses

- Tech up-take: 75% of EU companies using Cloud, AI, or Big Data
- Innovators: grow scale-ups & finance to double EU Unicorns
- Late adopters: more than 90% of SMEs reach at least a basic level of digital intensity

The EU also has the goal of reducing over-reliance on digital solutions created elsewhere.

Provision versus use as productivity drivers

In contrast to the Draghi reports focus on tech *per se*, and European tech in particular, the greatest potential to benefit from tech comes

[42] Europe's Digital Decade: digital targets for 2030. *https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en*

from the use of tech services throughout the economy.

An implication of this is that it is crucial that the best available tech services are available within the EU and can respond and scale in relation to demand.

Even if the goal is narrow, say to foster European tech startups, then the conclusion is the same, since the success of the startup is dependent on the quality and availability of tech building blocks including cloud.

Scale and financing for cloud

The Draghi report proposes that public funding be utilised to complement private investment in tech. However public funds will be scarce and are most unlikely to be available at the scale required for connectivity, cloud and AI.

Investment by big tech in cloud and AI during 2025 is projected to be around $300 billion.[43] Ensuring the market is conducive to private investment is therefore key to achieving the goal of digitalisation and of raising EU productivity growth.

Further, taxing one part of tech to fund another, as Draghi suggests, would be expected to prove counterproductive, because it would diminish the ecosystem overall.

The evolution of cloud

Cloud is growing rapidly and evolving. A pivot towards AI is underway (requiring a different compute mix and larger compute clusters), alongside device based inference e.g. smartphone or autonomous vehicle.

The precise evolution is highly uncertain since AI is a comparatively new market and it is unclear how the optimal location mix for compute will evolve between cloud, edge cloud and device.

The demand for edge-computing, and compute embedded within networks, is particularly unclear. The Body of European Regulators for Electronic Communications (BEREC) note, based on consultation feedback, that:[44]

"*edge computing has a limited business case*"

Given this, it would be wise to allow device, edge and cloud-based compute to evolve in response to supply and demand, rather than take a prior view regarding the need for 10,000 edge nodes by 2030.

Sovereign versus global cloud

Policy makers in nations or regions including the EU may wish to keep some compute and/or data within their borders/region for reasons of privacy or strategic autonomy (beyond what customers themselves might demand).

Specific providers may also be precluded from providing specific equipment or services on national security grounds.[45]

Cloud providers offer solutions designed to meet such requirements. For example, AWS

[43] DCD, November 2024, Morgan Stanley: Hyperscaler capex to reach $300bn in 2025. https://www.datacenterdynamics.com/en/news/morgan-stanley-hyperscaler-capex-to-reach-300bn-in-2025/

[44] BEREC, October 2024, Report on the outcome of the public consultation on the draft BEREC Report on Cloud and Edge Computing Services. https://www.berec.europa.eu/en/all-documents/berec/reports/berec-report-on-the-outcome-of-the-public-consultation-on-the-draft-berec-report-on-cloud-and-edge-computing-services

[45] Euronews, September 2024, Eleven EU countries took 5G security measures to ban Huawei, ZTE. https://www.euronews.com/next/2024/08/12/eleven-eu-countries-took-5g-security-measures-to-ban-huawei-zte

will offer a sovereign cloud in EU,[46] and plans to invest €7.8 billion into AWS European Sovereign Cloud.[47]

Sunk investments by tech companies in the EU also provide assurance that they are committed to the market.[48]

Technical solutions can also enable privacy for AI queries and responses to be assured, irrespective of the location of compute. If the concern is privacy, security and robustness to interception, technical means may be available that do not require localisation.[49] [50]

Privacy and security may be addressed by agreements regarding data processing with trusted partners, technical solutions (encryption, private cloud compute) and localisation. Local ownership is neither necessary, nor sufficient, for privacy.

Non-localisation of data may also offer security or redundancy, as illustrated in the case of Ukraine. Ukrainian law required most government data and certain private data to be housed on servers in Ukraine. However, in February 2022 the law was changed to allow transfer of data outside of Ukraine, and essential data was transferred - in suitcase-sized solid-state computer storage units – to Amazon's cloud computing system outside of Ukraine.[51]

The EU does not wish to be dependent on others in ways that involve unacceptable risks to privacy or security. However, with resource constraints and advantages in some areas and disadvantages in others, priorities for relative autonomy need to be carefully assessed. As Draghi commented:

" some digital sectors are likely already "lost", Europe still has an opportunity to capitalise on future waves of digital innovation. The EU's competitive disadvantage will likely widen in cloud computing, as the market is characterised by continuous massive investments, economies of scale and multiple services offered by a single provider."

