



Digital mergers: recent insights and policy implications[☆]

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ABSTRACT

This paper examines merger control in digital markets and the enforcement challenges it raises. We discuss recent developments in the U.S. and the EU and analyze how specific characteristics of digital markets can either enhance or mitigate the exercise of market power. We study the effects of digital mergers on competition both in the market and for the market, and assess their implications for innovation. The paper concludes with policy recommendations aimed at improving enforcers' assessment of digital mergers.

1. Introduction

Consolidation projects involving digital players have played a major role in both Big Tech's growth strategies and the recent policy debate. As shown in Table 1, the main digital platforms have completed a very large number of such acquisitions.¹ Acquisitions, as opposed to IPOs, are currently the dominant exit strategy for start-ups (Ederer and Pellegrino, 2023; Eisfeld, 2025).

Big Tech companies have acquired companies at various stages of development. Table 2 reports illustrative acquisitions by the "big-five": Alphabet (formerly Google), Apple, Meta (formerly Facebook), Microsoft and Amazon. Some of these transactions involved well-established companies with mature user bases. For example, Microsoft acquired LinkedIn 13 years after its launch, when the platform had moved beyond its initial phase of rapid growth. Similarly, Apple acquired Shazam 16 years after the music recognition app's debut. By that stage, Shazam had

entered a phase of stability, if not decline, as reflected in its reported acquisition price being significantly below the billion-dollar mark. In 2023 Amazon acquired One Medical, a membership-based health care company founded in 2007 that offers virtual care as well as in-person visits with about 815,000 members at the time of the acquisition.

Conversely, other acquisitions targeted early-stage startups before they could potentially emerge as formidable competitors. Instagram and YouTube exemplify this approach. Meta acquired Instagram just two years after its launch, transforming it over the next 12 years from a 50-million-user app into one of the world's largest social media platforms, now boasting over 1.4 billion active users. Similarly, Alphabet acquired YouTube only a year after its launch. Over time, YouTube evolved into the world's largest video platform, further strengthening Google's leading position in the online search and digital content markets.

The debate on antitrust in digital markets and its empowerment has played a central role in the last few years, driven by a perception of

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¹ See Gautier and Maitry (2024). Other scholars have offered estimates on the number of acquisitions by Big Tech companies. Focusing only on the "big five," Motta and Peitz (2021) report 42 acquisitions by Amazon, 33 by Apple, 21 by Facebook, 48 by Google, and 53 by Microsoft in the period 2015–2020. A report by the Federal Trade Commission (2021) lists over six hundred acquisitions by the same five firms that fall below the thresholds for notification in the period 2012–2019.

Table 1

Big-tech acquisitions during the 1996 – 2021 period.

Big Tech	Firms acquired between Jan 1996 and Jan 2021
Alphabet	106
Amazon	128
Apple	104
Meta	264
Microsoft	257
Total	859

Notes: Big Tech companies considered here are Alphabet, Amazon, Apple, Meta and Microsoft. Source: [Gautier and Maitry \(2024\)](#).

underenforcement and calls for more effective intervention.² Merger control is one of the central themes. This paper reviews recent academic insights on the effects of mergers in digital markets and examines their implications for the enforcement of merger control.

The paper is organized as follows. Section B briefly reviews recent case law and reforms in merger control, mostly in the U.S. and the EU. Section C discusses the definition of relevant markets in digital cases. Section D addresses the analysis of digital mergers, further distinguishing between the assessment of competition in digital markets (D.1) and the effects of digital mergers on competition (D.2). Section E covers recent contributions on the effects of mergers and acquisitions on innovation. Section F summarizes the main policy insights and suggestions.

2. Recent developments in digital merger enforcement policy and case law

Some recent high-profile digital merger cases involve established firms. In *Amazon-iRobot*, vertical foreclosure concerns emerged on both sides of the Atlantic (see Section D.2.b for a discussion of the exclusionary effects of digital mergers). In the EU, the European Commission (EC) opened a Phase-II investigation in July 2023, expressing the view

Table 2

Some notable acquisitions by Big Tech companies.

Buyer	Alphabet			Apple	Meta		Microsoft		Amazon
Acquired company	YouTube	Waze	Fitbit	Shazam	Instagram	WhatsApp	Skype	LinkedIn	One Medical
Year of launch	2005	2008	2007	2002	2010	2009	2003	2003	2007
Acquisition year	2006	2013	2019	2018	2012	2014	2011	2016	2023
Acquisition price (\$ bn)	\$ 1.6	\$ 1	\$ 2	\$ 0.4	\$ 1	\$ 19	\$ 8.5	\$ 26	\$ 3.9
Users (at time of acquisition)	NA	NA	30 mn	160 mn	50 mn	450 mn	170 mn	430 mn	0.815 mn
Users (latest available date)	2.5 bn	140 mn	38.5 mn	NA	1.4 bn	3 bn	2.27 bn	770 mn	NA

Sources: Data about price of acquisition come from: SEC for YouTube, Waze and Fitbit; Meta Investor Relations for Instagram and WhatsApp; Microsoft Investor Relations for Skype and LinkedIn; Financial Times for Shazam (the price of acquisition was not officially disclosed). Data on users at time of acquisition come from: Statista for Instagram; Meta Investor Relations for WhatsApp; Microsoft Investor Relations for Skype and LinkedIn; SEC for Fitbit; European Commission for Shazam. Data on current users come from Statista for Skype, LinkedIn, Fitbit, WhatsApp, Instagram, YouTube; Google for Waze.

Notes: The reported cases are selected as illustrative examples of acquisitions by Tech giants spanning targets with different prospects and at very different stages of development—from mature companies to very young startups that nonetheless sometimes commanded exceptionally high acquisition prices.

that acquiring iRobot, one of the leading suppliers of robot vacuum cleaners, could enable Amazon to profitably foreclose rival manufacturers by restricting or degrading their access to Amazon Stores. During the investigation, the EC remained in close contact with the U.S. Federal Trade Commission (FTC), which also scrutinized the deal and indicated it was preparing a legal challenge based on similar theories of foreclosure and self-preferencing. Facing opposition in both jurisdictions, Amazon and iRobot abandoned the deal in January 2024.

