Trends in Digital Markets

A CMA Horizon Scanning Report

14 December 2023

Foreword

The CMA's 2023 Annual Plan represented a step-change in our strategic approach, laying a strong foundation for us to meet future challenges and deliver the next decade of value for those we serve. Core to this is an investment in the capabilities we need to operate as a modern, agile authority amidst an increasingly turbulent external landscape. From macro-economic and geopolitical uncertainty, to the relentless drumbeat of technology innovation, understanding and anticipating shifts in our operating environment has never been more critical. We are evolving and expanding our horizon scanning capabilities in response to this need, investing across people, skills, systems, and tools.

Our Technology Horizon Scanning Function, co-led by our DaTA and Digital Markets Units, has been an early forerunner of this work over recent years. Responding to the pace and systemic impact of change in technology markets, the function has produced a broad sweep of analysis (both internally and through the Digital Regulation Coordination Forum) across Web3, quantum computing, virtual reality and other emerging technologies. Most recently, the impetus for the CMA's pro-active early review of the nascent market for foundation models originated from within this function. That report takes a notably forward-looking perspective, recognising that this is an extremely fast-paced, innovation-led market, characterised by high levels of disruption in both the emerging business models and the technologies themselves.

This forward-looking approach is equally critical in digital markets, with rapid transformation underway across multiple sectors and consumers interacting with a vast and evolving array of products and services every day. Today, more than ever, the CMA must be on the front foot of changes in the digital economy and I am proud to be launching the 'Trends in Digital Markets' report in that spirit.

This report marks the first publication from the Technology Horizon Scanning Function and, as such, is markedly different from other CMA publications. Our aim is to draw on available evidence to discuss and present possible future developments and potential implications for competition and consumers. By its nature, our exploration of potential future developments is neither fully comprehensive, nor foolproof. Nor should the emerging thinking in this report be taken as any form of CMA position, policy, or conclusion but rather as an exploration of what may be important in these markets in the coming years. We may revisit these trends in future work and new evidence might emerge. Equally, others conducting their own analyses may arrive at different possible implications for the same trends or could choose to prioritise different ones.

Finally, we have drawn on invaluable external expertise from the CMA's Digital Expert Group, and others, during the production of this work, for which I would like to express our heartfelt thanks. The fast-moving and systemic nature of digital and broader technology markets warrants a collaborative, open dialogue amongst a broad range of stakeholders and I hope that this report will promote many such constructive discussions.

Sarah Cardell

Chief Executive

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Executive summary

1. Digitalisation continues to transform every sector of the UK and global economy, and as such what can be considered 'digital' is constantly evolving. It is more important than ever for us as the UK's principal competition and consumer protection authority to be on the front foot in understanding how markets are changing and what the implications and impacts of those changes might be. The CMA conducts a range of scanning activities across the organisation to identify areas of interest across the economy both digital and non-digital. As part of that, the horizon scanning function of the Data, Technology and Analytics unit and Digital Markets Unit is focused predominantly on digital and technology.

2. Our first 'Trends in Digital Markets' report examines ten trends which we believe will have an impact for and in digital markets over the next five years and beyond. We identified these trends through a horizon scanning process that involved collecting and collating trends from a variety of sources, including a survey with experts from a broad range of fields and expertise, and primary scanning of news sources and reports. The trends were prioritised using a set of criteria specific to the strategic priorities of the CMA to select the final list of ten. Each chapter of the report focusses on one trend and has been produced through a combination of desk research, consultation with experts, and evidence gathered during our scan. More information on methodology is in Annex A.

3. Some of the trends we've prioritised may be more or less surprising depending on expertise or knowledge, but we hope that even where they are less surprising, we have provided interesting explorations of what may happen in the future given the current context. Many of the trends we highlight also have common themes and challenges as well as similar benefits. For example, the trend on increasing technology convergence overlaps with platform integration and with technology firms moving into new markets. Similarly, many of the trends (including trends that were highlighted in our scan but are not discussed in detail in the report, see Annex B) are likely to have considerable connections to foundational or enabling technologies such as Artificial Intelligence (AI).

4. This report is not intended to be a comprehensive review of all trends in digital markets, or even of each trend we have explored given the uncertainty of future developments, nor does it reflect any legal or policy position from the CMA. Rather, it sets out some exploratory thinking. The CMA will continue to explore these issues and use these trends to future-proof our thinking about markets and how they might change. We will continue to engage on these trends and related issues through the Digital Regulation Cooperation Forum, our next CMA DaTA Conference, and other domestic and international fora. Our horizon scanning work could also help inform our implementation of the future digital markets regime, as and when the legislation is passed.

5. Each chapter sets out the signals and evidence about the given trend, possible future developments, and how the trend might impact competition and consumers. Below is a brief overview of each trend:

Trend 1: Rapid and widespread deployment of AI Foundation Models

Foundation models (FMs) are a type of AI technology that are trained on very large datasets that can be adapted to a wide range of tasks and operations. We published our 'AI Foundation Models: initial review' in September 2023 to help create an early understanding of the market for FMs and how their use could evolve. This chapter gives an overview of the work undertaken in the FM review, exploring how the deployment of FMs could result in harms to competition and consumers if larger firms are able to leverage access to key inputs for FM development and if they are able to leverage their positions in downstream markets where FMs are deployed.

Trend 2: Increasing technology convergence enables the creation of new and disruptive products and services

Technology convergence (TC), when two or more existing technologies are combined, is not new, but it is possible that the development and ubiquity of digital and enabling technologies, such as the internet, have enabled TC to happen more and on a bigger scale. It is likely that this could be even more pronounced with the development and integration of other enabling and general-purpose technologies such as AI. There are potential benefits for competition and consumers but also potential risks that regulators may need to be aware of, such as market disruption or the ability of some firms to leverage existing capabilities, though we found limited information on competition and consumer elements from the literature during our research. However, utilising techniques and tools that can help policy makers and regulators better anticipate TC could be beneficial. This might include foresight techniques as well as data science and AI. Being on the 'front foot' of TC may help to ensure the benefits of new technologies and new markets are maximised and the risks minimised.

Trend 3: Digital platforms increasingly integrate additional services

There is an emerging trend towards greater platform integration, which could develop in a variety of ways. Whilst it may bring convenience to consumers, this trend could also raise potential concerns from consumer lock-in and competition, to data privacy. The 'app-in-app' approach appears to challenge app stores' roles as gateways to apps, and indeed incumbents seem to invest in developments to anticipate such changes.

Trend 4: Digital firms continue to raise prices for API access

Firms' decisions to adjust their Application Programming Interface (API) prices may influence user and developer access to certain features, notably for third-party app ecosystems and foundation model training. For firms, tiered pricing could encourage them to refine their primary offerings, innovating to consolidate platform value. Maintaining a balance between accessibility and innovation is likely to be increasingly important.

Trend 5: Growing incumbent and new entrant activity in the markets for CPUs, GPUs and AI accelerators

The microchip industry, particularly the microchip design section of the industry supply chain, may be heading into a period of significant change. This change may be driven by innovation by incumbents and arrival of new entrants in core logic chip markets, including markets for central processing units (CPUs), graphics processing unit (GPUs), and AI accelerators. These new entrants may not meaningfully disrupt the wider market or could possibly be subsumed in future industry consolidation. Alternatively, if some of the larger technology companies succeed in creating competitive products, there may be potential risks arising from vertical integration. Overall, if these developments result in increased competition, the result may be cheaper and more innovative microchips, benefitting the entire digital economy.

Trend 6: Interoperability improvements are uneven but remain an important driver of market outcomes

Interoperability in digital markets has been improving through regulatory intervention and industry initiatives, though it may be constrained in some markets due to technical factors and market incentives. It continues to be an important aspect of effective competition in digital markets. It is a powerful force in preventing market 'tipping' and preventing the leveraging of vertically integrated platforms into new markets. The overall benefits of developments that might increase interoperability will depend on the trade-offs involved, which may need to be considered on a case-by-case basis.

Trend 7: Larger technology firms continue to expand into new markets

Larger firms moving into new markets could apply across numerous sectors, including finance, energy, and health. We have focused on 'HealthTech' as this sector came out most prominently in our scanning. There are opportunities for new technologies or treatments in health that may be enabled by the involvement of larger firms who might have access to data, technologies, or computing power. This in turn could lower costs but could also pose competition risks. There are also potential consumer issues such as data privacy, algorithmic biases, and the reliability of new technologies.

Trend 8: Increased application of digital twins

Digital twin markets have seen notable growth in recent years. Their applications range from city-scale modelling for improved disaster management to individual health monitoring. Digital twins may create opportunities for new services and for new entrants, although firms with existing capabilities and resources may be in a stronger position to benefit. There can be consumer benefit but also challenges which include issues of data privacy, potential for misuse, and limited interoperability.

Trend 9: Increased development and usage of open-source software and hardware

Open-source software has shaped modern software infrastructure and helped create a dynamic digital economy, potentially lowering barriers to entry by providing critical inputs, reducing total costs of ownership, and preventing vendor lock-in. Now, open-source hardware development and usage is gathering pace. This brings the prospect of increased benefits to consumers and competition. However, there remain some concerns over how open-source functions, particularly in sustaining how open-source projects are maintained, and in ensuring they are fairly advertised. These difficulties are not insurmountable, and if addressed the full benefits of open source may continue to be felt across digital markets.

Trend 10: Consumers continue to want personalised experiences but remain conscious of how their data is used

While many people like tailored online products and services, many are also worried about how their data is used and want to have some control over it. In future, experiences, products, and services could be increasingly personalised, or conversely this trend could stagnate or slow if concerns about privacy and data use become more prevalent. Developments such as privacy enhancing technologies could potentially help balance efficiencies, competition, and privacy.

Background and overview

6. As the UK's principal competition and consumer protection authority, the Competition and Markets Authority (CMA) seeks to promote an environment where people can be confident they are getting great choices and fair deals, that competitive, fair-dealing businesses can innovate and thrive, and the whole UK economy can grow productively and sustainably. The CMA is therefore fully invested in understanding not just the technologies and markets of today but also to think about the new technologies and markets that may emerge in the future.

7. To ensure we are on the front foot as an organisation we have invested in growing our capabilities to keep pace with technological and digital developments. Alongside creating our Data, Technology and Analytics Unit (DaTA unit)[2] we have been investing in growing our futures capability and conducting a range of 'horizon scanning' activities – broadly defined as using methods and tools to look ahead with the purpose to identify the strategic issues that will be important in the future. In particular, our DaTA unit and our Digital Markets Unit (DMU) have established a horizon scanning function that has to date focussed on emerging technologies. In 2022, the DaTA-DMU horizon scanning function identified AI foundation models as an important emerging technology; this was essential for the decision to launch, and preparation towards, our AI Foundation Models initial review.[3] Our horizon scanning and futures experts also use futures and foresight tools across the organisation on a range of topics and issues, including conducting scenario planning, and contributing to the horizon scanning work of the Digital Regulation Cooperation Forum (DRCF).[4] This horizon scanning work will continue to be important, including to inform our implementation of the future digital markets regime, as and when the legislation is passed by Parliament.[5]

8. During 2023, the horizon scanning function focussed on trends in digital markets which has culminated in this 'Trends in Digital Markets' report. For the purposes of the report, we use the term 'digital markets' in a broad sense to include markets which could already be considered 'digital' and technology businesses and markets in the process of digitalisation. The trends we present are the result of a scanning exercise involving wide-ranging research and input from multiple experts, including from the recently appointed CMA Digital Expert Group.[6]

9. We present here the implications of what could be significant trends in digital markets in the next five years and beyond. This shortlist follows a prioritisation process designed to highlight those trends with greater strategic importance to the CMA, considering their potential impact on competition and on consumers. Through this work we indicate our exploratory thinking and our ambition to help shape markets in a way that maximises benefits and minimises harms for consumers. As with any work that uses futures and foresight tools such as horizon scanning, the aim is not to predict but rather to explore possible future developments and their implications.

10. Each chapter of the report focusses on one trend and is based on a combination of desk research, feedback from experts, and evidence compiled during our scan. They each set out the signals[7] and evidence about the trend, possible future developments and how the trend might impact competition and consumers. Summaries of the trends are provided in the executive summary.

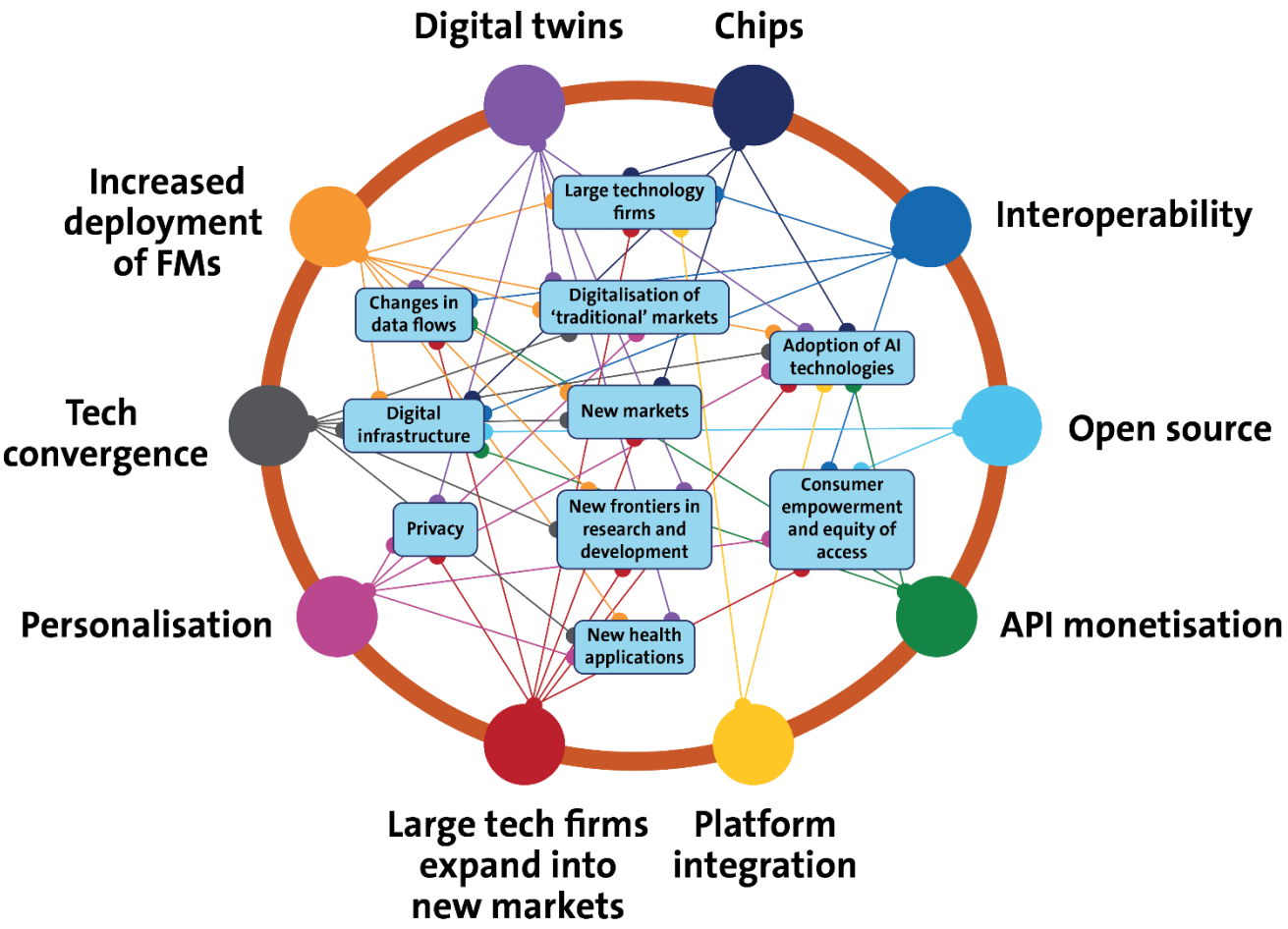
11. We recognise that these trends are situated within larger complex and dynamic systems. As such, where possible, we have noted some common observations and challenges across them. In particular, large incumbent technology firms, with their digital capabilities and infrastructure, appear well placed to respond to and

disproportionately benefit from a number of these trends. The impacts on consumers are likely to be complex, and maximising benefits and minimising risks will in many cases require considering consumer impacts in a holistic manner (eg taking account of impacts on consumer privacy, or sustainability). It is also important to note that for many of these trends there are multiple possible future developments and outcomes, and as these types of development can occur at a fast pace, this may warrant continued proactive monitoring.

12. The trends also interconnect in a number of ways (see Figure 1). Trends on interoperability and open source can shape entire sections of digital markets, and as such connect with all trends. For example, interoperability and open source will be important for the development of digital twins, chips markets, the digitalisation of multiple sectors, but also as platforms pursue further integration or API monetisation. Further, increased deployment of FMs and applications of digital twins cross-over with the trend that large technology firms increasingly move into other sectors such as health; technology convergence shapes and is shaped by many developments.