The key to achieving autonomy goals is to be precise and focussed about the concern, to aim to address it in a least cost manner and to recognise trade-offs and be realistic about where Europe's advantage lies whilst not compromising the benefits from openness to global technology services.

Unnecessarily promoting local but potentially less efficient cloud provision would compromise the aim of 75% of EU companies using Cloud, AI, or Big Data; and of growing scale-ups who can avoid compute related up-front financing costs and gain flexibility from a vibrant cloud market. An efficient and responsive cloud market is also valuable for SMEs who lack the in-house expertise to reach a basic, or more advanced, level of digital intensity.

Finally, given the growth in demand for electricity for cloud services and AI to support

[46] Garmen and Peterson, October 2024, AWS Digital Sovereignty Pledge: Announcing a new, independent sovereign cloud in Europe. *https://aws.amazon.com/blogs/security/aws-digital-sovereignty-pledge-announcing-a-new-independent-sovereign-cloud-in-europe/*

[47] Amazon, May 2024, AWS plans to invest €7.8 billion into the AWS European Sovereign Cloud. *https://www.aboutamazon.eu/news/aws/aws-plans-to-invest-7-8-billion-into-the-aws-european-sovereign-cloud* ma

[48] ECIPE, 2024, ICT Beyond Borders: The Integral Role of US Tech in Europe's Digital Economy. *https://ecipe.org/wp-content/uploads/2024/03/ECI_24_PolicyBrief_06-2024_LY03.pdf*

[49] Apple, June 2024, Private Cloud Compute: A new frontier for AI privacy in the cloud. *https://security.apple.com/blog/private-cloud-compute/*

[50] Apple, October 2024, Security research on Private Cloud Compute. *https://security.apple.com/blog/pcc-security-research/*

[51] Los Angeles Times, December 2022, How Amazon put Ukraine's 'government in a box' — and saved its economy from Russia. *https://www.latimes.com/business/story/2022-12-15/amazon-ukraine-war-cloud-data*

digitalisation of the economy, and constraints on electricity availability in the EU (including the shut-down of some nuclear capacity), the trade-off involved with overly strict localisation requirements may include a shortage of cloud capacity. Openness to trade in cloud and AI services is likely to be essential to meet demand in the EU.

Cybersecurity

Cybersecurity is a significant threat in relation to digitalisation, and cloud services can offer robust security. A unified set of standards could be beneficial for the market and EU integration, however, differences over the preferred approach have delayed adoption of the so-called European Cybersecurity Certification Scheme for Cloud Services (EUCS).[52]

The approach to cybersecurity should remain open to all market participants without introducing discriminatory requirements against non-EU cloud vendors. Indeed, a protectionist approach including data localisation could undermine security by limiting cross border sharing of threat intelligence. An open and non-discriminatory approach to cybersecurity should be pursued.

Cloud enablers

Investment in cloud is dependent on demand, regulatory permitting to build cloud infrastructure, openness to investment by global cloud providers and availability of inputs including connectivity, chips and electricity.

Demand

Focusing on demand, tech up-take by EU companies and governments is a key enabler, and cloud - by simplifying digital transformation via services – is in turn an enabler of digital transformation. Demand for cloud and digital transformation are complements.

Permitting

The time required to gain permission to build cloud infrastructure can be out of step with the pace of change in the industry. The EU Gigabit Instructure Act 2024 includes provision designed to facilitate permitting for networks, but not cloud, infrastructure. The UK Government has proposed permitting reforms for data centers.[53]

Chips

Chips are available from global providers, however greater demand for chips improves the viability of diverse supply, including within the EU.

Connectivity

Cloud services require connectivity, and connectivity requires applications to create the willingness to pay needed to monetise investments in connectivity. Cloud services will also be utilised to improve the efficiency of connectivity providers.

However, these considerations do not imply that the services are in some sense converging and should be subject to the same regulation.[54] Cloud computing and pharmaceuticals development also overlap, but it would make no sense to propose similar regulation for the two.