Vertical foreclosure also lies at the core of *Microsoft-Activision*,

² See the reports by [Cr  mer et al. \(2019\)](#) for the DG Competition, by [Furman et al. \(2019\)](#) for the CMA and the report prepared by the [Stigler Committee for the Study of Digital Platforms \(2019\)](#).

another case that illustrates convergence in the theories of harm examined across the Atlantic. Microsoft supplies the Xbox console along with related gaming services, while Activision is a major content producer. The concern was that Microsoft could restrict access to key Activision content, most notably Call of Duty, to disadvantage rival consoles and providers of cloud game streaming service. Institutional approaches, however, diverged. In the US, the FTC sought a preliminary injunction to block (or at least pause) the merger, but in July 2023 the Northern District of California Court held that the evidence of anti-competitive effects brought by the FTC did not meet the legal standard for an injunction (a decision affirmed by the Court of Appeals for the Ninth Circuit in 2025). In the EU, following a Phase-II investigation, the EC concluded in 2023 that Microsoft was unlikely to harm rival consoles or multi-game subscription services, but it identified a risk in cloud game streaming. The EC cleared the merger subject to behavioral remedies granting cloud-gaming providers broad licensing rights to Activision's content.³

Convergence in theories of harm is also visible in *Google-Fitbit*, where the key concern was that Google could leverage Fitbit's health and fitness data to reinforce its position in advertising markets (see Section D.2.b for a discussion of the exclusionary effect of data-driven mergers). Yet, enforcement tools differed. In the EU, following a Phase-II investigation, the EC cleared the merger in December 2020 subject to binding commitments, most notably restrictions on the use of Fitbit health data for Google advertising and safeguards to preserve Fitbit data access for rivals.⁴ In the U.S., by contrast, no formal enforcement action was brought: Google closed the deal in January 2021, while the DOJ indicated that its investigation would continue post-closing, effectively creating a "close-at-your-own-risk" scenario.

Booking-eTraveli, instead, exemplifies divergence between EU and U.S. merger enforcement in digital markets. The transaction would have combined a leading provider of hotel online travel agency (OTA) services and one of the main providers of flight OTA services. In 2022 the FTC cleared the transaction unconditionally, as did the UK Competition

³ The UK Competition and Markets Authority reached a competitive assessment broadly similar to that of the EC, identifying cloud gaming as the main area of concern. However, unlike the EC, it considered the proposed behavioral commitments insufficient and initially prohibited the merger. Approval was granted only after the transaction was restructured so that cloud-streaming rights for Activision's games outside the EEA were divested to Ubisoft. The case illustrates that convergence in theories of harm need not imply convergence in remedy design.

⁴ Similarly, in *Amazon-One Medical* the main concern was that integration could allow Amazon to access and leverage sensitive health data within its broader ecosystem, creating risk of exclusionary conduct and consumer harm. The FTC did not take any action but issued a public statement emphasizing that its scrutiny would continue.

and Markets Authority (CMA). By contrast, the EC developed an “ecosystem theory of harm” and blocked the deal in September 2023. After a phase-II investigation, the EC found that the transaction would have strengthened Booking’s dominant position in the hotel OTA market. Because flight searches are often an early step in trip planning and have a high propensity to lead to cross-selling of accommodation, the merged firm could use eTraveli as a powerful customer-acquisition funnel. Given consumer inertia, a substantial share of users searching for flights would likely remain within Booking’s ecosystem, making it harder for rival hotel OTAs to expand and effectively challenge Booking’s position.

As noted in Section A, digital mergers have increasingly targeted start-ups and small, innovative companies. Some of these targets are described as *nascent (or potential) competitors*: firms that are not yet active in the market, or are active but exert little competitive pressure at the time of the acquisition, but have the potential to become significant competitive forces in the future. (Section E.2 discusses the insights of the relevant economic literature.) Such targets often generate zero or minimal revenue when acquired and fall below revenue-based notification thresholds. As a result, these transactions may escape merger review, leading to a phenomenon known as stealth consolidation.

Some of these acquisitions, most notably Facebook’s purchases of Instagram and WhatsApp, have fueled substantial ex-post debate about the adequacy of enforcement.

Facebook-Instagram was not reviewed by the EC because Instagram’s turnover was too small to meet the EU notification thresholds at the time. It was reviewed in the UK, where merger control operates under a voluntary notification system and the competition authority can proactively investigate mergers, whether completed or in progress. The Office of Fair Trading (the UK antitrust authority at the time) concluded that there was no “realistic prospect” of a substantial lessening of competition: Instagram was primarily a mobile photo app with only limited social-networking functionality and, therefore, was not well placed to compete with Facebook in the short run, in social networking and advertising. The FTC also investigated the deal (in the U.S. notification can also be triggered by deal value; here, the \$1 billion purchase price was far above that threshold) and closed its investigation without taking any action.

This case illustrates the difficulty of blocking such transactions—when they are investigated at all—because the standard of proof developed for mergers between established competitors fits poorly when potential anticompetitive effects are inherently uncertain and may materialize only in the future, if the target grows into a meaningful rival.

Similar considerations apply to *Facebook-WhatsApp*. The EC approved the merger in 2014, finding limited competitive overlap (WhatsApp was not a close competitor to Facebook/Messenger and multiple alternatives existed in consumer messaging). Some argued WhatsApp could evolve into a social network, but the Commission found it was not a close substitute for Facebook’s richer social networking functionality. For broadly similar reasons, the FTC did not bring an antitrust challenge in the U.S. These decisions were criticized ex-post also because the review did not adequately account for the data advantages created by the transaction.⁵

In December 2020, the FTC sued Facebook/Meta alleging illegal maintenance of monopoly power in social networking, explicitly citing the acquisitions of Instagram and WhatsApp as part of the alleged strategy. According to the FTC’s complaint, Facebook executives quickly recognized that Instagram posed an existential threat to Facebook’s monopoly power. The acquisition allegedly aimed to neutralize that threat and make it harder for another social networking competitor to

gain scale. Around the same time, according to the complaint, Facebook’s leadership understood that a successful mobile messaging app could enter social networking, by adding new features or by spinning off a standalone social networking app. By acquiring WhatsApp, Facebook allegedly neutralized an emerging threat and ensured that any future threat would face greater difficulty gaining scale. The FTC sought remedies including divestiture. In November 2025, a federal judge ruled against the FTC (meaning Meta was not forced to divest Instagram/WhatsApp), but in January 2026 the FTC announced it would appeal that adverse ruling.