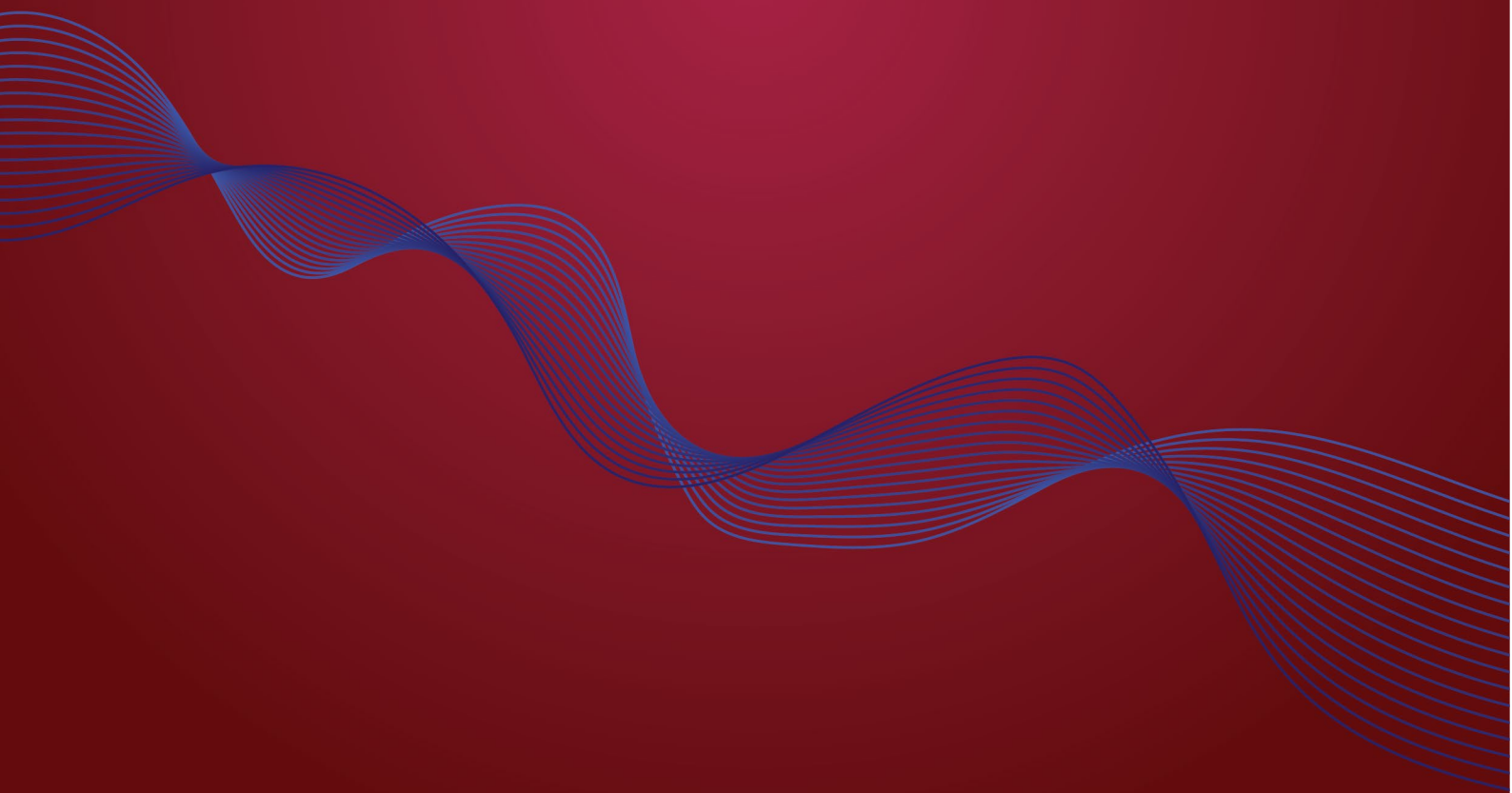
13. There were other interesting trends (see Annex B), including, perhaps unsurprisingly, a number of trends explicitly related to AI. We included the trend on the rapid and widespread deployment of FMs in the shortlisted ten as this was the most overarching trend on AI.

Figure 1: Diagram summarising interconnections between the ten trends covered in the report



Trend 1

Rapid and widespread deployment of AI Foundation Models



Introduction

14. Foundation models (FMs) are a type of AI technology that are trained on very large amounts of data that can be adapted to a wide range of tasks and operations.[8] FMs have many possible user-facing applications including chatbots, writing assistants and code writing, and generation of images for artistic or commercial purposes. Whilst they can be used directly by consumers, new products and services that utilise the technology are already being developed by new and existing businesses. Many AI Trends were identified and prioritised in our scan (see Annex B) however, we chose to focus on the deployment of FMs as it represents an overarching AI trend, and one that is more likely to impact several markets.

15. We published our 'AI Foundation Models: initial review' in September 2023 to help create an early understanding of the market for FMs and how their use could evolve.[9] The Initial Review covered three themes:

    - Competition and barriers to entry in the development of FMs.
    - The impact FMs may have on competition in other markets.
    - Consumer protection.

    The Initial Review comprehensively covers content we would expect a trend on the rapid and widespread deployment of AI Foundation Models to explore, including the many uncertainties around how FMs might be developed and deployed, and impact competition and consumers. Given the work already done in this area, this chapter explores similar content to the Initial Review and we would encourage those interested to read the review for a more in-depth exploration of FMs and their potential impacts.

Signals and evidence about this trend

16. FMs are being used across the economy in a range of consumer-facing applications such as search, social media, and language services. They are also being researched and applied across a wide range of industries, from healthcare, finance, education, music generation, legal and many more. Our Initial Review noted that they could be used to improve existing products or services as well as create new ones. For example, Google, Microsoft, Adobe, and Slack have all announced plans to integrate generative AI features into their existing products and environments, and new use cases have been developed by Bloomberg, Snapchat, and Duolingo.[10]

17. In our Initial Review we stated that due to the broad range of use cases of FMs, the market for FMs is expected to continue to grow rapidly. For instance, Boston Consulting Group, a management consulting firm, predicts that the total addressable market for uses of generative AI will increase from $18 billion in 2023 to $121 billion in 2027. Furthermore, Gartner, another management consulting firm, predicts that by 2024, 40% of enterprise applications will have embedded conversational AI, up from less than 5% in 2020. By 2025, Gartner expects generative AI to account for 10% of all data produced, up from less than 1% in 2022.[11]

Possible future developments

18. FMs have the potential to be transformative across the spectrum of human activity, from searching, to learning, to creating, to how we solve problems across health, engineering, design, and education. In the process, as with any technological breakthrough, they have potential to disrupt existing markets and create new ones. In the years ahead, FMs may transform a range of industries and how we live and work: these changes may happen quickly and have a significant impact.

19. Our FMs report noted a service that could emerge, but not yet seen in full form, is a generally capable virtual personal assistant, which incorporates FM and non-FM services to offer consumers support across a whole range of needs. Another potential example could be in Robotics, where researchers are already experimenting with FMs for a range of robotics applications including reasoning, planning, instructions, and navigation.[12] There could be many more examples across health and drug discovery, education, finance, that are yet to be envisaged but could have immense potential (the combination of AI with other technologies is explored in Trend 2 on technology convergence).

How might this trend impact competition?

20. Our Initial Review discussed a number of uncertainties related to FMs that could have an impact on competition in FM markets. The Review noted that FM developers need access to the key inputs of computing power, data, technical expertise, and capital to compete effectively. These inputs are important for developing, deploying, and using FMs. Equally for competition in downstream markets there were uncertainties such as the ability for firms to have access to a wide range of FM deployment options, and for consumers to be able to make effective choices.

21. In discussion of these and other uncertainties the Initial Review stated that if these uncertainties tipped towards a negative direction this could impact competition negatively over the longer term. This might happen if larger firms are able to constrain access to key inputs which limit smaller FM developers' ability to compete with larger, more established businesses that have greater resources. This could lead to a decrease in competition and innovation in the FM sector, which could ultimately harm consumers. Similarly, if larger firms are able to gain or entrench market positions through leveraging their positions in adjacent downstream markets or in the upstream development of FMs, this could result in lower quality products and services and/or higher prices.

How might this trend impact consumers?

22. The development of FM products and services may provide consumers with considerable benefits. However, as with any new technology, there is also the risk that it could be used by bad actors that seek to cause harm.

23. Consumers can interact with FMs in a variety of ways. This might be via chatbots or through integrated services such as with Bing Chat. They might also interact with them via add-ons within existing applications and services such as with Duolingo. The biggest risks to consumers as identified in our Initial Review were that consumers could be exposed to significant levels of false information which might impact their ability to make informed decisions, AI-enabled fraud, or fake reviews.

Trend 2

Increasing technology convergence enables the creation of new and disruptive products and services

Introduction

24. Technology convergence (TC)[13] is when two or more existing technologies are combined to create new products or services.[14] For example prior to the ubiquity of smartphone adoption, consumers used several devices such as telephones, watches, music players, and digital cameras. Smart phones brought these separate devices into one and created a new smartphone market.[15,16] TC may be associated with what the World Economic Forum (WEF) defines as the Fourth Industrial Revolution (4IR), which it says is 'characterised by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres'.[17,18] It is also believed that the 4IR will lead to economic growth as a result of convergence.[19]

25. TC is also closely related to the concept of 'enabling' or 'foundational' technologies' ie technologies which underpin the progress, creation, or development of other technologies.[20] Enabling technologies can often lead to integration or convergence,[21] though are not necessarily combined with other technologies to create new ones. Enabling technologies are important for TC however, as they often provide the basis for it; this might include technologies such as sensors, cloud computing, and internet.

26. It has been suggested by some academics that TC has been increasing since the year 2000 with the emergence of the internet and use of digital communications. Arguably humans have been converging technologies for much longer with a large impact, albeit occurring less often. Cars were effectively the result of horse-drawn carriages converging with internal combustion / steam engines to create the horseless carriage, which had a significant impact on society.[22,23] Technological developments, however, may not be the only driver of TC. Other drivers might include regulation, or consumer preferences for converged versus dedicated products.[24,25]

27. TC may be important for many reasons. One paper argues that the source of competitive edge for companies is no longer related to economies of scope, scale, or expertise but rather the 'economy of convergence'.[26] Another paper suggests TC might create new and better products and services for consumers, create economic benefits and growth, or lead to the emergence or creation of new and innovative markets.[27] However, there may be potential risks with TC, it has potential to make some markets obsolete unexpectedly, and there may be risks to consumers if new products or services are rushed to market. Disruptions from TC may also be more difficult for regulators and policy makers to anticipate but doing so may mean regulators can ensure regulation and competition enable innovation, whilst also protecting consumers and ensuring products and services are compliant with the law.

Signals and evidence about this trend

28. A number of sources argued that TC has been more diffuse and had a bigger impact on society since the year 2000.[28,29] Digital communications and the internet are proposed as defining factors for driving TC, enabling it to happen more, and on a larger scale. One driver is that different types of communications can increasingly be accessed the same way.[30,31,32] Mobile technologies such as smart phones, a product of TC, have been estimated to account for an increase in global income per capita of $3000 between 2000–2019.[33] This equates to an expansion of the global economy by over $2.4 trillion for the same period, and in 2019 mobile technology represented 2.9% of the GDP of Europe. By 2021, GDP from mobile technology rose to 4.5%, generating value of almost €1 trillion according to a GSMA report.[34] This could indicate that where TC happens there is potential for large economic benefit.

29. A 2021 report that included interviews with industry experts and academics stated that 'most companies believe they will be impacted by convergence to some degree in the

next few years'.[35] The same report also suggested a correlation with digital maturity and higher use of technology, and therefore convergence, and that fifty-nine percent of companies with the highest rates of digital maturity said convergence was one of the most critical influences on their business.[36] This could indicate that businesses see TC as an important aspect when competing in a digital economy or the 'economy of convergence'.

30. There are many recent examples of TC, beyond the smart phone, that support the claim that TC is on the rise and has been since the early 2000s:

- Chatbots, which are used by many organisations to provide consumer support or information, are the result of the convergence of automated conversation, document sharing and instant messaging technologies.[37]
- The Internet of Things (IoT), where physical devices, buildings and even cars are connected by a combination of hardware, software, sensors and network connectivity, is another example of TC.[38]
- Wearables, such as smartwatches, can enable a person to make phone calls, track heart rates, and communicate with other devices through integrating various technologies, as well as providing the base function of telling the time.
- Rideshare apps are another example of where TC not only created a new service but also disrupted an industry. Apps like Grab, Bolt, and Uber utilised the combination of GPS, smartphones, and a mobile application so that consumers can order a taxi at the push of a button. This disrupted traditional taxi services, particularly as drivers just needed a car and a smartphone.[39]

31. There are many more examples of TC, some of which are predictions of where TC might arise. These predictions range from those that have emerged, such as the integration of edge computing into consumer devices, or computer vision for Augmented Reality (AR), as well as some that have not yet been realised such as the integration of blockchain with other technologies.[40] There are also some claims that technologies such as cloud computing, IoT, AI, AR, and Virtual Reality (VR) are converging to create new use cases and solutions.[41]

32. It is difficult to say definitively whether the trend of increasing TC will continue, but the potential for new products and services created by TC to disrupt, or transform, existing markets is high.[42] Undoubtedly, digital communications and the internet have enabled TC to happen more, and on a bigger scale; and this may continue as new digital and other technologies make it easier. Whether TC continues to increase or not may be less important than the abilities of those working in policy or regulation to spot where TC might happen to better understand how it might impact markets, industries, and consumers and to ensure they have the right capabilities to deal with the technologies of today as well as tomorrow.[43] This may be particularly important for TC that could have big impacts or implications for society and consumers, such as TC that involves AI. Arguably existing regulations did not fully anticipate, or capture Uber's new business model and regulators had to adapt and act; for example, a high court ruling decided that Uber drivers were workers and should have contracts with Uber.[44]

33. However, anticipating and identifying the emergence of new technologies, including TC, can be difficult. This can be impacted by multiple factors including whether this emergence is evolutionary versus revolutionary eg is the development of a technology incremental over time or does a new innovation seemingly appear from nowhere; revolution may be trickier as it can be considered akin to 'black swan' events.[45] Tech convergence may also be a sign of shifts in markets or the creation of new ones[46,47,48] which may add to the importance of anticipating so that potential benefits can be maximised and emerging risks mitigated and managed.TC can also vary geographically. In 2021 UBS suggested that China could be a leader in TC. WeChat,

a Chinese social media app, is a good example of the TC of an 'everything app' and one which other businesses are trying to replicate.[49,50]

34. Despite difficulties, there are a variety of methods that can be used to improve the identification of TC earlier in its emergence. These include traditional foresight methodologies such as horizon scanning or forecasting, as well as potentially automated analytical tools utilising AI and Machine Learning. New techniques are being used to identify TC and the emergence of new markets.[51] This includes deep neural networks[52] and machine learning approaches to analyse patent data[53,54] or Wikipedia[55] which may speak to the importance of identifying and understanding TC as early as possible to plan, be prepared and create strategy.[56,57] Ultimately if policy makers can anticipate TC, they may be better prepared to ensure that markets work well when they emerge and as they develop.

Possible future developments

35. If TC does continue to increase, particularly with new or emerging technologies, we might see unexpected developments, alongside those that might be more expected.[58,59,60] Some possible future TCs that may have greater impact are:

- Immersive devices that include things like AR and VR may converge with IoT, Digital Twins, AI and / or robotics to create new immersive interfaces or extended / digital reality applications. This may include machines that are able to respond to users' needs by reading emotions or body movements to make recommendations.[61,62]
- Similarly, there is speculation that nanotechnologies, biotechnologies, information technologies and cognitive science will converge in a way that will lead to improvements in human performance.[63,64,65] This may reflect what the WEF described as a blurring of the physical, digital and biological in the 4IR.
- Along the same lines neural technologies or brain computer interfaces (internal or external devices that interact with the nervous system or brain signals)[66] could be combined with AI to provide a more efficient and effective way of analysing electrical brain data. This may mean that the recording and understanding of brain activity may be easier, leading to the creation of newer devices that can be controlled by brain signals or potentially brain-to-brain interfaces that allow people to message 'telepathically' via a device.[67]

36. There are many other possible combinations of technologies that could prove transformational in the future. This might include quantum computing combined with and boosting the computational capabilities of AI,[68,69] AI technologies combined with blockchain and supply chains, or smart cities which make use of sensors, edge computing, and AI.[70] Due to the variety of possible combinations of existing or new technologies and the potential impacts, it is important, where possible, to be on the front foot to ensure that the benefits can be realised and potential risks mitigated.

How might this trend impact competition?

37. TC could benefit established firms or industry leaders if they are better able to use existing positions or technology expertise to leverage into new markets or leverage existing users into new markets through TC. Established firms may have advantages such as access to talent or compute power, they may have resources to develop existing or new technologies that might be used in or lead to TC or could utilise economies of scope.[71] The types of organisations which might have the latter advantages may be those which diversify their investments or R&D efforts in a variety of technologies or markets. However, TC may also lead to the devaluation of complementary assets (eg if a firm makes smartphones but also digital cameras,

cameras could be devalued as a result of developing smartphones) which may provide a counter effect of creative destruction rather than continuing to reinforce industry leader positions.[72] The potential creation of new markets may also allow new firms with innovative ideas to thrive, provided they are able to enter or expand in these. This may help maintain an incentive, for incumbents in markets which may become obsolete, to innovate to keep pace.

38. Another area that may impact the ability for firms to drive TC is mergers and acquisitions, and other forms of investment. Larger firms may have the financial or other resources to acquire firms that are developing technologies that they might want or need to create beneficial TC or keep pace as a result of TC. In recent years there has been a trend of bigger firms buying or investing in smaller firms in a range of technologies from AI to VR. For example, Facebook (now Meta) bought the Oculus VR company in 2014, many years before the envisioned Metaverse[73] and many firms are investing in AI labs such as DeepMind (now Google DeepMind) and OpenAI. Beyond considerations of whether these acquisitions are good or bad for competition, this phenomenon may speak to firms being proactive in investing in new technologies not just as technologies in their own right, but with the potential to integrate with other technologies for greater benefit or value.