[52] Alex Roure, October 2024, The EUCS Saga: Europe Cannot Afford to Further Delay Its Cybersecurity Framework. *https://project-disco.org/european-union/europe-cannot-delay-its-cybersecurity-framework/*

[53] UK Government, September 2024, Proposed reforms to the National Planning Policy Framework and other changes to the planning system. *https://www.gov.uk/government/consultations/proposed-reforms-to-the-national-planning-policy-framework-and-other-changes-to-the-planning-system/proposed-reforms-to-the-national-planning-policy-framework-and-other-changes-to-the-planning-system*

[54] Analysys Mason, September 2024, The European telecoms regulatory framework: not a good fit for the public cloud. *https://www.analysysmason.com/consulting/reports/eu-cloud-telecoms-regulation/*

Even within the telecoms sector different regulatory approaches are applied to infrastructure (conditional on the level of competition) and services, to fixed versus mobile and to fixed incumbents versus entrants.

Appropriate regulation should depend on the specific issues arising in different sectors and the extent of competition in specific markets. It is not useful to suggest that the same regulation should apply to different services, rather an analysis of specific problems and markets is required.

Further, the complementarity of cloud and telecoms also does not imply – as some have argued - that mandated (or arbitrated) data related fees should flow from one party to the other. Cloud and telcos engage in free peering and pay commercial fees for the use of one another's services. The market for data transit and interconnection generally works well.[55]

Further, cloud providers are intermediaries, allowing customers to cache content close to end users who request it via applications.

Introducing traffic related fees would reduce use of applications and demand for networks, thereby harming the investment case in relation to cloud and networks.

The pursuit of gigabit connectivity for everyone should not come at the price of compromising the supply and business and consumer demand for cloud-based applications.

Electricity

Cloud computing requires electricity. To ensure the efficient use of cloud infrastructure high utilization is required, necessitating near continuous, or baseload, electricity.

To meet the needs of large AI training and inference clusters - 100's of MW's, even GW's – of electricity may be required at a single location; potentially introducing grid constraints or requiring co-location of generation and compute.

As a matter of policy, and cloud provider preference, de-carbonisation of electricity generation is an objective.

Historically cloud providers have stimulated demand for renewables, and tech companies are by far the biggest buyers of green energy by means of power-purchase agreements.[56] However, to meet the need for continuous supply of electricity at scale in the near term, there is growing interest in securing existing nuclear supply and bringing forward new nuclear including small modular reactors and prospectively nuclear fusion.

From a policy perspective it is therefore important to focus on de-carbonisation rather than renewables *per se*, and to focus on allowing the supply side to respond rather than constraining demand.

Rather than viewing demand growth as adding to the challenge of de-carbonisation, it should be viewed as an opportunity to stimulate and finance investment and innovation in relation to green energy supply.

The risk from over-regulation and the opportunity from getting it right

The availability, rather than source, of high-quality cloud and AI services at scale is key to achieving higher productivity growth in

[55] BEREC, June 2024, BEREC Report on the IP Interconnection Ecosystem. *https://www.berec.europa.eu/system/files/2024-06/BoR%20%2824%29%2093_draft%20BEREC%20Report%20on%20the%20IP-IC%20ecosystem_1.pdf*

[56] The Economist, January 2024, Data centres improved greatly in energy efficiency as they grew massively larger. *https://www.economist.com/technology-quarterly/2024/01/29/data-centres-improved-greatly-in-energy-efficiency-as-they-grew-massively-larger*

Europe, and to supporting scientific and technical progress.

To address Europe's challenges including an ageing population, de-carbonisation and security, higher productivity growth and innovation is necessary.

In relation to productivity growth the Draghi report notes that:

"…a 2% increase in the level of TFP within ten years could already be sufficient to cover up to one third of the fiscal spending (investment subsidies and government investment) required to implement the plan."

Namely, an increase in productivity growth of 0.2% per annum is material over a decade, and a 0.2% deficit in productivity growth is within the bounds of the plausible impact of over-regulation of cloud.

Cloud-AI can be thought of intelligence which complements human labour. This is valuable, given the anticipated decline in the working age population in Europe.

Cloud and AI will also support focused innovation in areas that will help manage the challenges of an ageing population, de-carbonisation and security.

Over-regulation, and barriers to trade in cloud and AI services, could therefore cause significant harm. The EU has legitimate values and interests it wishes to protect; however, the approach should be focused so as not to undermine digitalisation.

The risk is not just that marginally higher cost or lower quality cloud and AI services are available; but that the services required by EU enterprise, government and the scientific community may not be available; or may not be available at the scale required.

One or more of the inputs for scaling cloud and AI - electricity, skills, capital, and permission to build - may be constrained, particularly in the near-term.

The flexibility to utilise the best available cloud and AI services is therefore essential if digitalisation is to proceed at the pace required to support productivity growth, innovation and the global competitiveness of European industry.