Overall, these cases show that traditional merger control faces some difficulties in capturing the specificities and competitive risks of digital acquisitions.⁶ Together with persistent challenges in detecting and reviewing deals, especially acquisitions of small or fast-growing targets that fall below notification thresholds, this has fueled a perception of insufficient enforcement. In response, authorities on both sides of the Atlantic have introduced new approaches and tools to strengthen scrutiny of digital mergers

In the U.S., in December 2023, the Federal Trade Commission and the Department of Justice released their new Horizontal Mergers Guidelines,⁷ after a phase of intense debate and public consultation. Although the new Guidelines apply across the economy, several provisions are particularly relevant to digital markets. Guideline 4 (*Mergers Can Violate the Law When They Eliminate a Potential Entrant in a Concentrated Market*) represents a tool for examining the acquisition of small competitors and start-ups. Guideline 5 (*Mergers Can Violate the Law When They Create a Firm That May Limit Access to Products or Services That Its Rivals Use to Compete*) speaks to concerns central to self-preferencing and vertical foreclosure. Guideline 6 (*Mergers Can Violate the Law When They Entrench or Extend a Dominant Position*) and 7 (*When an Industry Undergoes a Trend Toward Consolidation, the Agencies Consider Whether It Increases the Risk a Merger May Substantially Lessen Competition or Tend to Create a Monopoly*) address dynamic patterns of entrenchment driven by systematic acquisitions. They are complemented by Guideline 8 (*When a Merger is Part of a Series of Multiple Acquisitions, the Agencies May Examine the Whole Series*), which allows the agencies to examine a series of acquisitions as a whole rather than each transaction in isolation. Finally, Guideline 9 (*When a Merger Involves a Multi-Sided Platform, the Agencies Examine Competition Between Platforms, on a Platform, or to Displace a Platform*) explicitly addresses mergers involving multi-sided platforms, a key feature of many digital markets.

In the EU, the Digital Markets Act (DMA) marked a significant shift from traditional ex-post antitrust intervention to ex-ante regulation of core digital platform services. However, neither the DMA nor the other recent digital regulations address mergers. Merger control remains under the exclusive jurisdiction of DG Competition, including the review of mergers in digital markets.⁸ The DMA merely requires gatekeepers to *inform* the Commission of any acquisition they undertake, regardless of the target’s size. Importantly, this duty to inform is distinct from an obligation to notify, as it does not require the Commission to review the transaction, and it applies only to gatekeepers.

Acquisitions by large companies of *nascent competitors* can, therefore, continue to escape scrutiny. To enhance its ability to investigate such transactions, the EC reinterpreted art. 22 of the European Union Merger Regulation (EUMR). Art. 22, also known as the “Dutch clause”, was originally intended to allow EU Member States without their own

⁶ See Argentesi et al. (2019) for an ex-post review of some prominent digital mergers evaluated by the UK Competition and Markets Authority (CMA).

⁷ See Department of Justice, Antitrust Division (2023).

⁸ In 2025 the European Commission started the process for the Review of the Merger Guidelines. In parallel to a General Consultation, the EC has carried out an In-depth Consultation on seven key topics of the review, which include “Innovation and other dynamic elements in merger control” (topic C) and “Digitalization” (topic E).

⁵ Interestingly, the EC later fined Facebook €110 million (2017) for providing misleading information during the merger review related to the ability to match Facebook and WhatsApp user accounts.

merger control regimes to request that the Commission reviews mergers with potentially significant anti-competitive effects. Under the expanded use of art. 22, "below-threshold" mergers could be referred to the EC. For example, the French Competition Authority referred to the EC the *Illumina-Grail* merger under art. 22, even though Grail had no significant EU turnover. As a result, the EC reviewed and ultimately blocked the merger in 2022. In September 2024, however, the European Court of Justice (ECJ) annulled the Commission's decision,⁹ criticizing its reinterpretation of Article 22. The ECJ ruled that Member States could not refer transactions they lacked jurisdiction to review under their national laws. The Court also highlighted the importance of predictable and clear turnover thresholds for merger reviews, arguing that the EC's approach undermined legal certainty for businesses.

The ECJ's ruling limits the Commission's ability to scrutinize below-threshold transactions. However, some Member States have adopted alternative mechanisms to address such deals. In Italy, Law No 188/2022 introduced the use of "call-in powers" under Article 16-1 bis of the national competition law framework. These powers allow the authority to review "below-threshold" transactions if three cumulative conditions are satisfied: (i) no more than six months have elapsed since completion of the transaction; (ii) one of the two turnover thresholds provided for in Article 16 of the Law is exceeded or the total worldwide turnover generated by all the undertakings concerned exceeds 5 bn euros; and (iii) the Authority finds, on the basis of available evidence, that there are concrete risks for competition in the national market or in a part of it. Moreover, the Italian Antitrust Authority has introduced the possibility of using the ratio between the acquisition price and the target's revenue as a screening device to identify transactions warranting deeper investigation.

In 2017, Germany and Austria introduced an additional threshold for mandatory notification based on the value of the transaction (400 mln euros and 200 mln euros, respectively). Discussions about adopting value-based thresholds have emerged in other countries, including Japan and South Korea.

In the UK, call-in powers are intrinsic to the voluntary notification system. In addition, the new 2021 Merger Assessment Guidelines (MAGs) better equipped the CMA to address mergers involving potential competitors. In particular, paragraphs 5.2 and 5.3 distinguish between two categories of loss of potential competition: (i) *loss of future competition*, i.e. loss of competition between the merging parties that would have occurred in the future, absent the merger, after the potential competitor entered the market; (ii) *loss of dynamic competition*, i.e. reduction of innovative efforts by the potential competitor (aimed at entry and expansion) and/or by the incumbent (aimed at mitigating the risk of losing market shares). This distinction matters because it clarifies that, in order to prove to the required standard that the merger harms potential competition, the CMA does not need to show that entry by the potential competitor would have been more likely than not in the absence of the merger. Instead, it is sufficient to demonstrate that, absent the merger, the parties would have continued investing in innovation. This facilitates enforcement, particularly in digital markets, where predicting the likely evolution of the target in the counterfactual is often complex.