39. There is limited information on TC and wider competition but some of the potential benefits from TC are lower barriers to entry if certain products become cheaper as a result, lower costs of equipment, market responses that can be quicker and new business or market opportunities that converged technologies might bring; Uber's use of smartphones being one example.[74]

How might this trend impact consumers?

40. We found limited information in the literature we reviewed on the impacts TC might have for consumers. One paper stated however, that TC could mean new and innovative products and services, more convenience, and cheaper and better products and services. It also stated that TC could reduce the number of devices a person might need or have to carry and reduce waste, particularly in being energy efficient as only using one device.[75] However, there is limited available evidence to support these points therefore more research might be needed to understand or demonstrate wider consumer benefits of TC.

41. There are also potential risks for consumers, although again we found limited evidence in the literature. Risks might include products or services being rushed to market which could present safety or security issues. Another possible concern could be lack of a clear route to redress if things go wrong with new technologies, particularly if regulations need to be adapted or created quite quickly for new products, services, or business models. The benefits and the risks with TC, much like for any new technologies, will need to be carefully assessed and managed.

Trend 3

Digital platforms increasingly integrate additional services

Introduction

42. The way that users access digital services has evolved. In the pre-web era, individuals were required to install a separate application on their computers for each individual service. The web marked a pivotal shift, enabling users to access a multitude of services through a single interface, the web browser. Subsequently, the rise of mobile apps allowed for a more personalised experience, where users could curate their interactions with various businesses by simply adding icons on their home screens, eliminating the need for repeated web searches. Today, there are potentially more efforts to move towards one app for everything, further standardising on a single interface. One example of this is how social media platforms are integrating services such as in-app shopping and financial services.

43. This trend towards greater platform integration has the potential to meet the needs of both businesses and customers. This may benefit businesses because a comprehensive app could be designed in a way that customers don't have to leave for additional services. In turn, knowledge of the full customer journey could help improve the app's design and monetisation strategies. Customers themselves might welcome having to deal with only one interface, as this reduces the cognitive load and friction in accessing services. Customers might feel safer too, relying on one trusted party as much as possible, instead of having to make decisions about data privacy with each new app. However, those customers might not always realise the full extent of how one platform may use the data they generate every day. And a comprehensive app could risk reducing competition and innovation if consumers 'single home' and competing apps are excluded.

44. This trend is a potential early indicator of the development of 'super-apps' like WeChat, a popular app in China which has over 400 million daily active users and more than 3.2 million developer apps, including its own payment platform and social media, all deliverable on the WeChat app.[76]

Signals and evidence about this trend

45. Increasingly, with 'social commerce', individuals can discover, browse and purchase all in one platform without needing to interact with any other websites or applications.[77] TikTok and Instagram in particular have been integrating in-app shopping, complementing their personalised advertising of goods and providing a potentially more seamless checkout process as users don't have to switch apps. Reduced friction, such as users not having to switch apps, might lead to greater conversions[78] and revenues for sellers.[79] Similarly, businesses and shoppers in Brazil and India can now complete transactions entirely on WhatsApp, which integrates functionalities from marketing to in-app payments.

46. Platforms also benefit from such in-app integration. For example, they typically charge sellers a commission fee (eg Meta takes a 2.9 – 3.49% processing fee for sales using the Facebook and Instagram in-app checkout;[80] Tiktok levies a 1.8 – 5% commission on products sold through Tiktok Shop).[81] Further, commentator Ben Thompson suggested such in-app integration might more fundamentally support the platforms' advertising-based business models. For example, Instagram, which relies heavily on advertising, can use in-app integration to address the challenges of measuring cross-app conversions in the post-ATT (Apple's App Tracking Transparency)[82] world.[83] This is because ATT limits cross-app tracking but not the use of first-party data.[84] We note that, in addition, TikTok and Instagram have their own in-app browsers, allowing them to follow a user's journey on external websites.[85]

47. Recently, the media have reported ambitions for 'X' (formerly known as Twitter) to become 'the everything app'.[86,87] 'X' could model its everything app on Tencent's 'super-app' WeChat, which combines social media, messaging, gaming, marketplace and payments.

48. Asian markets have developed and grown more super-apps, each bundling together a variety of services which complement one another. These super-apps build in-app services using components known as 'mini-apps', small apps that require a super-app to run.[88] Chinese companies have proposed standards for these mini-apps in international fora, although adoption so far has mostly occurred in China, as well as Korea and Japan.[89]

Possible future developments

49. Meta, TikTok and others may pursue further platform integration. However, growth of super-apps has been relatively limited so far in Western economies.[90,91] As an indicator, many of the newer Asian super-apps outside China have performed poorly, and some commentators have argued that, with scarce funding in the current economic climate, they are struggling to balance scale and profitability.[92] The Economist previously argued that 'X' (formerly Twitter) might not have the scale required to readily become a super app; adding that there could be other barriers to gaining and retaining consumers such as difficulties building in-app payments that are acceptable to app-store rules, and similarly for other mini-apps.[93]

50. Super-apps might also require strong alignment between the functions or services on offer and potential consumer's needs. What worked well for WeChat might not work in markets where consumers are used to many choices for each function or service. For example, super-app Ping An, which combines insurance, healthcare and wealth management, does well in Chinese markets where function integration is common. However, consumers in America and Europe may prefer to buy these services from separate entities.[94]

51. Platform integration could also arise altogether in a different way. With rapid improvements in Foundation Models (FMs) – large, machine learning models trained on very large amounts of data – FM-powered chatbots may increasingly be accessed through mobile devices[17] and could become a new gateway for products and services. For example, FM-powered chatbots may use plugins to provide additional user content and there is a possibility that this could become popular with users for accessing products and services. For instance, ChatGPT currently supports plugins across various industries[95], including travel (eg Expedia[96]), financial services (eg Klarna[97]), delivery (eg Instacart[98]) and restaurant booking (eg OpenTable[99]). At present, consumers have to install their chosen plugins and are taken to the external provider's website to check out. However, FM providers might seek to further reduce friction in the customer journey, by further integrating plugins and keeping consumers within the FM service, although we are not yet seeing this functionality.

How might this trend impact competition?

52. The market for integrated platforms or super-apps has the potential to become concentrated within a single or very small number of platforms. This may be the case as incumbent platforms might be able to exploit existing user bases, as may happen when a firm offers a set of interrelated products and services. In addition, a number of network effects may come into play. Larger platforms might benefit from direct network effects: a higher number of users potentially translates to more value for any given individual user, as they can communicate with more friends or other users. There may also be indirect network effects: more users could increase incentives for

other services and providers to develop mini-apps or plug-ins to access those users, and therefore the more convenient the super-app might be for any given new user. There is also potential for incumbents to benefit from strong data network effects, by building ever more data-driven tailored services including digital advertising.

53. If platforms are able to exploit an undue competitive advantage and give preferential treatment to their own or their partners' downstream products or services, there may be cause for concern. As is common with platforms performing an intermediate role with other businesses hosted on them, integrated platforms and 'super-apps' can curate the selection of services on offer, and there may be a concern that platforms will only partner with certain organisations, or that the 'super app' may be able to pick the 'winners' and 'losers' in downstream markets.

54. Alternatively, there is potential for the market to develop in a way where different platforms target different customer segments, or where consumers see value in being a part of multiple integrated platforms. It is unclear whether individual consumers would choose 'single-homing' or 'multi-homing'[100] between different super-apps providing similar services. The extent to which integrated platforms lend themselves to single or multi-homing may impact the degree to which consumers face issues such as consumer lock-in. Convenience and consumer bias could also mean a consumer might go 'all in' on a super-app and therefore miss out on better products or services provided through other means. There might also be high switching costs between platforms, which could be compounded by a lack of horizontal interoperability.[101] For example if users cannot easily port their social graph, a representation of their social network, or other data. If consumers are able to be 'locked in', integrated platforms could face reduced competitive pressure and may be able to lower quality and potentially charge higher prices.

55. Integrated platforms and super-apps also have the potential to raise barriers to entry and expansion. Platform integration might mean incumbents could consolidate their user network whilst making it harder for entrants to capture a user base, in the absence of multi-homing or horizontal interoperability. Some antitrust regulators have taken action in response to these concerns - for example the Chinese regulator has intervened to enforce interoperability of payment services across rival platforms, and to prevent firms from penalising sellers operating in more than one online marketplace.[102,103] For new apps, it may become hard to acquire and expand their user base without a presence as part of a potential integrated platform.

56. Increasingly, interesting competition dynamics might arise between super-apps and the Apple and Android mobile app ecosystems. The 'app-in-app' approach seemingly challenges the app stores' roles as gateways to apps. But it might still serve the incumbents' interests by keeping consumers in the mobile app ecosystem, in a context where they become less willing to download apps as recent research suggests.[104] Meanwhile, Apple and Android may pursue other routes, as they have been working on their own versions of mini-apps – Apple Clips and Google Play Instant – giving them control over terms and conditions.

How might this trend impact consumers?

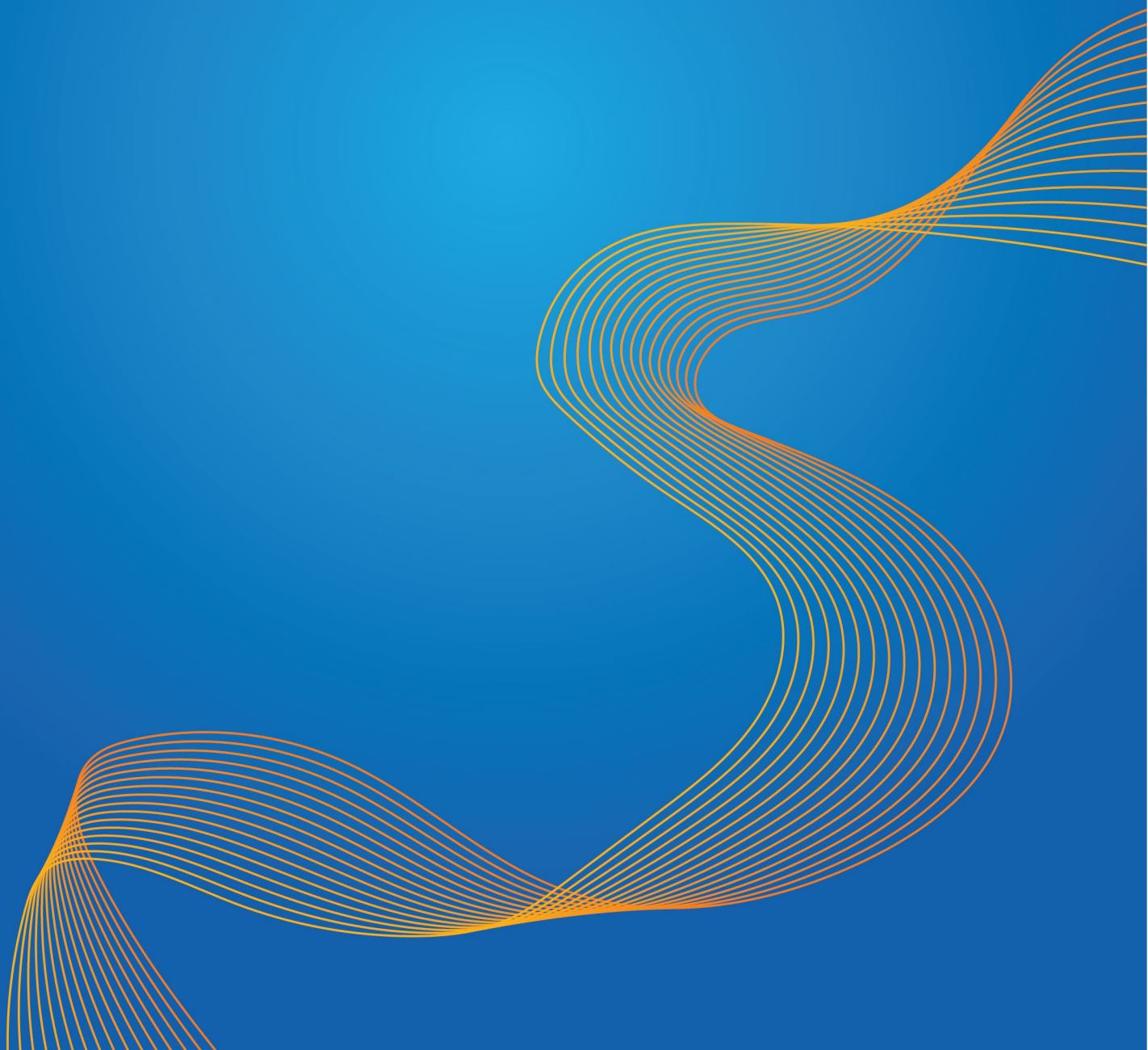
57. Increased platform integration and 'super-apps' may offer convenience to consumers by bringing multiple services into the same platform. A number of experts we engaged with agreed that apps with integrated services such as super-apps could lead to consumer benefits. For example, integration of transactional services into social networking platforms can lower the costs on consumer to search for what they want or need, or more generally lower transactional costs.

58. However, as pointed out above, in case of consumer lock-in and reduced competition, consumers might miss out on higher quality services or lower prices. Additionally, some commentators have suggested fraud could be more common in Asian 'host apps',[105] for instance exploiting the convenience and rapidity of new payment methods.[106] There are also concerns about security vulnerabilities introduced by mini-apps, for example due to improper permission management.[107,108]

59. Implications for data privacy may also be significant. Consumers may feel safer staying within one trusted party, rather than having to trust multiple providers. But first-party data collection and processing are not inherently better for data protection than third-party – both can equally fall short of key principles such as transparency, fairness and purpose limitation.[109] Social media platforms that have integrated in-app browsers and shopping are already able to capture rich data trails from their users' activities, and to build super-profiles they can use for advertising. The purpose of such data collection might not always be clear to users. Platforms might even persuade users that a greater integration of services requires such collection and multi-purpose uses.

Trend 4

Digital firms continue to raise prices for API access



Introduction

60. Application Programming Interfaces (APIs) are a set of functions and procedures that allow the creation of applications that access the features or data of another operating system, application, or other service. They act as building blocks of interoperability and data exchange between separate systems.

61. Freely available APIs allow developers to use the data of large platforms to create add-ons, plugins or third-party applications which leverage existing services. Two examples are Tweetbot for Twitter (now known as 'X') and Apollo for Reddit, which respectively let third-party developers access the data needed to build customised functions for Twitter and Reddit content. These functions can include things like scheduling tweets and custom gestures.

62. One potential driver of this trend is AI Foundation Models (FMs) using large amounts of data accessed via APIs for training and development, firms are increasingly seeking to turn their APIs into a key source of revenue. This monetisation of API access could have notable implications for developers and consumers, particularly in the case of third-party apps. Ultimately, changes in API access could affect developers, consumers, and competition.

63. One indicator of this trend is that in 2023 'X' (formerly known as Twitter), one of the largest social media platforms and the 20th most used API in 2022,[110] began charging for access to its API. Reddit enacted similar changes and attracted widespread protest from users across 3500+ communities on the site against 'unfair' pricing and a restriction of third-party and user accessibility (see case study in Box 1).[111]

Signals and evidence about this trend

64. A 2020 report from Google suggested that one in three firms with over 1,500 employees monetised APIs in 2020, and 50% of such firms planned to implement API monetisation capabilities in 2021; this was described as 'the area that organisations are most intent on ramping up'.[112] Additionally, in separate API market surveys, 60% of respondents view their APIs as products, with the highest in financial services.[113]

65. Like products, there is a shift in APIs being thought of as tools for direct revenue generation, instead of a tool for platform expansion as has often previously been the case. By enabling third parties to offer complimentary tools and applications, platforms' content could reach more users' demands without needing to develop the tools in-house. One example of this expansion by increased function offering includes third-party widgets and tools like TweetDeck, which gave users advanced Twitter functionalities like managing multiple accounts, scheduling Tweets, and tracking hashtags.

66. Many API use-cases exist through a top-down relationship, with smaller firms 'calling' API data[114] from market leaders to build interoperable features. Therefore, it is significant that larger firms like Twitter, Reddit, Slack and Shopify are beginning to make their API access subject to paid tiers.

67. Notable examples of large API monetisation efforts include:

    - Twitter/X also introducing a new tiered access system, 'Twitter API version 2' with different data limits and price points for individual and commercial users, with Twitter/X enterprise access costing a reported $500,000 per year[115]. Twitter was the second most used API in 2022 so it is significant for developers[116].

- The 'Google Maps Platform' introduced in 2018 increased charge thresholds at the free usage tier and requires billing details for continued usage even for those under the paid data use threshold[117].

Box 1: **Case Study on Reddit API changes**

Case Study: Reddit API Changes

Reddit is an online social platform comprised of thousands of 'subreddit' communities which span a wide range of topics and interests. Reddit has had notable third-party app offerings like Apollo and Reddit is Fun, which used the Reddit API to offer features unavailable on the official app. Examples of these functions include creating custom user gestures or enabling multi-window viewing of Reddit content.

In April 2023, Reddit announced its plans to charge for access to its API, which gives developers access to one of the largest data corpuses on the internet. The announcement states that from July 1, developers requiring higher usage limits would be charged $0.24 for every 1,000 API calls.[118] This could amount to less than $1 per user per month for many apps. For large third-party offerings like Apollo, this has been estimated to total up to a $20 million per year. All of the most popular third-party apps shut down in response to the changes, as they claimed the API changes would make it impossible for them to operate without pushing huge new costs onto users.[119]

In response to the announced API changes, thousands of subreddits, some with tens of millions of subscribers, went private or restricted their access in a temporary boycott starting on June 12. The blackout was so impactful that it even caused Reddit to crash temporarily.