The revised Guidelines signaled the CMA's intention to take a tougher stance against acquisitions involving potential competitors. Indeed, in November 2021 the CMA blocked *Meta's* (formerly Facebook) acquisition of *Giphy*, a transaction that had been completed in 2020, and ordered Meta to divest. Meta appealed, but the Competition Appeal Tribunal confirmed. The final prohibition decision was released in October 2022. Giphy was the market leader in the global market for searchable GIF libraries, which social media platforms (via GIFs and GIF stickers) use to improve users' experience and engagement. Moreover, before the acquisition, Giphy had explored monetization through digital

advertising by hosting GIFs for commercial brands, the Paid Alignment model, a project that was discontinued after the acquisition. The CMA concluded that the deal had removed Giphy as a potential challenger in display advertising. It also identified a vertical foreclosure risk: Meta could limit or degrade access to Giphy's services for rival social media platforms, thereby weakening their ability to compete in the social media market. This case is often cited as a landmark example of an authority prohibiting an acquisition of a potential competitor.

Another notable recent case is the proposed merger of *Adobe* and *Figma*, which the parties abandoned in December 2023, after the CMA's Provisional findings and the EC's Statement of Objections, but before the final decisions. Adobe is a global leader in creative design software, i.e. tools like *Illustrator* and *Photoshop* that enable the creation or editing of digital content, such as photos ('raster images'), graphic illustrations ('vector images') and videos. Figma is the market leader in web-based collaborative tools for interactive product design, used to design websites, mobile applications, and other digital products. Central to the case was the loss of potential competition. Each company was investing in new product development that could challenge the other's position. Adobe was investing in a web-based product-design software integrating functionalities from *Illustrator* and *Photoshop*, while Figma was extending raster and vector editing functionalities within its web-based product design tool. Each company could then be considered a potential competitor of the other. The concern of both authorities was that these innovation efforts by both the potential competitor and the incumbent, would be substantially weakened by the merger. (See Section E for a discussion of the literature on the effects of mergers on innovation.)

3. The definition of the relevant market in digital mergers

Antitrust merger review typically starts by defining the relevant market, to identify the parties' closest competitors.¹⁰ The review then proceeds with the competitive assessment, which captures how the transaction may weaken the competitive constraints the parties face pre-merger, and lessen competition.

Market definition is usually guided by the SSNIP (Small Significant Non-transitory Increase in Price) test: the relevant market is the narrowest set of products for which a hypothetical monopolist could profitably raise the price (usually by 5–10%). The market includes products that are sufficiently close substitutes for the merging firms' products (demand-side substitution) and may also include products that rivals could supply in the near future (supply-side substitution). In practice, the SSNIP test is sometimes implemented with formal estimation and simulation, but it is often used as a logical framework to organize different pieces of evidence.

On the demand side, the definition of the relevant market in digital cases shares many features with traditional industries but adds complications that stem from the multi-sided nature of most digital platforms. We use the following definition: a multi-sided platform supplies products or services to distinct groups of users who experience cross-side externalities (indirect network effects) from participation and/or use by agents on the other sides. It typically supplies a range of products to each side; within a side these products may be complements (e.g., two apps used together, such as a photo and messaging app) or substitutes (e.g., two similar navigation apps).

Complementarity across products is a key feature of digital ecosystems. While the term lacks a fully settled definition, we can think of an ecosystem as a set of products linked through a core service (such as an operating system, search engine, social network or marketplace), that

⁹ See [European Court of Justice \(2024\)](#).

¹⁰ See, for instance, [European Commission \(2024\)](#).

gives customers incentives to use products within the same ecosystem, rather than to mix-and-match by picking up different products from several ecosystems.¹¹

Some products delivered to users on the same side may also exhibit network effects: their utility increases with the number of other users on that side, as in messaging apps or community-based navigation apps.

Finally, a multi-sided platform provides products or services to different groups of agents, a feature we observe in many multi-product firms that sell to distinct customer groups.

This multi-product feature does not raise issues that are different from those faced in well-established review of mergers between multi-product firms. Defining the relevant markets requires listing all the products supplied by the merging parties and, for each product, defining the relevant market as the set of close substitutes offered by competitors. This list will include the products supplied to users on each side of the platform. What, however, makes market definition more complex in platform environments is the presence of cross-side externalities: the utility of users on one side may depend on the size, composition, and activity of users on the other sides.

A useful distinction is between *attention platforms* and *matching platforms*. Attention platforms, (traditional media such as newspapers, radio or TV stations, and digital operators such as online video streaming, social media, and search engines) attract users' attention with content and sell their attention to advertisers. The advertisers' willingness to pay, in turn, is increasing in the size and composition of the audience reached. Matching platforms, such as marketplaces or dating clubs, connect two sides (sellers and buyers, or potential partners, in the two examples), and generate positive cross-side externalities since the composition and size of each side enhance the experience of the other.

In multi-sided platforms, the SSNIP logic extends beyond the effect of a price increase or quality reduction on the demand for that product. Authorities must also account for feedback effects: reduced demand on one side changes the demand on other sides (positively or negatively), which then feeds back into the first side, possibly in a direction opposite to the initial adjustment, and ultimately affects the profitability of the hypothetical price increase.¹² Market definition, therefore, requires tracing these interdependent responses rather than relying only on the standard elasticity analysis.

Cross-side externalities affect not only the demand for products delivered to all sides but also the price structure, i.e., how total revenues are split across sides. Multi-sided markets often feature highly asymmetric price structures, whereby total revenues are collected across the different sides in very different proportions. In some cases, one side may even receive the service for free (think of a free-to-air TV for viewers or a search engine for users) or even be subsidized for participation.¹³ Accordingly, what would be an increase in price by the hypothetical monopolist in a traditional one-sided market requires, in a platform market, an assessment of how the hypothetical monopolist's enhanced market power would affect the entire set of prices and the price structure

(for instance, by keeping a zero price on one side and raising the price on the other).