Possible Future Developments

68. The increased adoption of FMs across multiple sectors like healthcare, education, and retail could encourage moves to create revenue through APIs directly, as one of the potential uses of APIs being that they may help train FMs more efficiently versus methods like data scraping. This is part of what Reddit CEO Steve Huffman describes as 'returning value' of the data previously used freely by FMs.[120]

69. If this momentum grows, we could see reduced interoperability as larger platforms may choose to keep their data behind paywalls, potentially leaving users with little choice beyond first-party platform offerings. If third parties are forced out of business due to API costs, niche user demands may have to be met by the firms holding APIs, and these may have to become more adaptive to users end-to-end.

70. If APIs become increasingly important to train FMs, FMs may become more expensive to develop. This may lead to fewer FMs available in general, and fewer FMs that are made freely available in particular, as FM developers may need to pass on costs. This could reduce the availability and uptake of FMs and AI tools.

71. If the use of APIs as revenue streams continues to grow, demand could grow for more control over API access eg through copyrighting. There have been long-running legal battles between technology firms over control of API rights, some of which went before the US Supreme Court.[121]

How might this trend impact competition?

72. The trend of API monetisation could present challenges for effective competition. High API access fees could serve as a barrier to entry for firms entering digitised markets where market leader APIs are standard. For startups, as well as current market participants, these costs could be high.

73. Potential barriers to entry could also impact venture capital dynamics. The absence of free API tiers could make it more challenging for startups to demonstrate a viable product to potential investors. To access APIs, companies may find it more expedient to enter collaborations with larger incumbents.

74. Such concerns could arise in markets where AI is used, as API data has historically been a valuable resource for training AI algorithms.[122] If these APIs become more expensive, new firms may find it difficult to compete in sectors where AI is increasingly important. This could benefit current market participants that have access to AI models trained on previously free APIs. Large and well-established firms may have the financial resources to afford API charges to keep training their models with the best data available.

75. However, tiered API pricing could be a tool for firms to consolidate the value of their base products, incentivising them to invest in the base services, potentially offering functions previously developed by third parties. If the leading platforms offer these services as first-party services, competitors will have to improve their own offerings to differentiate themselves. Ultimately, this could lead to positive market innovation and better value propositions for users, as well as creating opportunities for smaller firms to leverage their open access as a means of competing.

76. Platforms holding a significant market share may raise the price of API access if there are fewer substitutable alternatives for developers and users. This could result in increasing lock-in and potential price increments over time. On the other hand, where there is notable competition at the platform level, firms' leeway to increase charges for API access may be limited. In the long run, charging for API access could incentivise stronger competition at the platform layer, as new entrants might possess a greater ability to undercut established platforms with lower API access charges. However, the realisation of this competitive edge hinges on their capability to overcome broader barriers to entry within the platform service domain.

77. Similar to Open Banking, which aimed to increase competition and innovation in the financial sector, open-API app offerings might appeal to particular user and developer demographics. To mitigate costs associated with market leader APIs, collaborations among smaller entities might be a viable consideration, potentially fostering a more diverse and competitive market landscape.

How might this trend impact consumers?

78. The rising trend of API monetisation could have implications for both consumers and researchers. First, we could see an increase in costs passed down to consumers on affected platforms. For example, Spotify suggested that its increased subscription fees were due to Apple's increased API costs.[123] The CMA has previously looked into these cost increases as part of the Mobile Ecosystems Market Study.[124]

79. Another potential effect is the narrowing of consumer choice; should APIs have high price increases for APIs, third-party providers might have to take decisions like passing costs onto users or ceasing business. Those with accessibility needs may not have these met, and others may have reduced quality of experience when using potentially more rigid first-party apps. Although firms like Reddit have given

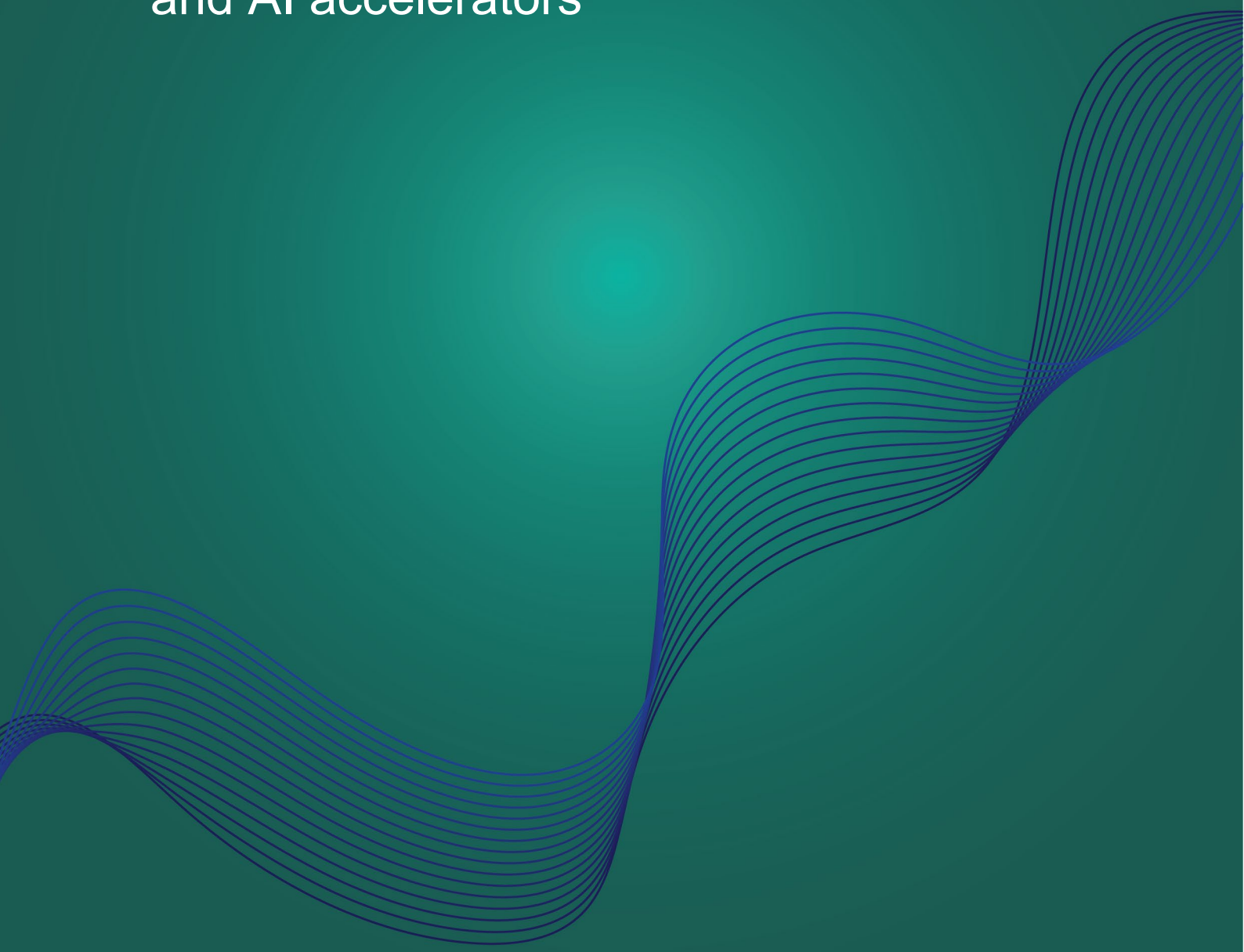
exemptions on API charging for accessibility apps, there is still a net loss in flexibility as the power of discretion over 'appropriate' use is increasingly given to the firm controlling the APIs.

80. The quality of services and levels of consumer satisfaction could also suffer. There can be a measurable decline in user engagement when access to key data is restricted, in part due to reduced diversity of content and potential user interaction. One study identified dips in user engagement when data is restricted in this way[125].

81. Lastly, increased API costs could limit the ability of academics to collect data for research. A number of experts we engaged with highlighted concerns stemming from the potential for API cost increases to hinder the ability of researchers to collect data to analyse the risks and benefits of online platforms.

Trend 5

Growing incumbent and new entrant activity in the markets for CPUs, GPUs and AI accelerators



Introduction

82. A microchip (or just 'chip') is a set of electronic circuits on a small, flat piece of semiconductor material, usually silicon.[126] Chips form the basis of all modern computational technology and are therefore one of the drivers of the modern economy. Because of this foundational importance, dynamics and developments in the microchip industry have the potential to be of vital importance to the global economy.

83. Creating chips is complex and expensive.[127] As a result, the industry has, for the most part, split into companies specialising in smaller sections of the microchip creation process (see Figure 2). These include 'fabless' companies, which design chips; 'foundry' companies, which transfer chip designs onto silicon wafers; and Outsourced Semiconductor Assembly and Test (OSAT) companies, which assemble the chips from silicon wafers, package them in protective material, and test them for functionality. Finally, there are still some Integrated Device Manufacturers (IDMs) like Intel, which may be involved in multiple or all steps of the process.[128]

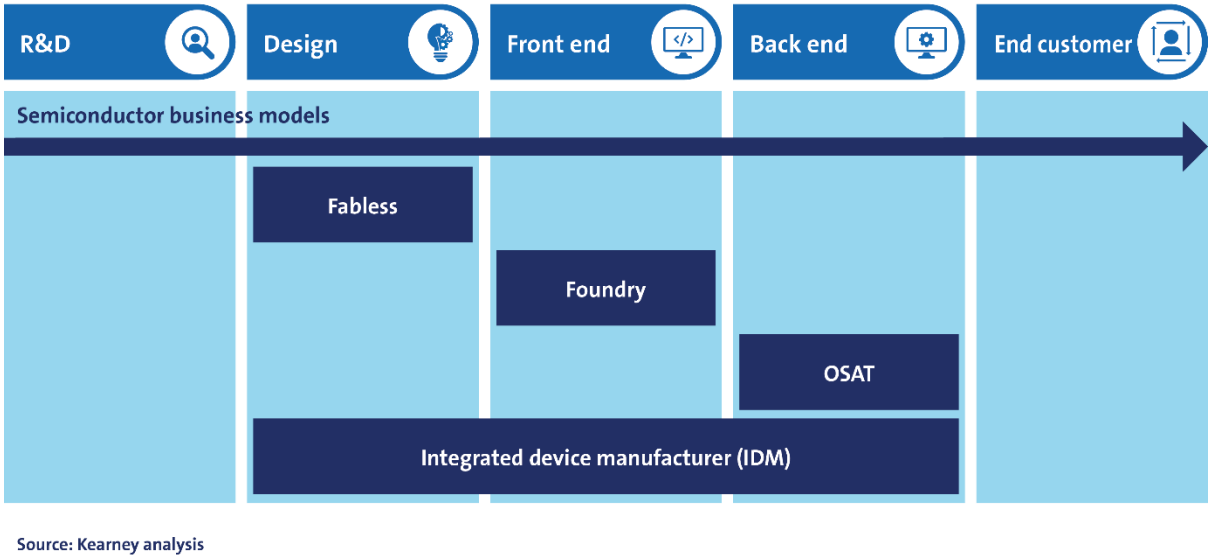


Figure 2: Microchip stages of production. Source: Kearney (02/06/2022).[129]

84. Fundamentally, the microchip industry categorises offerings in terms of technology (digital or analog) and/or functionality.[130] There are, broadly speaking, four categories of microchips based on functionality. These include:

- Logic microchips; complex microchips which process information to complete computational tasks. These may include microprocessors like Central Processing Units (CPUs) or Graphical Processing Units (GPUs). More specialised chips, like Field Programmable Gate Arrays (FPGAs), may also be called logic chips. FPGAs are chips that can be configured after manufacture, allowing them to be optimised for specific applications.
- Memory microchips; microchips designed to store information.
- Application Specific Integrated Circuits (ASICs); simpler, single-purpose microchips typically made for a single company. Microchips that fulfil a single function but are sold to many companies may also be called Application Specific Standard Products (ASSPs).

- Systems-on-a-Chip (SoC); microchips which integrate several (or all) of the above chip functions into one.

85. This trend highlights recent activity of interest in logic chip end markets, with particular attention paid to the design and manufacture of desktop and data centre Central Processing Unit (CPU), Graphical Processing Unit (GPU) and AI accelerator microchips. 'AI accelerator microchips' is a broader category typically used to refer to ASICs, GPUs and SoCs which are specialised in performing tasks necessary for training of AI models or running ('inference') of AI workloads.

Signals and evidence about this trend

86. There has been significant supply and price volatility across a wide variety of microchip products over the last three years, including logic chips. This volatility has had a significant impact across the world economy, with a particular effect on the automotive industry.[131] This trend was driven by a confluence of factors: the fundamental inflexibility of microchip production capacity and lead times combined with a sharp increase in demand during the pandemic, global supply chain disruptions, as well as the continuing concentration of the microchip foundry market in a few geographic locations which created knock-on effects for the rest of the supply chain and resulted in widespread shortages.[132,133,134,135]

87. More recently, increased interest in AI has driven up technology company market valuations, and some chip companies offering products aiding AI acceleration have also benefitted.[136] In particular, Nvidia's market valuation has risen at a much faster pace than its competitors (see Figure 3), with Q2 2023 revenue results confirming Nvidia as a primary beneficiary of the demand for AI accelerator hardware.[137,138] This increase in valuation highlights that incumbent companies in the microchip design and manufacture markets are potentially seen as hard to challenge, and that they are potentially seen as able to maintain a strong market position. This possibility is further reinforced by reports that Nvidia's leading position in AI acceleration may be deterring funding for start-up competitors.[139]

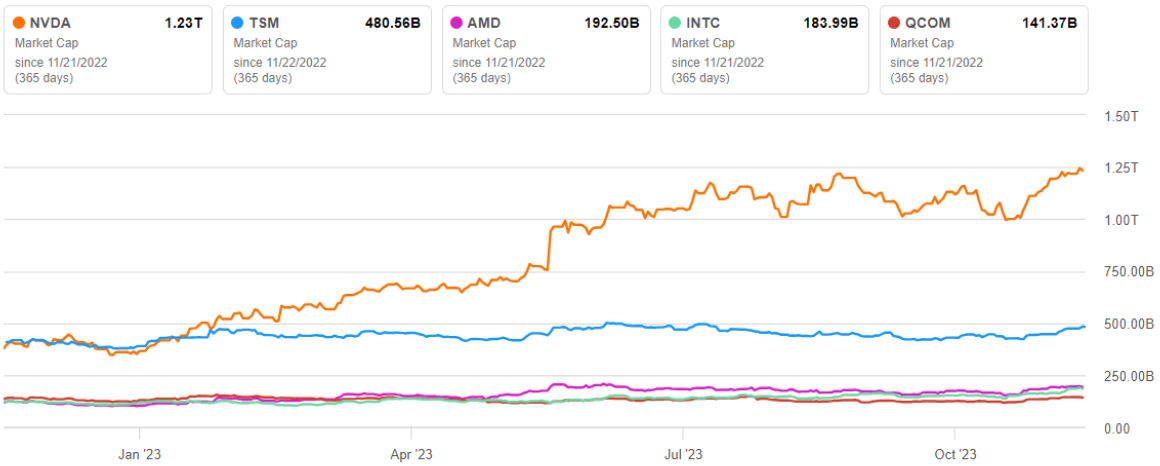


Figure 3. Market valuation of Nvidia and several key chip companies, in USD. Seeking Alpha (22/11/2023).[140]

88. While incumbent chip design companies currently maintain a leading position in their respective markets, there are several developments which may impact this, including:

- Established chip design companies (Intel, AMD, and Nvidia) seem to be intensifying competition in the GPU and CPU segments between themselves.

AMD has reportedly increased its market share in the enterprise CPU market from 5% to 18% over the last four years, while Intel has attempted to enter the discrete GPU chip market, both on the consumer side with its ARC series GPUs and in the datacentre with its Max series GPUs.[141,142] A second iteration of Intel's consumer GPU chips is expected by market observers to be released in 2024.[143] Finally, NVIDIA may soon be entering the CPU market, potentially further increasing competition in that segment. NVIDIA has unveiled its datacentre focused, AI-tailored Grace Hopper chip, expected to be shipping in 2024, and is reported to be developing a consumer CPU for possible release in 2025.[144,145]

- Large Cloud Service Provider (CSP) companies, namely Amazon, Google, and Microsoft are increasingly developing their own CPUs and AI accelerator chips, hoping to create alternatives to current market options.[146,147,148,149,150,151]
- The recent surge of interest in AI has made prominent newer AI accelerator chip design companies that some outlets, for example the Register and the Wall Street Journal, included in the list of those possibly capable of disrupting incumbents.[152,153] But their ultimate impact on competition is uncertain; for example, the FT has reported that the prospect of competing directly with incumbent chipmakers, benefitting from significant barriers to entry and significant available resources, meant that 'some start-ups have pivoted away from a head-on competition with Nvidia'.[154]

Possible future developments

89. A number of factors have been cited as the most significant underlying drivers of microchip supply volatility. The ones that have been forecasted by analysts that continue to have a significant effect include:

    - Supply chain disruptions due to geopolitical events and natural disasters.[155]
    - Geographic concentration of manufacturing capability.[156]
    - Talent shortages in developing and manufacturing microchips.[157]

90. Efforts are underway to tackle the above factors. These include the planned construction of new 'fabs' (microchip manufacturing plants); efforts to geographically diversify manufacturing capacity to manage geopolitical risks; initiatives to build new, more resilient supply lines, and further plurilateral international action to secure chip supply.[158] The UK's own National Semiconductor Strategy outlines similar measures.[159]

91. Despite the above, ensuring stable future microchip supply may take time. The implementation of aspects of these initiatives has already run into a number of issues and delays, including serious talent shortages delaying production, and disputes over necessary subsidy amounts delaying project commencement.[160,161] Even without delays, the sole process of building a 'fab' is long and difficult, taking upwards of three years.[162] Though semiconductor shortages seem to be over for now for most industries, until the initiatives to address the industry's susceptibility to shocks translate to greater resilience, scope for further disruption remains.[163]

92. CPU and GPU markets may be heading into a period of higher competition from established companies specialising in chip design. Intel reportedly continues efforts to develop products to enter the GPU market, possibly providing an alternative to Nvidia and AMD's GPU products.[164] This includes both potential consumer and enterprise GPU plans.[165] AMD continues to expand in the consumer and enterprise CPU market.[166] Arm based PC CPUs, currently mainly comprising of Apple and Qualcomm chips, also reportedly continue to increase market share, though so far possibly less successfully.[167]

93. In addition to competition from established competitors, the three largest cloud companies have all developed, or are reported to be developing, in-house CPUs and SoCs.[168] These companies have the capability to compete with established chip designers through their ability to fund development and leverage established economies of scale, increasing the possibility of intensified competition in the CPU market in the future.