Zero price, moreover, has a different meaning in one-sided versus platform markets. In traditional markets, a zero price signals the absence of a commercial transaction and may imply that a supplier is not competing in that market. In platform markets, instead, a zero or negative price is often an aggressive pricing strategy rather than a withdrawal from competition, whose profitability can be understood only by considering cross-side effects: maximizing participation on one side to extract more revenue from the other. A free-to-air TV delivering content for free to viewers,¹⁴ or a search engine not charging users is a typical strategy of operators which compete fiercely for users' attention, while monetizing from advertisers.

A second issue that takes on new dimensions in multi-sided markets is differentiation. As in one-sided markets, platforms differentiate products to soften price competition and segment users. For instance, marketplaces differentiate sellers' product mixes, and video streaming platforms offer different content portfolios, etc. In multi-sided markets, in addition, platforms may differentiate through business models, adopting different price structures (for example, free-to-air vs. pay-TV, or marketplaces charging sellers vs. marketplaces charging buyers). These different price structures might suggest that the operators do not compete in the same markets: in the broadcasting example, viewers are a source of revenue only for Pay-TVs, and only the free-to-air stations collect money from advertisers. This observation raises a relevant question for market definition: whether Pay-TVs exert a competitive constraint on free-to-air broadcasters in advertising. Traditionally, the answer was negative, because Pay-TVs do not offer commercials to advertisers. Yet, if a Pay-TV raises its subscription fees, some viewers may switch to free-to-air programming, increasing the advertisers' willingness to pay and enabling the free-to-air stations to raise ad prices. Hence, even when direct competition on the same side is not observed, cross-side externalities maintain active competitive constraints between the two types of broadcasters. In other words, competition for viewers' attention is sufficient to create a strategic link also on the side in which the two operators do not compete directly. Similarly, a marketplace that charges only sellers may reduce their participation if it raises the fee, thereby inducing some buyers to patronize a marketplace which sets a positive fee only for buyers. Recognizing that platforms with very different business models may still exert strong competitive constraints on one another is an important and non-trivial exercise in defining the relevant market in multi-sided settings.

Business-model flexibility also matters for supply-side substitution. A video streaming Pay-TV operator that currently relies only on subscriptions may quickly introduce advertising if market fundamentals change, because it already controls the key asset: audience reach. The evolution of video streaming confirms this: Netflix was initially developed as a pure subscription-video-on-demand (SVOD) service in which viewers paid a monthly fee to access the content portfolio; as subscribers skyrocketed, however, there was a potential rent to be offered to advertisers, with the additional advantage of being able to target personalized commercials to different groups of viewers sorted by their viewing choices. Not surprisingly, new business models have emerged, with premium channels still offered ads-free, together with cheaper video streaming channels where ads are placed during programming (AVOD: advertising-video-on-demand). More broadly, by redesigning pricing and product features, platforms can easily modify their business model and enter new markets. This illustrates why a given operator may be included in a relevant market where it is not yet active.

The flexibility of the business models makes post-merger evolution

¹¹ The recent Communication of the European Commission on the definition of the relevant market, for instance, includes the following statement in paragraph §104: "Digital ecosystems can be thought of as consisting of a primary core product and several secondary products whose consumption is connected to the core product, for instance, by technological links or interoperability".

¹² One may argue that these interactions are reminiscent of those arising when consumers buy complementary products. In that case, an increase in one price reduces the demand for the corresponding product and, therefore, also the demand for the twin product. The latter, in turn, would further shrink the demand for the initial product. In the case of multi-sided platforms, however, these interactions involve different groups of agents and different interconnected relevant markets, rather than being driven by the preferences of the same consumers.

¹³ Negative prices are rarely used, due to the possibility of fake participation or usage. However, membership may be subsidized by providing free additional services to the participants (Amelio and Jullien 2012).

¹⁴ Although the broadcasting market pre-exists the digital era, it has been deeply influenced by new digital operators, for instance through video streaming services and personalized choices. Hence, in what follows we shall refer often to the TV industry to illustrate the examples.

crucial although it is hard to forecast. This is particularly important for attention platforms on the side of the content delivered. The acquisition of Instagram by Facebook and the post-acquisition evolution of Instagram into a full-fledged social network, discussed in Section B, is a textbook example.

A further key issue in many digital mergers is data. Platforms collect detailed information about users. A search engine, for instance, collects users' queries and click patterns; a marketplace records its customers' searches and purchases; and a video-streaming platform observes its viewers' searches and choices. While data collection is not unique to digital markets (think of large retailers collecting detailed information on customers through fidelity cards), digital services often generate richer data and enable broader profiling across activities. Data can support service personalization and higher consumer surplus, but it can also increase surplus extraction, for instance, through personalized pricing, as shown in [de Cornière and Taylor \(2025\)](#). Data is also an all-purpose input that can be leveraged across unrelated businesses, making it a frequent motive for acquisitions, as in *Google-Fitbit*, *Microsoft-LinkedIn*, *Amazon-iRobot*, to quote just some examples.

Data-driven mergers may, however, be hard to interpret and analyze both when defining the relevant market and when assessing their impact, being potentially motivated by a wide range of business development strategies ([de Cornière and Taylor 2024a](#) and [Chen et al., 2022](#)). Market definition in these cases requires identifying products that might be neither substitutes nor complements, but that may be connected by data reuse across apparently unrelated markets. For instance, the Google-Fitbit merger might have an impact on the digital health and health insurance markets.

Overall, traditional market-definition tools remain a useful starting point to identify the set of products offered by platforms and their close substitutes on each side. However, the additional role of cross-side externalities often makes the distinction between the definition of the relevant market and the competitive assessment unclear, blurred, and unnecessary. Rather than treating these as strictly sequential stages, the analysis should focus on the understanding of the competitive dynamics that govern interaction among platforms and rivals. In the next section, we discuss the main elements to consider when assessing competitive dynamics and the exercise of market power in digital markets.