94. The AI accelerator market may also be facing increased competition. Across both high performance computing and edge computing markets, a large number of new and established companies have developed and released AI accelerator chips, both for AI model training and inference.[169] Aside from market leaders in high performance computing AI acceleration like Nvidia, Intel, and AMD, companies that do not typically compete in high performance computing, like Qualcomm, are also offering AI accelerator solutions.[170] Moreover, newer companies like Sambanova, Graphcore, Tenstorrent and Cerebras also now offer a variety of AI accelerator chips.[171]

95. Notably, large technology companies, including Amazon, Meta, Google and Microsoft have all developed or have announced development of AI accelerator chips.[172,173,174,175] These are more likely to provide a feasible alternative to current market leaders, as these companies have the scale, funds and expertise necessary to compete, especially in terms of developing the software ecosystems these chips require. However, none of these companies currently offer their chips for purchase to other firms, and only market these chips for use as part of their cloud offerings, limiting their competition with AI accelerator chips available for direct purchase.

96. Despite the above activity, there is potential for market concentration in the long term. Incumbent chip design and manufacturing companies continue to benefit from economies of scale, which may prevent smaller, newer competitors from competing with established market participants.[176] Incumbent companies may also benefit from strong network effects arising from established third-party software ecosystem compatibility and familiarity with existing proprietary software stacks like Nvidia's CUDA.[177,178]

97. There are ongoing attempts to develop alternatives to these software stacks that work on a wider range of hardware, both from large technology companies like Google and OpenAI as well as from smaller companies, but they are yet to meaningfully displace Nvidia's CUDA framework.[179,180,181,182]

How might this trend impact competition?

98. As noted above, there are some indicators pointing to a possible strengthening of competition. However, there are also a number of factors that could pose risks to competition in future.

99. Potential M&A activities, for example large incumbents buying small players, could lead to consolidation. A number of recent mergers and acquisitions in the chip design sector highlight this possibility. For example, AMD acquired Xilinx for almost $50B in 2022, bringing a key vendor of Field Programmable Gate Array (FPGA) chips, a logic chip type sometimes used for AI model development, under the AMD brand.[183] Moreover, a recent survey by KPMG indicated that 'transformative' M&A activity over the next 3 years is predicted by around 32% of polled executives. A much larger proportion, 48%, anticipated smaller M&A deals in that period in the same survey.[184] There remains the possibility that incumbents could consolidate their positions by acquiring competitors, companies in adjacent markets, or new entrants.

100. Potential future CSP use of proprietary in-house AI accelerator chips creates the possibility of further vertical integration and potential vendor lock-in. For example, AI

accelerator chips made by CSPs, like Amazon's Trainium and Inferentia as well as Google's TPU v4 and v5e, are both available only on their respective cloud services. In the future, if an application was to be designed taking into account the synergies of those chips with particular software frameworks, and especially if the application was made using software stacks designed by the CSPs themselves, switching to a different CSP may be difficult or incur a possible loss of performance, leading to customers potentially being disincentivised to switch and potentially resulting in ecosystem lock-in.[185]

101. More broadly, chip design and hardware-software integration may become more important as the microchip industry heads towards the physical limits of microchip miniaturisation.[186] To keep up with the computational improvements associated with Moore's Law, chip designers will likely need to squeeze more and more performance out of process technologies at the same transistor size.[187] This may make architectural efficiencies, improved packaging methods, improved algorithms and software, as well as hardware-software integration ever more important as determining factors of overall performance and core differentiating qualities.[188,189]

How might this trend impact consumers?

102. If competition works well across CPU, GPU and AI accelerator markets, products may become less expensive for end consumers.[190] Conversely, if competition works less well in these markets, which might be due to consolidation, network effects or other reasons, consumers and businesses may end up facing persistently higher prices.

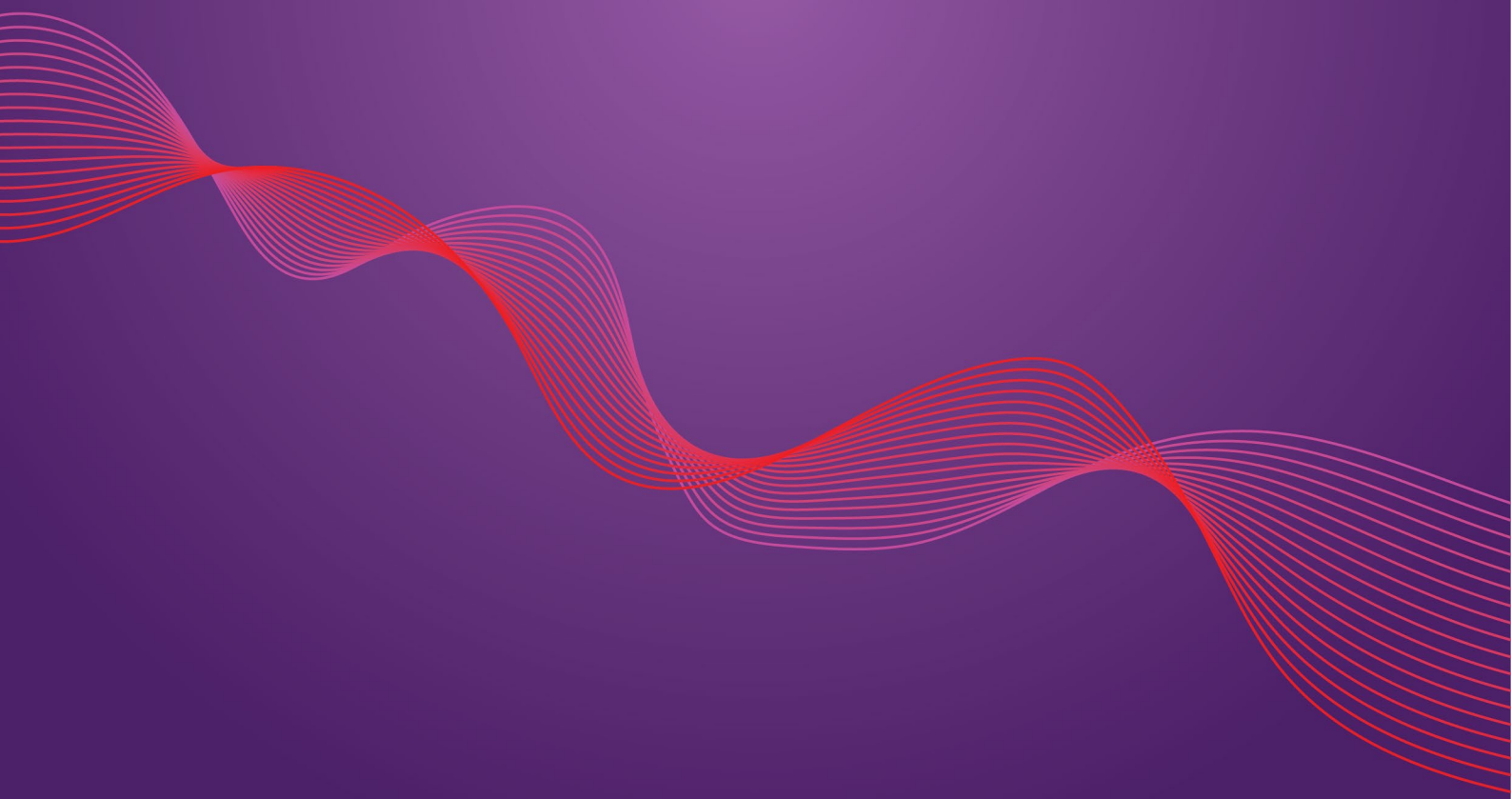
103. Another impact of competition working well may be the creation of products which provide better coverage of market niches and therefore increased consumer choice. For example, Intel's recent consumer GPU entry may have filled a previously neglected market niche in the low-end consumer GPU market segment.[191] If competition works less well, then there could be reduced consumer choice.

104. Moreover, increased competition may incentivise companies to innovate more on core capabilities and invest more in bold new architectures, potentially accelerating improvements in performance and efficiency that would benefit consumers. This can be seen in how Intel and AMD have used major architectural changes to compete over the last decade. For example, after AMD innovated in 2015 with the development of 'chiplets' in the Zen architecture, a sizable architectural change, Intel responded in 2021 with the introduction of 'efficiency' and 'performance' processor cores to compete more effectively in the consumer CPU market.[192,193] More recently, AMD has adopted the use of 'efficiency' cores with the Zen 4c architecture in their 'Bergamo' series datacentre CPUs in order to compete with Intel more effectively on energy efficiency.[194] AMD CTO Mark Papermaster stated in an interview in May 2023 that AMD plans to incorporate similar efficiency cores in 'hybrid' consumer CPU chips going forward.[195]

105. Notably, enterprise chip providers compete on microchip energy efficiency.[196] Increased competition may yield further advancements in this area as chip designers seek to further differentiate their products, accelerating progress towards global environmental goals. Decreased competition, on the other hand, could slow progress.

Trend 6

Interoperability improvements are uneven but remain an important driver of market outcomes



Introduction

106. Interoperability is the ability of different products or services to work with each other to accomplish a variety of tasks. This 'working together' typically relies on the use of standards and Application Programming Interfaces (APIs) and involves the sharing of data and/or functionality across and within devices, services or platforms.[197,198] Interoperability can be thought of as a core principle of the internet and is central to how it has historically functioned.[199]

107. Interoperability is in large part a technical term that is difficult to define more precisely; despite that, the technical details of what type of interoperability is at work matter. Papers from the Organisation for Economic Co-operation and Development (OECD) and Centre on Regulation in Europe (CERRE) on interoperability in digital markets cautioned that these differences necessitate assessing the effects of different types of interoperability in different markets independently, particularly because different types of interoperability may have different market effects, and because different digital markets may vary in how interoperability affects them.[200,201]

108. Though a detailed description of different types of interoperability is beyond the scope of this report, an important distinction between horizontal and vertical integration has been highlighted by the OECD, CERRE and Ofcom papers as well as expert attendees at the 2022 CMA DaTA conference.[202,203,204,205] Horizontal interoperability is the ability of products at the same layer of the digital value chain to work with each other (typical examples include email providers being able to send messages between each other, or the ability to repost Facebook posts on Instagram, or X). Vertical interoperability is the ability of services to exchange data or functionality at different layers of the digital value chain; this would include things such as the ability to install applications from an app store, or even the sideloading of applications directly from the internet.[206]

109. Interoperability, both vertical and horizontal, is a prominent topic in ongoing debates on how digital markets might be regulated. Horizontal interoperability has been seen as a potential way to mitigate market 'tipping' in digital markets – a term used to describe a situation when one product or service benefits from such strong network effects that it dominates a market. [207,208] Vertical interoperability has garnered interest because of its potential to lessen the ability of vertically integrated platforms to leverage market power into downstream markets and its potential to unlock additional distributed innovation.[209]

110. There are several factors that affect whether a product may be interoperable. As digital markets are comprised of many different devices and services from different vendors, their ability to interoperate may credibly be constrained by:

- The difficulty of overcoming the technical problems of establishing interoperability between different products and services;
- Co-ordination costs involved in implementing cooperation between a diverse set of distinct companies;
- Incentives to resist interoperability for anticompetitive reasons.

111. These factors may combine to influence where sections of digital markets fall on a spectrum between interoperable environments and 'walled gardens' – ecosystems of devices or services which are controlled by one company and exhibit limited interoperability.[210] These limitations may be further exacerbated by the pace of innovation in digital markets. A faster pace of innovation may lead to mechanisms like standard setting organisations that help enable co-ordination failing to keep up with

technological developments, possibly resulting in standards becoming obsolete and companies choosing to deploy non-standardised and less interoperable solutions.[211]

Signals and evidence about this trend

112. There have been some improvements in horizontal and vertical interoperability over the last few years through the development and adoption of voluntary standards. These include but are not limited to:

- The development of interoperability standards for consumer-oriented Internet of Things (IoT) device interoperability, most recently the Matter protocol. Adoption is low as ratification only occurred in late 2022, but key market participants like Apple, Google and Amazon already support the standard.[212]
- The resolution of some technical challenges impeding horizontal interoperability of messenger services, with the ratification of the Messaging Layer Security (MLS) encryption key management standard in July 2023 by the Internet Engineering Task Force (IETF).[213] MLS is already being implemented by Google into its messenger app, and other secure messaging protocols, for example Matrix, have announced they will adopt it.[214,215]
- Increased attention to and improvement of data interoperability in the healthcare sector.[216] In the UK in particular, the NHS has recently published the Interoperability Toolkit; a framework and a set of standards for achieving improved interoperability in healthcare.[217]

113. Several pieces of recent legislation have mandated increased interoperability in digital markets, and several more are currently under discussion. The EU's Digital Markets Act (DMA) 'contains an obligation for gatekeepers to ensure fair, reasonable and non-discriminatory general conditions of access to app stores, online search engines and online social networking services and provisions on interoperability of messaging services that take effect in March 2024. Further, EU Directive 2022/2380 mandates a 'common charging solution' for mobile devices, also starting in 2024.[218] In addition, the EU has reached a political agreement on the Data Act, which would introduce expanded rules for interoperability in IoT and Cloud, as well as to undertake 'measures to promote the development of interoperability standards for data-sharing and data processing'.[219]

114. Similarly, the UK's Digital Markets Consumers and Competition (DMCC) Bill, which creates the new pro-competition regime for digital markets, currently includes provisions for the CMA to have the ability to impose conduct requirements on companies designated as having 'Strategic Market Status' for the purpose of 'preventing a designated undertaking from [...] restricting interoperability between the relevant service or digital content and products offered by other undertakings'.[220]

115. However, improvements in interoperability may not be even across markets; and it is possible that even when interoperability is present, the continuing ability of some centrally positioned companies to dictate the terms of who is able to interoperate with their platforms, and how, may create uncertainty for how interoperability and the sections of digital markets built upon it will develop.

116. For example, the CMA's Online Platforms and Digital Advertising market study cautioned specifically about the ability of some social media companies to deny access to their APIs to companies that may compete with them for digital advertising.[221] This control over access to crucial information may impact effective competition. Another example of the uneven state of interoperability was raised by the CMA as part of its Mobile Ecosystems Market Study. There, the CMA found that vertical interoperability may still be lacking in mobile device ecosystems, both in terms

of the ability of mobile devices to work with accessories and in API access for functionalities like browsing.[222]

117. Moreover, there are widespread calls for interoperability in immersive environments. Calls for interoperability come from a variety of voices, including industry participants, individual commentators, and even multilateral fora and consortiums.[223,224,225] These calls in large part centre around horizontal interoperability; specifically the horizontal interoperability of different digital 'worlds' and the ability to transfer information and assets like avatars across different services with smooth authentication experiences.[226] Despite this widespread interest in interoperability, immersive environments remain siloed. Similar factors that prevent broader interoperability, especially the existence of technical barriers to standardisation and varying incentives to support it, seem to have limited immersive environments from deeper interoperability for now.[227]

Possible future developments

118. A number of experts we spoke with as part of our research agreed that regulatory and legislative pressure is often a large driver for increased interoperability in digital markets. As such, regulation could prove to be a strong influence on the development of interoperability in digital markets going forward. One example of this is in the effects of the EC's designation of 6 companies and 22 services as digital 'gatekeepers' under the new DMA.[228] Specifically for Apple and iOS, this move is reported to be pressing Apple to open up more vertical interoperability by allowing alternate app stores or sideloading – though as of October 2023, Apple has not officially announced or rolled out such capability, and it may be geographically restricted to the EU region if it does roll out.[229] Apple's recent announcement that it will support the RCS messaging protocol on iOS devices is also suggested to have been prompted by the DMA's interoperability requirements.[230]

119. Regulation is not the only potential route to improvements in interoperability. Interoperability, both horizontal and vertical, could also improve through industry initiatives. This includes work on new standards currently in development, like 'mini-app' standards for super-apps, or the proposed instant messaging standard called 'More Instant Messaging Interoperability (MIMI) with MLS', both of which are currently under discussion in the W3C and IETF respectively.[231,232,233] Interoperability may also be improved through the efforts of industry associations like the recently incorporated Metaverse Standards Forum.[234] It is uncertain what proportion of these initiatives will see widespread adoption, or for how long; there is a long history of proposals for interoperability that ultimately see incomplete uptake.[235]

120. Experts we spoke with as part of our research suggested that interoperability, especially mandated interoperability, is likely to encounter resistance from technology companies that may have strong incentives to oppose it. Those companies might want to preserve the competitive advantage they have from certain data or technology not being shared more widely.