4. The assessment of digital mergers

According to established practice, the definition of relevant markets sets the stage for measuring market power and the likely effects of mergers, based primarily on market shares and concentration ratios. In the 2023 US Merger Guidelines, a Herfindahl–Hirschman Index (HHI) larger than 1800 and an increase in its value larger than 100 trigger the presumption of a merger lessening competition.¹⁵ The European Commission also considers that a merger leading to a significant increase in concentration justifies the concern of anticompetitive effects and more scrutiny.

Merger analysis is usually structured around two questions: how competitive the market is pre-merger and how the merger is likely to affect competition. We consider these issues next.

4.1. The assessment of competition

The relationship between concentration and market shares, on the one hand, and welfare and consumer surplus, on the other, is rooted in a

well-established result in Industrial Organization that dates back to the Cournotian paradigm. According to this view, there is a link, through the equilibrium level of output and mark-up, between measures of concentration (particularly the HHI), and consumer surplus and welfare. A more concentrated market, leading to a restriction in output, reduces the welfare of consumers and the economy. The key question in digital mergers is whether this approach can be applied straightforwardly to platform markets, thereby justifying the adoption of formal or informal structural presumptions of anticompetitive effect based on measures of concentration.

We have argued that in multi-sided markets the price structure can be highly asymmetric, with the platform offering the service for free on one side (or subsidizing users) to maximize participation, while increasing margins and collecting money on the other. Market power (in the sense of price-cost margins) may be exerted primarily on the paying side. However, margins on the paying side depend not only on the market share on that side but also on the other through its enhanced willingness to pay. In other words, the relationship between market shares, concentration, and the exercise of market power cannot be assessed separately across relevant markets, with cross-side externalities determining which side of the market predominantly generates margins and the size of the rents extracted. Moreover, when market power leads to asymmetric price structures, the agents' surplus may be enhanced in one side and reduced in the other. Therefore, the simple relationship between concentration and supra-competitive margins in a given market cannot be mechanically transposed to platform markets.

4.1.1. Factors enhancing the exercise of market power in digital environments

Digital markets are characterized by several factors that push towards concentration, market tipping, and barriers to entry, alongside mitigating factors. Moreover, even in market environments where a tendency toward concentration and market tipping prevails, competition for the market may still constrain the exercise of market power.¹⁶

Digital services often exhibit high R&D costs and negligible duplication and distribution costs, leading to cost structures with large fixed and very low variable costs, which are often conducive to concentration, as in the natural oligopoly paradigm ([Sutton, 1991](#)).

Secondly, network effects can further push towards tipping. A larger user base can improve profiling and service quality through the data it generates, thereby creating a positive feedback loop. Data is also a key input for developing and training algorithms, as illustrated by generative AI, giving incumbents an advantage in innovation and expansion. When the network effect component prevails over the stand-alone value in users' utility, market competition progressively dries up, market contestability is reduced and high entry barriers are created.

Network effects also interact with expectations: users may coordinate on the perceived future winner shielding incumbents from competition even when rivals offer higher stand-alone value. Focality,¹⁷ that is, shared expectations that the leading product will be patronized even in the future, enhances incumbency advantage.

Switching costs may reinforce the incumbency advantage. In ecosystems, switching may imply losing accumulated data and complementarity benefits. Limited data portability and weak interoperability can therefore enhance switching costs and act as barriers to entry.

These factors can be relevant even in traditional one-sided markets. However, what often characterizes digital markets is the intensity and coexistence of all these factors. Moreover, in multi-sided markets, cross-side network effects amplify these forces through rich-gets-richer dynamics. For example, more users on a search engine generate more data, which improves profiling and enables the engine to offer advertisers

¹⁵ These thresholds have been tightened relative to those adopted in the 2010 HMG in the US, where the thresholds were 2500 and 200. Moreover, the 2023 HMG introduces a second threshold when the market share of the merged entity is larger than 30% with an increase of 100 in the HHI. [Shapiro \(2024\)](#) argues, however, that the new thresholds may end up being ineffective since the criteria for market definition have been relaxed in the new Guidelines.

¹⁶ See [Calvano and Polo \(2021\)](#).

¹⁷ See [Caillaud and Jullien \(2003\)](#) and, more recently, [Halaburda and Yehezkel \(2019\)](#) and [Halaburda, Jullien and Yehezkel \(2020\)](#).

more targeted services, thereby raising ad revenues. This increase in revenues, in turn, may lead to further investments in quality and complementary services, which increases user participation and engagement, and generates still more data. Proprietary and exclusive data can be crucial in sustaining such loops.

Hence, multi-sidedness significantly increases the tendency to concentration and the emergence of market leaders. At the same time, concentration may combine the exercise of market power, particularly on the paying side, with an enhanced surplus, specifically on the other side. The impact of concentration, therefore, may pose delicate issues of comparability and balance in the surplus of the different sides.¹⁸

4.1.2. Mitigating factors

Several factors can mitigate the exercise of market power. Some are familiar from the analysis of one-sided markets, while others are more specific to multi-sided environments.

As shown in [Armstrong's \(2006\)](#) pioneering work, product differentiation can support coexistence of multiple platforms in the same market, with each platform serving, on each side, a subset of agents who have a stronger preference for its intrinsic characteristics. Similarly, network effects may be local, generated by subsets of agents that are closer to each other. As in one-sided markets, these features may relax price competition and limit the tendency to market tipping on a given side. In addition to the effects of differentiation on a given side, differentiation by business models, which occurs in multi-sided markets ([Calvano and Polo, 2019](#)), can also avoid competition to extract money from the same side, favoring the coexistence of more operators in the same market.

Multi-homing is another important mitigating factor. When users participate on multiple platforms, no single platform controls exclusive access to users, as would happen if some of them would single-home, weakening platforms' ability to act as a bottleneck and the exercise of market power on the other side.¹⁹ Dominant platforms may nevertheless limit multi-homing through exclusivity clauses that discourage the use of multiple outlets, and price-parity clauses that reduce the attractiveness of alternative channels.