How might this trend impact competition?

121. There is debate over the precise effect of different kinds of interoperability on different markets. A recent paper by CERRE has characterised horizontal interoperability in digital markets as having both positive and negative effects on competition and innovation in different contexts.[236] Most experts that took part in the 2022 CMA DaTA conference had more positive views of horizontal interoperability.[237] Vertical interoperability tends to be seen as more unambiguously positive for competition, though both the CERRE and OECD papers still caution about implementation challenges like formalising appropriate access conditions.[238,239] Given these debates

the precise benefits of interoperability to competition, especially as a tool of regulation, may need to be assessed on a case-by-case basis.

122. Increased levels of horizontal interoperability may help competition through limiting network effects and therefore lowering barriers to entry and lowering switching costs in digital markets. With horizontal interoperability present, small services may not require a 'critical mass' of users to be viable, as they could access the network effects of larger competitors.

123. However, the relationship between increased horizontal interoperability and competition benefits may not always be clear cut. For example, significantly increased horizontal interoperability may require the creation of a standard. A recent CERRE paper argues that in the case of faster-moving markets with diverse incentives to support or oppose interoperability, the adoption of standards may dampen innovation.[240] Moreover, the paper argues that implementation of a standard for horizontal interoperability may dissuade multihoming due to decreased differentiation, as a user can go 'all in' on one platform.[241] Ofcom's recent interoperability discussion paper also suggests that increased horizontal interoperability is more desirable in cases when multi-homing is less prevalent.[242] As such, the effects of interoperability on competition may be heavily dependent on the specific market context.

124. One of the greater benefits of increased vertical interoperability may be in unlocking access to markets downstream of platforms or services, especially in ecosystems that remain 'closed' or heavily vertically integrated. This increased market access could in effect allow new entrants to compete on more equal terms with vertically integrated products, increasing competition.[243]

How might this trend impact consumers?

125. Interoperability, both horizontal and vertical, can provide increased consumer choice and control.[244] If horizontal interoperability were to increase, consumers may be able to choose services and products not only based on their network effects, but on a broad array of other differentiating factors, potentially unlocking additional innovation. If vertical interoperability were to increase, consumers may potentially be able to mix and match offerings from different providers without being 'locked in' to a vertically integrated ecosystem, also potentially unlocking innovation.

126. However, in some cases increased interoperability may be technically challenging and result in unintended trade-offs, especially in terms of security and innovation. At least two different experts have noted that the DMA's requirement for horizontal interoperability in messaging services will require overcoming significant technical challenges.[245,246] Likewise, moves toward increased vertical interoperability in mobile platforms, such as those demanded by the DMA, may affect platform security in several different ways. For example, Apple argued that decreasing the company's control over its app ecosystem has potential to translate to decreased security through increasing the number of ways its devices could be attacked by malicious actors.[247] Finally, poorly designed standards may reduce innovation in digital markets.

127. Despite that, increased interoperability does not necessarily mean decreased security in the long term. Security is determined not only by the number of potential ways to attack a system, but also by the quality of systems involved in detecting, preventing, and mitigating malicious actions. Increased competition in the market for security methods that could arise from increased vertical interoperability on key platforms, like mobile device ecosystems, may help incentivise innovation and ultimately help mitigate security concerns. A key issue in managing the desired level of interoperability will be determining the actual level of security risk and balancing it

against the foreseen consumer and competition benefits of interoperability in specific cases.

Trend 7

Larger technology firms continue to expand into new markets

Introduction

128. The digital transformation of sectors across the economy has allowed larger technology firms to explore new avenues for growth. These technology firms are gradually becoming participants in a variety of sectors. For instance, as cars are increasingly connected to the internet, over 600 car models from 40 brands are already compatible with Apple CarPlay in the UK, [248,249] alongside 63 brands for Google's AndroidAuto.[250]

129. This extends to finance too, with Meta having tried to launch their own cryptocurrency Libra (renamed Diem),[251] and Apple & Goldman Sachs' credit card partnership having 6.4 million US users as of 2021.[252] Energy infrastructure is also increasingly digitalised (see Trend 8: Increased application of digital twins).

130. The digital transformation of healthcare came up in multiple high-scoring trends in this scan (See Annex B), so this chapter will focus on large technology firms moving into the health market, or 'HealthTech', but it is worth noting as set out above that this trend may apply across a range of sectors.

131. For the purposes of this report, HealthTech refers to the general trend of digital technologies being used in healthcare initiatives. This includes, but is not limited to, new and existing healthcare providers using new technologies to transform and deliver services. For example, utilising the health data-collection capabilities of wearables (such as fitness trackers and smart watches) when creating care plans. And technology firms moving into healthcare markets, particularly utilising their existing capabilities to do so.

132. Spending on public health infrastructures among European economies has risen in the preceding decades and this rise is set to continue, projected to reach 12.5% of GDP by 2060,[253] with a 'substantial' part of rising spending attributed to the adoption and funding of new technologies in healthcare.[254] A 2022 KPMG survey notes that, while health has previously been slower to adopt new technologies versus other sectors, 60% of US healthcare organisations will now make AI and Machine Learning key areas in the next year, versus 48% in all other sectors, as well as 63% reporting progress on their digital efforts, versus 44% for other sectors.[255] This suggests that emerging technologies could become particularly prevalent in health initiatives.

Signals and evidence about this trend

133. According to a report by Tech Nation, the UK HealthTech market expanded by 50 times from its original size between 2011 and 2021,[256] while Bloomberg reported global HealthTech is projected to grow to as much as $1.5 trillion by 2030.[257] It is possible that, if investment continues to grow and technologies get more advanced, the HealthTech market will grow even bigger and attract more investment.

134. Market growth, in part, could be linked to the interest and investments by larger technology firms in this space. Some larger technology firms have made key acquisitions related to HealthTech, for example, Oracle's purchase of Cerner in 2021 and Google's acquisition of DeepMind in 2014. It is possible that in the future, larger firms' ability to use scale and capabilities in advanced technologies like AI may impact the HealthTech market, as these technologies become more integrated into healthcare research and treatment.

135. One example of the increased use of technology in health is the rise of wearable health devices: according to Statista research, the sales revenue for wearable devices rose by 64.5% between 2020 and 2022.[258] Wearables such as Apple Watch and Fitbit

have tools like ECG (electrocardiogram) monitoring that can be used to assist with identifying heart conditions like Atrial Fibrillation. Using deep learning and AI, these technologies have potential to become more wide-ranging and sophisticated, possibly detecting diseases like diabetes from collected health data.[259]

136. In addition, the advanced capabilities of larger technology firms are being used in collaboration with existing health organisations. Notable collaborations include the NHS and DeepMind on an app to help flag kidney injuries in real time,[260] as well as Microsoft and AWS/Amazon collaborating with Novartis to operationalise AI and cloud solutions to help with researching new treatments.[261,262]

Possible Future Developments

137. A survey of those in the healthcare market by McKinsey showed that 61% viewed the main purpose of digital health services as increasing patient wellbeing.[263] This may support the assertion that healthcare market players are confident in technology and the transformation in healthcare as a whole through digitisation. It is possible however that technology firms equipped with large amounts of consumer data and refined tools entering the healthcare segment could put pressure on the traditional healthcare market. This in turn could put pressure on healthcare providers, as they find themselves having to navigate an evolving HealthTech landscape with both larger firms, traditional providers, and potentially smaller technology companies offering new technologies or business models.

138. In the same McKinsey survey, 90% of healthcare leaders speculated that consumers are utilising unified health platforms,[264] where a wide range of healthcare services are available on a single interface like a mobile app. It is possible that technology firms that have existing ecosystems of wearables, apps, and data management infrastructures, could be better placed to meet this demand, potentially even creating 'super apps' with a multitude of services, including health, in one place.

139. Apps that offer a range of services have already gained favour in Asia and Latin America (eg Tencent's WeChat and Rappi in Brazil). Convenience could be a factor to adoption of super-apps and in one report 74% of consumers indicated that the immediate availability of health appointments is their top priority.[265]

140. AI may also enable a variety of HealthTech applications to be highly personalised, particularly as medical research frontiers advance. Increased personalisation could be delivered through apps or wearables, as well as technologies like AI and Machine Learning, potentially giving patients access to advanced bespoke treatments like gene therapy in future.[266]

How might this trend impact competition?

141. Larger firms which have existing technological capabilities and offer a wide range of services may be better placed to move into HealthTech and might be able to do so swiftly to achieve market penetration or potentially consolidation. Surveys among consumers and those with HealthTech offerings indicate a growing demand for integrated digital health services centred on convenience and accessibility.[267,268] Larger firms with existing infrastructure and capabilities may be better placed to take advantage of this growing demand. With AI, this is particularly true, with about 70% of AI experts housed within a handful of major tech firms, and Google alone having 30% of all US Health AI patents.[269]

142. Larger firms could also potentially enter the HealthTech market through buying smaller firms and incorporating the products or services of these firms into existing ecosystems, rather than taking on the Research and Development (R&D) costs of

innovation themselves. This might create a reduced incentive for R&D to create competitive offerings, ultimately leading to fewer choices in the market. Acquisitions also have the potential to reduce the availability of health data sources to others in the market if they are subsumed into existing firms or infrastructures. This in turn could create barriers to entry as firms may need access to this data to create new or better products or services.

143. There are potential risks for healthcare providers if HealthTech becomes part of the ecosystems of larger firms. One risk is that being embedded in one ecosystem could create high exit costs for healthcare firms, providers and patients, if they wish to switch. This has potential to create a lock-in effect which in turn may limit competition and innovation and the number of options in the market, as well as potentially weakening healthcare provider control and reducing consumer/patient transparency.[270]

144. Those with larger or existing market presence may also have the potential to guide standards and practices as the HealthTech market evolves. If market leaders come to set protocols and precedents that new entrants find difficult to adhere to, this may lead to a centralisation of decision-making on industry standards and protocols in a way that might hinder competitors. This could lead to a HealthTech market that is defined by the practices beneficial to some firms' business models over others.

145. Standards and protocols, however, can also help to establish best practices**,** fostering an environment where only high quality and the most accessible services are viable. This could also help to attract investment in what is a newly emerging market, particularly if the investment of larger firms provides confidence to attract startups and investors offering collaboration, acquisition potential, or complementary services. This investment also has potential to reduce healthcare costs and to open up the HealthTech market to further innovation as the number of market participants increases. This could include innovative smaller firms as well as larger firms.

How might this trend impact consumers?

146. As healthcare becomes more digitalised and data-driven, strategies to safeguard privacy and sensitive patient data are likely to become increasingly important. Levels of transparency on some existing data-sharing arrangements have been ruled incompatible with privacy laws, for example the Royal Free NHS trust's collaboration with Google's DeepMind.[271] Should these types of data-sharing arrangements expand in scope and scale, there may be more focus on privacy concerns, particularly if details on patient data handling are inaccessible due to complex algorithms or proprietary data infrastructures. Equally, the positive potential for collaborative projects in healthcare are dependent on the extent to which firms may be willing to share capabilities or data with existing healthcare organisations. In some cases, firms may decide that not sharing may be more beneficial to compete in HealthTech markets.

147. Another potential risk is that technologies under development, or new personalised tools, may not provide the value for patients that they promise.[272] Equally these types of technologies might encourage an overconsumption of health data and information by non-medical audiences.[273] In 2020, a BMJ study found that no existing health self-assessment app was able to match the diagnostic accuracy of GPs, and the apps' accuracy levels were highly variable,[274] meaning consumers could potentially gain less reliable services. If consumers are using this information to inform decisions about their health, reliability and accuracy could be even more important factors to consider.

148. There are also potential issues around equity of healthcare and the use of algorithms. Whilst issues of bias in algorithms are not new, there is potential for algorithms trained on or used in healthcare to inadvertently discriminate against minority groups that could impact negatively on their healthcare needs.[275] This point was of particular concern to the experts we spoke with as part of our research. These experts argued that understanding and identifying where bias could occur from the adoption of advanced technologies could be critical for identifying areas where patients could receive disparities in care.

149. Alongside the potential risks for consumers there are many potential benefits. With technology and healthcare convergence, patients may increasingly have control of their healthcare in the palm of their hand. The involvement of technology firms in health could also help to grow personalised medicine and potentially enable a democratisation of personalised medical services with a focus on convenience for consumers to access faster, more tailored care.

150. Similarly, greater involvement in health markets from technology firms could enable exciting frontiers in research**.** For example, technology firms' capabilities could allow medical researchers to use tools such as advanced AI to advance the development of new lifesaving treatments for patients. As an example, Google DeepMind's AlphaFold AI was used to help solve the 'protein folding problem', a significant development that could pave the way for an acceleration of development and availability of new treatments for cancer and other diseases.[276,277]

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Trend 8

Increased application of digital twins

Introduction

151. Digital twinning refers to the virtual modelling of a physical system, object or process, to simulate its life cycle or behaviour – sometimes in real-time. Things that can be twinned include consumer products, physical landscapes, infrastructure, and potentially even humans.[278]

152. Digital twins (DTs) have attracted increased attention in the last few years as notable DT projects have taken shape, using complex data flows that can support real-time modelling, feedback, and predict behaviours. Existing DT projects include simulations of whole cities,[279] millions of jet engines, and complex bodily organs.

153. These models are already used for product development and monitoring, as well as for the development and research of disease treatment. The potential application of DTs is growing as IoT (internet of things) sensor technology grows more advanced and becomes more widely adopted, enabling more advanced data flows to support DTs.

Signals and evidence about this trend

154. The DTs market has been forecast to be worth as much as $138 billion[280] by 2030 – an expansion of over 44 times the size from 2020. Megaprojects in DTs have already been applied at scale using drones and satellites. Digital copies of the entirety of Shanghai and Singapore have been produced,[281] with the island of Tuvalu planning something similar.[282] These megaprojects have also been used to influence real-time policy decisions. For example, the digital model of Shanghai was used to help Chinese authorities model and test COVID-19 responses, as well as monitor the spread of the virus.[283]

155. The predictive potential of DTs has generated interest for their use in research. The EU has DTs collaborations with firms including Neurotwin, who are actively using DTs of human brains to inform research into the prevention and treatment of Alzheimer's.[284] Similarly, Dassault Systèmes' 'Living Heart' project uses twinning to visualise heart conditions and model treatment scenarios.[285]

156. In addition, DT modelling is used to assist in environmental sustainability initiatives**.** Through initiatives like Nvidia's "Earth-2" and the European Commission's "Destination Earth", DTs are used to simulate real-world scenarios, enabling the testing of sustainability strategies like emission reduction and resource management in a virtual environment before real-world implementation.[286,287]

157. DTs also have sustainability applications on a smaller, product-level scale. Large firms like GE already have over 1 million active DTs,[288] and every Tesla vehicle produced has a DT.[289] DTs have been used to help test and optimise products, as well as identify potential faults before they occur. Illustrating this optimisation dividend, GE estimates a 20% gain in net electricity generation on wind farms where twins have been introduced.[290]

Possible Future Developments

158. Brains and hearts are already being digitally twinned which could, in the future, enable individuals to receive insights from their own DT to inform health related decisions. For example, a mother might receive real-time data from her baby's DT, indicating potential health risks to her and to the child. The potential, as quoted by GE's former Digital CEO Bill Ruh, is having a "digital twin at birth" that collects sensor data to

predict health outcomes over a lifespan.[291] Predictive individual healthcare constitutes, according to Ruh, the "ultimate digital twin".[292]

159. Should major cities follow suit in adopting DTs like Shanghai and Singapore we might witness the emergence of interconnected DT cities. Such a network could revolutionise urban planning, disaster response (as seen in Shanghai during COVID), and infrastructure development.[293] Digital technologies, particularly DTs, are increasingly being used as key tools for managing and mitigating climate change impacts across multiple sectors. These digital replicas create feedback loops that facilitate real-time monitoring, understanding, and optimisation of various systems, including power grids, urban planning, and transport networks.[294] These are partly why, for infrastructure design, DTs may become a powerful tool for gaining accurate real-time monitoring of climate emissions. Large projects like "Earth-2" and the digital replication of Tuvalu serve as examples of how DTs could be used for conservation going forward.

160. Digital twinning closely interacts with AI and Machine Learning (ML) to improve its functionality.[295] This relationship suggests that as AI and ML continue to evolve, so too could the capabilities and applications of digital twinning, possibly making it an increasingly viable tool to complement AI initiatives.

161. However, there are notable caveats. The proliferation of DTs using IoT sensors could generate an unprecedented volume of data. To handle and store this data, robust, high-capacity infrastructure may need to be constructed. This could exacerbate existing or create new issues regarding data privacy, security, and potential market entry. This may be in part due to the high-cost requirements for providing this data infrastructure as well as for the IoT devices which collect this data.

How might this trend impact competition?

162. Digital twinning is capital intensive and requires sophisticated technological capacities. As DTs potentially become more complex, requiring expertise and sophisticated technology, smaller firms might find it increasingly difficult to compete. Firms who may already have established platforms and resources, could find it easier to access the expertise and technologies required which could in turn make the market less accessible for new entrants.