Data may also favor the growth of new entrants. If data usage exhibits decreasing returns up to a scale that is achievable by competitors, the incumbent's advantage may be reduced. Moreover, data from different activities can be complementary in profiling agents, and data brokers may supply data to smaller firms, reducing gaps in access. The relevance of these factors in reducing the incumbency advantage is an empirical matter that may vary across market environments and requires careful analysis by enforcers. At the same time, the key role of data for competition in digital markets suggests that remedies and commitments that increase data access, portability, and interoperability can be particularly effective.

4.2. The effects of mergers in digital markets on competition

In the previous section, we reviewed the main elements that affect competition in digital markets, both positively and negatively. We can now address the impact of mergers between digital platforms on

competition.

A robust result in traditional one-sided markets, which holds in a wide range of oligopoly models, is that a merger increases price(s) and reduces output, consumer surplus, and total welfare in the absence of significant cost efficiencies. The magnitude of these effects depends on the pre-merger market structure, the intensity of competition, the size of the firms involved, as well as the relevance of barriers to entry and buyer power. The change in market outcomes is driven by the insiders internalizing the externalities that characterize strategic interaction in the market and by the outsiders further adjusting their market strategies. These robust analytical predictions underpin enforcement practice, which typically assesses the impact of a merger absent efficiencies and, if harm is significant, considers whether claimed efficiencies are merger-specific and sufficient to offset it.²⁰

We can, therefore, start assessing whether this body of presumptions also applies to high-tech industries where the leading actors are platforms. To this aim, it is useful to distinguish the impact of digital mergers on competition in and for the market. In the former case, the focus is on mergers possibly weakening competition in a market that still includes competitors post-merger. In the latter case, instead, we look at the exclusionary effects of the merger that builds barriers to entry and can marginalize or even exclude rivals, restricting competition for the market.

4.2.1. Non-exclusionary effects: the impact of digital mergers on competition in the market

When we look at the impact of a merger on competition in the market, it is analytically convenient to consider a fairly symmetric pre-merger setting, in which the key driver of the adjustment in the market equilibrium is the reduction in the number of firms and the emergence of a new entity endowed with a larger set of assets. In this framework, therefore, we can investigate whether the merged entity increases price (s) and restricts output(s), the standard result in one-sided markets.

The impact of a merger in a multi-sided market immediately appears more complex than in traditional one-sided environments. For example, a contraction in output on one side by the merged entity, reflecting the internalization of externalities on that side, triggers a change in the agents' willingness to pay on the other sides, propagating these adjustments across sides and platforms. Consequently, the adjustments insiders make after a merger involve changing their choices on all sides, and outsiders' reactions are similarly affected.

The literature on mergers in two-sided markets features results that confirm traditional predictions as well as others that appear non-standard. The variability in results often depends on specific features relevant to platform markets. In this sense, the usual predictions appear to be less robust.

In the context of attention platforms, several papers have examined the impact of media mergers on the price and quantity of advertising. The impact of a merger is deeply affected by the agents on either side single- or multi-homing. An early result in [Anderson and Coate. \(2005\)](#) shows that when users single-home, each platform represents an exclusive channel for advertisers to reach its captive users, and competition for viewers is intense. Since advertising is a nuisance for users, competition limits the amount of advertising, raising its price. A merger, by reducing competition for viewers, allows the merged entity to increase advertising and lower ad prices, a non-standard result. One may argue that the quantity of ads represents an implicit "price" for viewers to access free content. Hence, the merger reduces the price advertisers pay and increases the "nuisance price" for viewers. Therefore, in platform markets, a merger may have opposite effects on the two

¹⁸ Moreover, particularly in the case of attention platforms, concentration in the advertising market may affect competition in the product markets in which advertisers operate. See [Prat and Valletti \(2022\)](#).

¹⁹ More precisely, multi-homing may emerge also in one-sided markets when customers choose more than one product. In platform markets, however, the effects of multi-homing are enriched. When a platform serves a group of single-homers on a given side, it is the gatekeeper to reaching those agents for those belonging to the other side, being able to charge a high price to the latter. Multi-homing reduces these rents, since the maximum price that the platform can charge is the incremental (and not the absolute) value of reaching the agents on the other side through that platform in addition to the rival one.

²⁰ The screening on the size of the detrimental effects can be rationalized considering that modest efficiencies, able to correct a limited anti-competitive effect of the merger, are presumably more likely than large efficiencies needed to turn a severely detrimental merger into a competitive one.

sides.

Anderson et al. (2016) show that the assumption of single-homing agents crucially drives the above outcome. When at least some users and advertisers visit multiple outlets, a platform can charge advertisers the full value of its exclusive users plus the incremental value of its shared users. Hence, each platform sets ad prices that reflect the composition of its exclusive and shared users. After a merger, those users who were previously patronizing the insiders move from being shared to being exclusive to the merged entity, changing the mix of served users. As the fraction of exclusive users increases, the merged entity can raise ad prices. These results suggest that a very common feature of platform markets, multi-homing, may dramatically alter predictions about the impact of mergers on the different sides.

Cross-side network externalities are another element that affects the impact of a merger. Correia-da-Silva et al. (2019) analyze mergers when platforms follow Cournot quantity-setting strategies and agents on both sides single-home.²¹ The authors show that if the pre-merger adjusted prices are above the (average) marginal cost, a merger harms consumers; the opposite occurs if these prices are below the marginal cost. When pre-merger prices on both sides are large enough for the externality-adjusted price to exceed average marginal cost, the market power effect of mergers dominates potential efficiency gains from more extensive participation on each platform, reproducing the standard result in one-sided markets. When both pre-merger externality-adjusted prices are instead below average marginal cost, the reverse holds. Hence, cross-side network externalities, when significant, may reverse the standard result in one-sided markets.

Mergers may also affect non-price dimensions. Post-merger, the new entity can adjust horizontal characteristics, for instance in terms of content, thereby reducing the degree of differentiation in the market. In assessing media mergers, there is a recurring concern about homogenizing individual outlets toward mainstream content.