163. The central role of AI, ML and big data in DT advancements might favour larger tech firms and/or businesses with existing AI/ML capabilities. This may allow firms with these existing capabilities to utilise them for greater predictive accuracy and agility for better DTs versus smaller competitors without similar capabilities.

164. DTs also have potential to create new markets, services, and business models, or to revitalise existing sectors or encourage new entrants. However, there may be pressure on smaller firms to offer more niche, specialised services to compete with the potentially extensive solutions offered by larger firms. Though larger firms would be the main players in this potential scenario, smaller firms' investment into niche markets could improve market diversity.

165. Additionally, DTs might often rely on data accessibility between firms, as well as industry standards and interoperability.[296] Relatedly, if a small number of firms come to control the cyber-physical infrastructure necessary for DTs there are potential risks for consumer 'lock in' to services or products if the cost and inconvenience of transitioning twin data to other firms is deemed to be too high.[297]

166. There is also the possibility of network effects with DT platforms, should a twin platform become more valuable as more users engage with it. The increase in collective data relative to competitors could put popular platforms at a technological advantage if the data helps train twin technologies to be more accurate. This could potentially create a cycle where the most popular platform attracts even more users, making it challenging for newer or smaller competitors to enter or effectively compete in the market.[298]

How might this trend impact consumers?

167. A potential benefit of DTs for consumers could be highly accurate, real-time health monitoring and predictive capabilities. This has potential to enable early detection of potential health concerns, allowing consumers to make more informed decisions about their health. This could also mean more treatment options available through research from initiatives like NeuroTwin.

168. Counter to this is the potential misuse of twin data by malicious actors. Data protection and security may be key considerations when mapping infrastructure and people with DTs. Insights gained from DTs could also create the potential for intensive surveillance or new types of crime.

169. There are also significant potential positive outcomes. DTs in city modelling could lead to enhanced resilience and risk management protocols. Responses to floods and earthquakes, as well as responses to public health emergencies like future pandemics, could be made more efficient and accurate, ensuring more secure urban spaces, increased security and protection of civilians. A current initiative is DT-GEO (A Digital Twin for Geographic Extremes) which in collaboration with 26 research institutions seeks to ‘analyse and forecast the impact of tsunamis, earthquakes, volcanoes, and anthropogenic seismicity’ and strategies to manage them.[299]

170. Another benefit of twinning for consumers is how DTs products could be designed for individual needs. A hypothetical example could be shoes tailored to individual gait patterns, optimised for comfort and longevity, and adaptive clothing could be particularly beneficial for individuals with disabilities and unique needs. This adaptable product design, informed by DTs, may lead to more efficient product design and therefore lower costs for consumers. A car, for instance, might predict maintenance needs, saving on unexpected repair costs. Companies may have reduced operating costs in testing, maintenance and quality assurance, thus potentially lowering prices.

Trend 9

Increased development and usage of open-source software and hardware

Introduction

171. ‘Open source’ can be understood as a general approach to the development and licensing of intellectual property.[300,301,302] Open-source practices initially arose as a way of navigating the limitations of proprietary software in the 1980s, and the term itself was coined in the 1990s. The notion then developed steadily over the next thirty years. [303] The availability of open-source products has been credited with significant economic benefits.[304] There is no centrally enforced definition of ‘open source’, but there are two main accepted components of this term.

172. First, an open-source project must be licensed for free use, reproduction and modification of the original, although precise licensing conditions can vary.[305] Second, the development of an open-source product is typically not confined to an internal team but is open and public. Documentation, blueprints, source code, and other relevant information is expected to be freely available for others to access. Anyone may potentially be able to submit ideas and suggestions for project development, or even take the underlying source code and/or documentation of an open-source product and take its development in a different direction to that of the original project (a process called ‘forking’ in the software development community).

173. Open source has been most widely practised in software development and has become very important in today’s software ecosystem. Modern digital infrastructure has become highly dependent on open-source software projects, maintained in large part (though no longer exclusively) by unpaid volunteers.[306]

174. The functional extent of the overall benefits of open source is debated. There is a popular belief that open source delivers significant benefits to the public and may perhaps be considered a public good.[307,308,309] Despite this, open source may still have some issues to address. An expert consulted by the CMA and a recent paper by Widder et. al. argue that the ‘open source’ label may need to be interpreted critically when invoked, as it may be prone to marketing misuse.[310] Moreover, a recent significant increase in cyberattacks that targeted open-source software has drawn attention to the security implications of how open source is developed, maintained and deployed.[311,312]

Signals and evidence about this trend

175. Synopsis’s Open Source Security and Risk Analysis (OSSRA) 2023 report found that open source software use has increased across virtually all industries. Though adoption levels between industries vary, even more ‘traditional’ and highly regulated industries like Aerospace are transitioning to use open-source code in their codebases.[313]

176. GitHub, the largest open source code repository in the world, reported in 2022 that open source repositories have grown 20% year-on-year and more than 20 million developers have joined GitHub in 2022 alone.[314] Commercial technology companies, large and small, have relied more and more on open source as a core component of their software development strategies, with GitHub estimating in November 2023 that ‘over 30% of Fortune 100 companies have now implemented ‘Open Source Program Offices’ to help structure organizational policies and procedures around open source’.[315] This increased acknowledgement of open source software has also translated to intensifying support for existing open-source projects, helping to some extent to fill the funding gap in some areas of critical importance, like security.[316]

177. Open-source initiatives have in some areas set industry standards for functionality and lead in their respective niches. For example, the Linux operating system (taking into account all of its ‘distributions’ – versions of the operating system built and maintained

by different groups) powers a large share of cloud server deployments, and all of the top 500 supercomputers in the world.[317,318] In Machine Learning (ML), the two top development frameworks for Artificial Intelligence (AI) are now developed as open-source projects. Google released TensorFlow, one of the most widely used ML frameworks, into open source as far back as 2015.[319] In 2016, Meta released and open-sourced PyTorch.[320]

178. Open-source hardware development and usage is also gathering pace. It is currently difficult to measure how much open-source hardware is deployed across different markets, but some notable open-source hardware initiatives enjoy widespread deployment by enthusiasts, academia, and industry. For example:

- The Arduino is a widely used, mostly open-source electronics platform, with its microcontroller offering being perhaps its best-known component. The Arduino's easy to use, open-source model has made it very attractive for enthusiasts and researchers to learn from, use as a prototyping platform and contribute to, creating a large software and knowledge ecosystem.[321]
- Open-source hardware is increasingly enabling access to specialised research equipment in academia. This may be critical for researchers in lower-income countries but is also relevant for the UK and other higher budget countries – open source hardware development allows for collaboration and faster iteration in areas of specialised instrumentation.[322] More specifically, UK-based activity for open source hardware in research is also mounting. For example, UKRN has released a primer on training on open-source equipment in August 2023.[323]
- RISC-V is an open-source Instruction Set Architecture (ISA) for microchips. Instruction set architectures specify what relevant processors can do; these instruction sets are then used by software to ask the processor to execute commands. Though RISC-V is a relatively new entrant in the ISA market, competing with ISAs such as x86-64 and AArch64, it is currently gaining pace among chipmakers as a possible new industry standard.[324] Its open-source nature is a benefit in the eyes of some developers – it means that no royalties need to be paid to a central developer like Arm, reducing costs.

Possible future developments

179. Open source as a development and licensing method is likely to continue growing in digital markets, both in software and in hardware. Larger technology firms have increasingly relied on open sourcing their products as a development strategy, increasing their contributions to the open-source ecosystem four-fold in the six years leading up to 2022. [325] This trend is likely to continue.

180. Further proliferation of the open-source development and licensing model could lead to increased consumer choice, especially in more specialised use-cases through faster iteration and collaboration with a wider diversity of contributors. One example is how open-source hardware development, combined with the higher availability of tools like 3D printing, is increasing access to specialised tools for environmental monitoring – tools that were previously inaccessible for smaller organisations due to resource constraints or which simply did not exist on the market before being developed by dedicated researchers.[326]

181. Another example of where open source may be important is in the field of Artificial Intelligence (AI). 'Open-source' AI models have been the subject of some media attention, especially in the context of their potential competition with AI models developed by larger technology companies.[327] The extent to which some such projects should be considered 'open source' is contested; there is a range of possible model 'openness' that varies from project to project. Moreover, the most performant general models are all currently closed source, in large part because the resources

and expertise necessary to train such models are available most readily to large corporate actors.[328,329] In many instances, open-source and open-source adjacent projects have managed to flourish even alongside well-funded competitors. For example, there are models such as Stable Diffusion, an open-source text-to-image model.[330] Nevertheless, it remains uncertain whether open-source models will continue to be released in future.

182. There is also a possible trend of some companies that utilised open source as a part of their business retreating into more restrictive licensing to protect themselves from what they see as questionably ethical behaviour. For example, one post by Josef Průša, founder of Prusa Research, a company specialising in developing open-source 3D printers, highlighted concerns about competitor companies taking open-source intellectual property, stripping it of attribution, and submitting local, restrictive patents for the resulting technology. He suggested the use of a more restrictive license as a solution to that perceived problem.[331] A response to the post by Thea Flowers, a member of the OSHWA board, broadly agrees that such 'clone' companies are a point of wider frustration for developers of open source hardware, but disagrees on how much those companies contribute back to the wider open source ecosystem and how best to resolve the issue.[332]

How might this trend impact competition?

183. There are multiple key potential benefits of open source for competition. A 2021 study by Blind. et al. carried out a stakeholder survey and concluded that 'the use and contribution of open source software (OSS) generates the highest benefits in the form of supporting open standards and interoperability'.[333] Lower costs through access to source code without having to pay royalties, 'freedom from proprietary software' and access to an active development community were also rated highly in impact as benefits of OSS, among others.[334] These may benefit competition through potentially lowering costs and barriers to entry, reducing the risk of vendor lock-in and lowering costs of finding talent.

184. There may be potential costs to relying on open source which may mitigate the benefits of open source to competition. Costs noted by respondents to the survey carried out by Blind et al. were tied in large part to costs of assuring stability, the costs of development of required capabilities and costs of personnel training. The respondents to the survey rated the impact of these costs much lower than the potential benefits, suggesting that open source may be a net benefit to competition.[335]

185. Moreover, though open source may reduce the risk of vendor lock-in, it may not remove that risk completely. An expert the CMA talked to as part of our research noted that 'open source' is in large part a licensing agreement which may be changed. Consumers may need to remain vigilant if they wish to avoid vendor lock-in.

186. Open-source software and hardware may also provide competitive constraints for proprietary competitors in certain cases. Research highlighted by Knut et. al indicates that open-source software may put price pressure on competing proprietary software.[336] A paper by Jaisingh et. al. studied incentives of proprietary firms competing with open-source software and found that companies producing proprietary software in direct competition with comparable open-source software may produce lower quality software than in the absence of such competition.[337]

187. There is some evidence to suggest that market conditions change the market outcomes of open source and proprietary software competition. A paper by Cheng et. al., found that depending on the presence of network externalities, competition between proprietary software and open-source software may result in worse

proprietary software quality.[338] Finally, a paper by Zhou and Choudhary indicated that competition with open source may reduce or increase proprietary software quality depending on the cost of enhancing software quality, among other factors.[339]

188. The tendency of some open-source developers to adopt more restrictive licensing may also complicate the effects of open source on competition dynamics. August et. al. modelled a three-way competition between a proprietary firm, an OSS originating firm and an OSS contributing firm and found that 'the economic incentives associated with investment in OSS vary substantially depending on the license governing it as well as the market conditions'. They conclude that 'increased license restrictiveness often leads to preferable market outcomes' unless competition takes place in 'a more competitive environment characterized by low-cost dispersion, [where] a quality-leading proprietor has incentives to scale back efforts and effectively impede OSS development under the threat of increased license restrictiveness'.[340]

189. When proprietary alternatives are unavailable, open-source software may potentially enable large cost savings across the entire economy by allowing companies to avoid 'reinventing the wheel' on commonly used capabilities and therefore lowering barriers to entry or increasing software quality.[341] This may be particularly crucial for smaller companies who may find it difficult to fund development of often complex, foundational capabilities.

190. Open source hardware and software use may improve the quality and quantity of available talent through making skills more transferable between companies, and unlocking contributions from a wider pool of talent.[342,343] Open source contributions and certifications are already considered indicators of experience, and are highly desirable.[344] This is particularly pertinent with the current talent shortage in digital markets.[345] Competition could also then potentially benefit from increased use of open source through lower talent acquisition costs, which could in turn lower barriers to entry and increase the number of new entrants in digital markets.

How might this trend impact consumers?

191. Some of the benefits listed above, such as increased innovation, may also be considered consumer benefits as they may lead to increased consumer choice, reduced costs and/or increased quality of products. However, there may also be some potential drawbacks to how open source may be used in digital markets. An expert we spoke with as part of our research along with a recent paper by Widder et al. argue that the 'open source' label is prone to being used as a marketing tool, potentially misleading consumers in certain cases. They note, in particular, the way in which 'open source' has been used recently by some AI-focused companies to label applications that do not correspond fully to what is understood as open source.[346]

192. Another potential consequence of the proliferation of open-source software for consumers is in the creation of new security challenges. There are some features of open source development and deployment that may make it more vulnerable to attack. Since one piece of open-source software can be used in a large number of applications, there are numerous potential targets for cybercriminals every time a vulnerability is found in any one piece of software. Moreover, to properly address a vulnerability in open source software, it often needs to be disclosed publicly, which alerts malicious actors to its existence. Even when not disclosed publicly, the availability of the source code and the open development model may make it easier for malicious actors to find vulnerabilities in the code, or even suggest modifications to the source code which may contain malicious capabilities. The difficulty of managing these risks is further complicated by the fact that open-source code use is frequently not well documented. Even when the original open source code is swiftly updated by its developers to fix a known vulnerability, the new code does not automatically get

updated in all the applications that utilise it.[347] All of these security challenges combined have potential to make targeting open source a growing part of cybercriminal operations, with supply-side attacks reportedly surging 632% in 2022.[348]

Trend 10

Consumers continue to want personalised experiences but remain conscious of how their data is used

Introduction

193. Content which changes according to user behaviour and preferences is not new but is increasingly becoming part of digital life. Many users of online platforms now anticipate, and often demand, superior degrees of dynamic content aligned with their personal profiles. Personalisation can be hugely valuable for consumers when done right. It can reduce consumer search time and increase the likelihood of offers that are of interest to them.[349,350] Personalisation can also harm consumers, for example when pricing is complex or opaque to consumers, when consumers cannot avoid it and where businesses have the ability and incentive to exploit consumer biases and vulnerabilities.[351]

194. For firms, personalised experiences have been found to lead to higher conversion rates,[352,353] with the data collected from personalisation allowing firms to gain valuable insights to provide more tailored products and services.

195. Based on the data collected on each consumer, platforms can use algorithms to create this tailored experience in line with a user's preferences and usage patterns. Examples of this personalisation include which options are presented to consumers, in what order, how prices are presented, the timing and content of notifications and reminders, and indeed whether and which offers are made.[354,355,356]

196. Typically, a rich volume of such user-generated data translates to a more refined and accurate system that can predict user expectations and behaviours. This can mean more relevant and tailored services for individuals, but also raises potential concerns, including competition, consumer protection, privacy, and discrimination.[357,358] The CMA previously found that many consumers value personalisation but also do not want the data they generate to be a free-for-all.[359] How this trend develops in future will have important implications for competition and consumers.

Signals and evidence about this trend

197. A 2021 McKinsey survey of US consumers showed that as many as 71% expect companies to provide personalised interactions online.[360] When these expectations are not met, 76% indicated that they experience dissatisfaction. The overarching sentiment observed among consumers is for companies to 'meet me where I am'[361], with the 2015 Deloitte Consumer Review finding 42% of consumers wanted guidance to come from brands.[362] Furthermore, according to Twilio Segment's 2021 State of Personalisation report, over 60% are more likely to become repeat buyers when offered a personalised experience with a retailer. This is a 16 percentage point increase from the 2017 version of the report (44%).[363]

198. Facilitating this personalisation necessitates advanced software solutions. According to a 2022 ReportLinker analysis, the 'personalisation software market' was valued at (USD) $943m in 2022.[364] At a compound annual growth rate (CAGR) of nearly 24%, it is projected to exceed $5bn by 2030.[365] Separately, IndustryARC projects that what they define as the 'recommendation engine market' might grow to $12bn by 2025, up from $1bn in 2018.[366]

199. A 2019 Forbes survey among marketing leaders quotes 57% as hoping to advance their personalisation capacity 'within the next year'.[367] In a separate 2023 report, firms with 40% or more revenue derived from personalisation seem to grow faster than the market average.[368]

200. The CMA's Online Platform and Digital Advertising market study highlighted the role of personalisation in online advertising.[369] Making use of sophisticated personalisation

has been a component of the continued growth of the UK's digital advertising market, now valued at £26.1bn with year-on-year growth of 20%.[370]

201. However, consumer concerns on privacy and data collection go in tandem with potentially increased appetite for personalisation. For instance, the UK Information Commissioner's Office (ICO) 2022 Awareness survey found that 50% of respondents felt unhappy with firms using data to show personalised ads, and 78% were concerned about personal information being used to influence behaviour.[371]

202. Further to this, in 2019, Ipsos Mori found that 69% of consumers felt they had little or no control over their online data[372]; the Data and Marketing Association (DMA) cited 88% of respondents in a 2022 report as wanting more control over their data.[373] This is not limited to the UK either, with almost 80% of European respondents in a 2022 EDAA survey preferring to have the option to turn off all personalised advertising at will.[374]

203. This is reflective of an overall trend in the evidence; consumers want personalisation, but they do not necessarily approve of widespread use of their data for this purpose. In fact, almost a third of respondents in a 2020 survey found this type of data collection invasive, while only 17% of respondents believed that they were getting a good deal out of letting 'free' services collect their data over asking them to pay.[375] Data protection authorities have taken action to ensure that data collection practices comply with relevant legislation.[376]

Possible Future Developments

204. One potential direction this trend could take is toward further personalisation. This could mean an increase in the level of personalisation for existing services, as well as an expansion of personalisation strategies into new markets. One current indication of where this potential expansion could be headed is McDonalds acquiring DynamicYield to use personalisation technologies in their drive-thru experience.[377] This could be a sign of how, in the future, the line between offline and online personalisation could become more blurred, with data-driven personalised experiences used across more 'traditional' services.

205. Another way in which personalisation could develop is through an increase in its ability to pre-emptively personalise, with algorithms mapping user data to potentially cater to needs and patterns of behaviours before the user articulates them. In the commercial domain, popular games like Candy Crush serve as a current example of experiences that offer hyper-personalisation as a component of their monetisation. This is done by utilising data to identify specific player habits, preferences, and even susceptibilities. By understanding player actions, these platforms can modify game difficulty, introduce timely rewards, or suggest in-app purchases, all in ways designed to maximise user retention and revenue. As technology continues to progress, sectors outside of gaming could leverage sophisticated personalisation algorithms to cater to their own 'whales',[378] possibly incentivising firms to have AI play a larger role in their monetisation strategies.

206. In a different scenario, personalisation levels could remain similar to what they are now, or even decrease. This could happen if firms became cautious about the risk of 'over-personalising', as using too much data could potentially result in diminishing returns for further personalisation and reduced user engagement.[379] Where this is the case, firms may choose not to invest the resources necessary to pursue further personalisation. This stagnation of, or reduction in, personalisation could also occur if consumer dissatisfaction toward the data collection practices used to power

personalisation increases, or in the event of potential regulatory developments affecting these practices.[380, 381, 382]

207. Wild card developments could take this trend in yet another possible direction. For example, privacy enhancing technologies (PETs) could make it possible to have both the benefits of personalisation but also ameliorate privacy concerns. An early sign of this might be moves towards using such technologies in digital advertising, away from individual tracking, although the extent to which they may preserve both user privacy and utility for advertising is still to be fully understood.[383] The use of local machine learning can also help have personalisation while not sharing user-generated data away.[384] Equally, developments in 'small data' machine learning could mean that similar or better levels of personalisation could be achieved without the need to collect and assemble large datasets.

How might this trend impact competition?

208. In line with the CMA-ICO joint statement, the ability for data-driven personalisation to augment a healthy competitive environment is best served when there is not differential access to data.[385] When there is differential access to data, as was found in the CMA's Online Platforms and Digital Advertising market study,[386] some platforms may find themselves with self-reinforcing capacities. Platforms with greater access to data might be able to personalise better than their competitors, becoming more accurate over time if user-generated data becomes richer, as well as potentially being more valuable to advertisers and better able to successfully monetise services.[387]

209. Developments such as PETs could in principle underpin greater, privacy-preserving data access, with benefits for competition.[388,389] The CMA previously established that, in enabling data access, there is a balance to be struck between competing factors: efficiencies, competition and privacy.[390] The way PETs may impact on these different factors will depend on their specific properties and implementation. PETs generally involve a trade-off between utility and privacy. If this trade-off is not well managed, it may lead to less efficient markets by reducing the quality of data which could be used to improve competition, without commensurate privacy benefits. Managing these trade-offs is therefore an important issue. This is a key consideration for the CMA and ICO in assessing the Google Privacy Sandbox as part of the CMA's antitrust investigation.[391] Further, while an individual assessment is necessary, it is possible that PETs could strengthen the position of incumbents in particular markets in a number of ways.[392] For instance, this could happen if the use of a PET disproportionately affects competing businesses by limiting their access to data which they need to compete (the incumbent may equally access less data but may have alternative data sources which cushion against this).

210. It is possible that firms may come to compete on the quality of their personalisation services (for example their recommender systems). This may favour established firms who are able to collect and store lots of consumer data, and firms which offer complementary services through which they can acquire valuable data. In a 2019 field experiment, personalisation by recommender systems led to an overall reduction in diversity of products sold, with an increase in market share for popular products.[393] However, firms may also compete on how they are able to personalise their overall offering to suit consumer needs. This may favour established firms, or this may encourage smaller businesses to innovate and to leverage specialised offerings.

How might this trend impact consumers?

211. Enhanced personalisation features could be a tool to help segment information and reduce overload in a way that increases user engagement and satisfaction among

consumers.[394] This potential positive effect could extend to consumer welfare too. For instance, personalised feedback is more effective than generic alternatives for computerised mental health interventions, such as those using mobile apps.[395]

212. However, while personalisation can help consumers make choices according to their preferences, it can also enable firms to exploit consumers' vulnerabilities and biases.[396,397] Personalisation may make it harder for consumers to identify harmful choice architecture practices.[398] The ICO and CMA have called for businesses to stop using harmful website designs (eg 'biased framing', 'sludge', 'confirmshaming') that can trick consumers into giving up more of their personal data than they would like.[399]

213. Firms might also utilise user-generated data for personalised pricing. Past work by the Office of Fair Trading has pointed out that this could have benefits for consumers. It might lower the effort and time they spend searching for products and help match consumers with products and services that suit them, potentially at lower prices.[400] However, the CMA has also noted that there can be potential harms from personalised pricing, particularly where it is potentially complex or lacking transparency. These harms can include losses of trust in online markets or increases in search and transaction costs due to consumers potentially shopping around to avoid the personalised price offerings.[401]

214. A drive towards greater personalisation could also potentially lead to a heightened information imbalance between businesses and consumers, where users' data is being used in ways that are potentially opaque to them, facilitated by rapid consent processes like clickwrap agreements.[402] One example of this potential imbalance is giving different users unique time-limited offers to, potentially artificially, inflate exclusivity and scarcity to encourage consumers to spend.[403] This type of imbalance could be particularly problematic for users in vulnerable states, as well as potentially affecting consumers' ability to identify when other types of harmful choice architecture are being used.[404] Ultimately, this could reduce transparency and consumer trust in platforms.

215. PETs or local algorithms could potentially allow content personalisation while ensuring greater privacy protection. However, PETs may potentially give consumers a false sense of security or trust in digital markets.[405] Not all PETs ensure anonymisation and they do not necessarily eliminate the risks of re-identification, rather they manage these risks specific to the context in which they are used.[406] In some cases, the assessment of the acceptable risks is embodied in the privacy-utility trade off that is part and parcel of the design and implementation of the PET. If these risks are not well managed, it may damage consumer trust in data markets and undermine the benefits of data sharing. In addition, PETs might introduce further complexity and opacity in how data is used for personalisation. This is important because, while consumers do not necessarily need to understand the actual technology, they cannot make effective choices if they do not understand the overall security or privacy impacts of their decisions.[407]

Conclusion and next steps

216. Digital markets and new technologies are rapidly evolving. The CMA is therefore fully invested in understanding not just the technologies and markets of today but also to think about the new technologies and markets that may emerge in the future. This will ensure that people can be confident they are getting great choices and fair deals, that competitive, fair-dealing businesses can innovate and thrive, and the whole UK economy can grow productively and sustainably.

217. This report explores the implications of ten trends that could be significant trends in digital markets in the next five years and beyond. These shortlisted trends were selected through a prioritisation process designed to highlight those trends with greater strategic importance to the CMA, considering their potential impact on competition and on consumers.

218. Through this work we have indicated early thinking on the potential future development of these trends, alongside the potential implications for competition and consumers. As with any future facing research the aim is not to predict but rather to explore and examine, and to create the space for conversations.

219. This future is uncertain, and as such the report does not reflect any legal or policy position from the CMA. The CMA will continue to explore and think about these issues and use these trends to future-proof our thinking about markets and how they might change. We will continue to engage on these trends and related issues through the DRCF, our next CMA DaTA Conference, and other domestic and international fora.

220. The research and analysis presented here will feed into continuing preparations for the digital markets competition regime and Digital Markets Unit, picking up on some of the trends, for example on interoperability. Our analysis will also be useful for the next phase of the CMA's AI Foundation Models review, which will include research and engagement on the AI accelerator chips market. Finally, we will use our scan and this report as a basis for further exploration of some of the trends, and as we continue to develop our horizon scanning capability.

221. We also hope this 'Trends in Digital Markets' report will encourage the further sharing of similar future-facing work by other competition and consumer protection agencies, and other regulators.[408] More broadly, we hope this report will help stimulate discussions and generate further insights at pace, for the benefit of people, businesses, and the economy.

Annex A: Methodology to identify and prioritise trends

222. The primary goal of the horizon scanning project was to identify and prioritise trends in digital markets that were relevant to CMA strategic objectives, as well as for competition and consumers more generally. We focussed predominantly on trends with a 0–5-year time horizon but also considered those which were likely to have impacts in the longer term of 6-10, and 10+ years.

223. We defined a trend as a directional shift that could have an impact in digital markets (this included things like technology adoption, changes in business models, or emerging strategies of firms in markets). Trends might arise due to a variety of internal or external factors, and we utilised a PESTLE framework to assist in identifying them.[409]

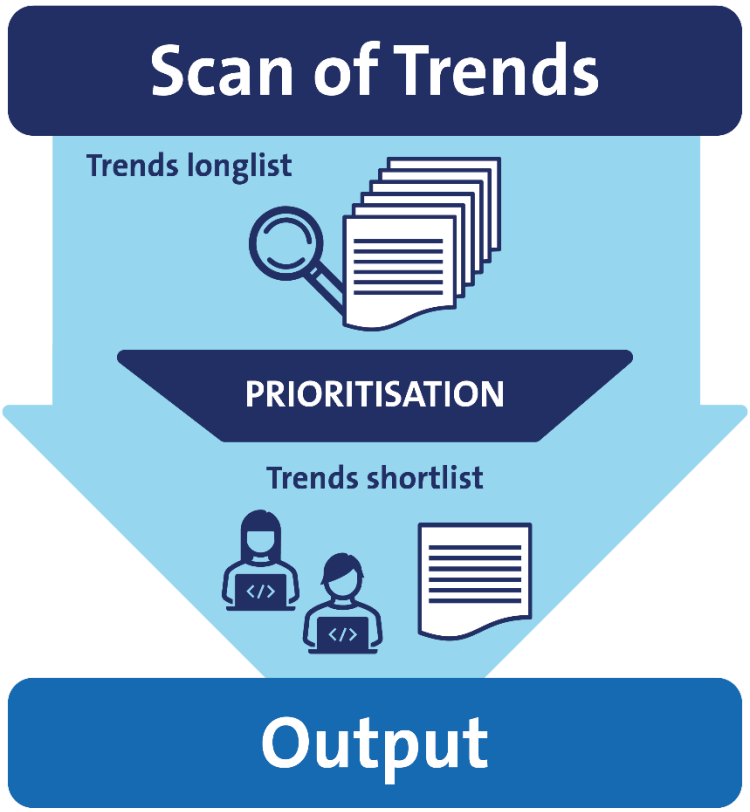

Figure 4: High-level overview of the horizon scanning and prioritisation process.

224. Our methodology included a series of steps (see Figure 4):

- **Scanning:** We started with a pre-scan to validate our approach and to identify the sources most likely to yield useful information. We then conducted a time bound scanning exercise of various sources such as reports, publications, and newsletters, as well as conducting an internal and external survey for both cross validation and as a source of trends. This was collected into a master list of potential trends (c400).
- **Collation and harmonisation:** The list of trends underwent a thorough review. Trends were subsequently grouped or merged to bring similar trends together and harmonised for more equitable comparison.

- **Prioritisation:** We prioritised with a two-phased approach. The initial list of harmonised trends (c200) were scored on 'strategic importance'. All trends that met a threshold (c118) were then scored on 'competition' and 'consumer' criteria. Most of the criteria were qualitative in nature but were cross validated by at least two members of the team. Finally, we ran an internal workshop to discuss the top 29 trends, during this workshop we decided to retain one overarching AI trend only and to include one trend that was not in the top 29 due to a qualitive assessment of its importance ('Increased development and usage of open-source software and hardware'). All included and excluded trends were validated at each stage of prioritisation to assess: 1. If we had included trends that we thought might 'fall out' of the rankings, and 2. If there were trends which we felt should have been included but were not. Open source was the only such trend. Our prioritisation criteria included:

    - **Strategic importance:** Time to market impact; Potential magnitude of disruption; Confidence that the trend is happening; The number of sectors potentially impacted; Novelty for the CMA; and Alignment with CMA's mid-term objectives[410]
    - **Competition:** The likelihood of harms to competition; The likelihood of benefits to competition; and Likelihood that the trends could benefit larger firms
    - **Consumer:** The potential for harms to consumers; and the potential for benefits to consumers

- **Expert input:** We sent our prioritised 10 'top trends' to a selection of internal and external experts for views on the scope of the trends, and for any existing materials that might help pull out the most significant aspects of each, particularly related to competition and consumer issues. We deliberately focused on how the trends might impact competition and consumers, as we believe that healthy competition will benefit the economy and businesses. We therefore chose not to have dedicated sub-sections for businesses and wider economy as this would significantly lengthen our discussion of each trend. But, where relevant, impacts on the economy are discussed in our analysis of 'signals and evidence'.

Limitations of approach

225. As with any horizon scanning process there will be limitations and often these result from trade-offs. These trade-offs could be in terms of depth versus breadth, rigour versus resource, and many factors which relate to the topic in which the horizon scanning is being applied. Whilst we tried where possible to account for any limitations in our process, there will be an element of 'you don't know what you don't know' and the possibility of 'missing' things. We will update and iterate our methods as we learn what works but have set out our limitations, as we see them, below:

- There is a possibility that our process has excluded important trends and included less important ones. We minimised this risk by using cross-validation where possible and validation on included and excluded trends.
- There is also the possibility that we did not identify important trends. This could be by virtue of using inappropriate methods or extracting information from inappropriate sources. Again, we minimised this by conducting pre-scanning to validate our approach.
- We also may have prioritised trends due to hype. This could be the reason why AI came out strongly in the top trends (albeit AI is an important topic). To avoid this, we chose to focus on the near term and the longer term. We also included prioritisation criteria that would minimise this such as 'novelty'. Where we had multiple trends on

similar topics, we chose to focus on the broadest trend as opposed to covering many trends on similar topics, this minimised duplicative trends in the report.

- Finally, many of our trends, particularly in collation and harmonisation, had significant overlap, were similar, or closely aligned. In this instance we merged trends (keeping the original trend and associated data) and opted to keep broader trends over narrower ones**,** as broader would likely cover the latter.

Annex B: Top trends not explored in the report

226. Several significant trends didn't make the final report but remain relevant, particularly those related more explicit to AI. While the report features only 10 ‘top trends’ the following trends still scored highly during our prioritisation exercise. We have included them below for reference:

- AI implementation is increasingly transforming multiple digital sectors.
- The continued rapid evolution of transformer and other AI architectures.
- Health and Tech sectors are becoming increasingly intertwined.
- An increase in the leveraging of health and digital data for personalised medicine.
- Increasing uses of AI to find, use and monetise data.
- Increased consumer use of virtual assistants and intelligent agents.
- Cloud services are increasingly integrating AI capabilities into their offerings.
- AI implementation increasingly prevalent and disrupts traditional markets (eg health, education).
- Larger technology companies continue to innovate to protect their core business.
- Increasing use of ‘deep tech’ as a basis for business models[411].
- Accelerating development of new computer interface technologies eg haptics, brain computer interfaces.
- Increasing potential arms race between AI harms and the responses to them.
- Companies are increasingly re-bundling services and production capabilities to compete.
- Increasing desire for better or more regulation of AI.
- Emergence of new health markets powered by AI.
- The size, utility, and usage of collated datasets is increasing.
- 'Deep tech' firms who invest in a wide array of technologies (AI, Quantum, IoT, Cybersecurity) are pushing the boundaries of multiple markets.
- Larger technology firms continue to show interest in newer areas of consumer tech (VR, neurotech, etc) through new products, services or acquisitions.
- Continued integration of digital and physical product interfaces.

Endnotes

Executive summary

[1] CMA (2023) AI Foundation Models: initial review - GOV.UK (www.gov.uk)

Background and overview

[2] Hunt, S. (2022) The technology-led transformation of Competition and Consumer Agencies: the CMA's experience.- GOV.UK (www.gov.uk)
[3] CMA (2023) AI Foundation Models: initial review - GOV.UK (www.gov.uk)
[4] See: Digital Regulation Cooperation Forum
[5] See: Digital Markets, Competition and Consumers Bill - Parliamentary Bills - UK Parliament
[6] See: Biographies of the CMA's independent digital experts - GOV.UK (www.gov.uk)
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Trend 1: Rapid and widespread deployment of AI Foundation Models

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Trend 2: Increasing technology convergence enables the creation of new and disruptive products and services

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[99] OpenTable is a service which allows the consumer to view and book restaurants.

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Trend 5: Growing incumbent and new entrant activity in the markets for CPUs, GPUs and AI accelerators
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Trend 6: Interoperability improvements are uneven but remain an important driver of market outcomes
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Conclusion and next steps
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