Digital platforms and ecosystems usually offer a wide range of complementary products, providing a smooth interoperability among them. Consequently, purchasing and using these services together generates “consumption synergies” across consumers that are, instead, not realized by mix-and-match purchasing patterns. Chen and Rey (2026) analyze conglomerate mergers and the effect of product portfolio expansion. The merged entity, by offering (or expanding) a bundle, adds a new purchasing option for consumers, creating portfolio differentiation that relaxes price competition and allows the platform to raise prices, capturing some of the consumption synergies while still benefiting its customers.²²

Data-driven mergers are particularly important in digital markets. De Cornière and Taylor (2024a) develop a general framework to study the effects of data-driven mergers, enabling the analysis of both pro- and anti-competitive effects for a variety of data-collection technologies. A data-driven merger may be procompetitive if, for a given surplus provided by rivals, it induces a firm to provide more surplus to consumers, whereas an anticompetitive merger works in the opposite direction. Merger assessment should also consider the counterfactual: would data transfer or data access occur without the merger? If data is subject to trade frictions, and its value depends on continuous updates, in some

cases a merger may be the only way to transfer valuable data across markets. When trade frictions are large, post-merger the data-originating firm, which is now also active in the data-receiving sector, has an incentive to produce more data by increasing output and cutting price, improving the quality of the data-receiving product, with a fall in its quality-adjusted price. A similar impact of data-driven mergers is shown in Chen et al. (2022). When, instead, data can be traded even without the merger, the transaction yields anti-competitive adjustments of the opposite sign.

4.2.2. Exclusionary effects: the effect of mergers on competition for the market

The results discussed in the previous section are derived in environments with relatively symmetric pre-merger equilibria, where multiple platforms operate with similar market shares. This setting fits markets with sufficient horizontal differentiation or capacity constraints (for example, some media markets). Digital markets, however, sometimes display winner-takes-all and tipping dynamics that produce highly asymmetric structures. In that case, a vertical or conglomerate merger can create or strengthen incentives for a dominant incumbent to leverage its position to exclude rivals in vertically related or adjacent markets, or to protect its core market from future competition.

The extensive literature on exclusionary practices²³ helps identify when, after a merger, the new entity has the incentives and the tools to exclude rivals (through tying, exclusive dealing, loyalty rebates, vertical foreclosure and similar practices) whereas in the pre-merger situation foreclosure was not profitable or feasible.

A merger may enrich the portfolio of products offered by the merged entity both horizontally, allowing to tie them in a bundle, or vertically, when the new firm extends its participation to additional segments of the value chain. The key point is to analyze whether foreclosure becomes a feasible and profitable practice once the changes introduced by the merger take place. Making this comparison requires understanding how the merger: (i) expands the assets controlled within the same organization; (ii) strengthens internal governance (authority) relative to reliance on explicit but imperfect contracts that were the only governance tool before the merger; and (iii) reduces transparency and visibility of the merged entity's practices for external parties, including a competition authority, weakening the enforcers' deterrence of anti-competitive practices. Enforcers should, therefore, ask whether and why the merger increases both the capability and profitability of exclusion.

Let us start with horizontal expansion in the portfolio of products. Consider a platform that dominates a core service and, after the merger, is also active in a complementary market. The concern is that tying the core service to the complementary one may exclude rivals in the complementary market. The traditional Chicago School argument claims that exclusion is unnecessary, because control of the core service should allow the dominant firm to extract enough profits from independent suppliers of the complementary service. We can notice that, if contracts allow the dominant firm to extract rents without excluding complementors, there is no need to merge to increase market power. The tying literature, however, highlights two main reasons why incentives to exclude may arise.

First, the dominant firm may be unable to extract sufficient rents from the complementary market through the control of the core service. Imperfect rent extraction can stem from the business model (for instance, the core service is offered free to users), contracting frictions (Greenlee et al., 2008; Carlton and Waldman, 2002; Chambolle and Molina, 2023; de Cornière and Taylor, 2021, 2024b), non-negative price constraints (Jeon and Choi, 2021), downstream competition between distributors (Ide and Montero, 2023) and limited price discrimination (Choi, Jeon and Whinston, 2026).

Second, dynamic considerations matter when the core service may

²¹ Since the quantity provided to each side affects users' utility on the other side, the latter make their choices based on the prices net of the externality benefit, that is, on externality-adjusted prices. Prices, then, equate demand and supply for each platform on each side. The logic of Cournot competition, such that committing to quantities leads the prices to clear the market, is therefore maintained, although enriched by the interaction across sides.

²² The effect of the merger on consumers who opt for stand-alone products, in turn, depends on whether it reduces competition in these markets. If the platform adopts mixed bundling, selling both the bundle and the stand-alone products, competition in the latter markets is unaffected, whereas a choice of pure bundling may restrict competition and hurt mix-and-matchers.

²³ See Fumagalli, Motta and Calcagno (2018) for an extensive review.

become contestable in the future. If the complementary market features significant scale economies (on the supply or demand side), tying can prevent rivals from reaching critical scale, thereby excluding them from the tied market. Exclusion from the tied market can then deter future entry into the core market (Carlton and Waldman, 2002) or, when entry is unavoidable, allow the dominant firm to extract rents from more efficient entrants (Fumagalli and Motta, 2020a).

Turning to vertical mergers, similar mechanisms can arise when a merger creates a vertically integrated firm that dominates, say, an upstream market while facing downstream competition. The concern is vertical foreclosure: refusing to supply a crucial input, degrading its quality or interoperability, or engaging in margin squeeze. Self-preferencing can be viewed as a related form of vertical foreclosure. Section B discusses several recent high-profile cases with vertical foreclosure as a key concern. In principle, control of the crucial input could allow the integrated firm to extract sufficient rents from downstream rivals (the Chicago School's one monopoly-profit theory). Yet the literature highlights that foreclosure incentives can emerge when rent extraction is limited by input-price regulation (Jullien, Rey and Saavedra, 2014) or by contractual frictions that foster opportunistic behavior (Hart and Tirole, 1990). Foreclosure incentives may also arise in a dynamic perspective where exclusion from the downstream market helps protect upstream dominance from future entry, or transfer dominance from upstream to downstream (Fumagalli and Motta, 2020b).

Contractual frictions may be particularly acute when the input quality is unverifiable. In this case, Allain et al. (2016) show that a vertical merger alters the incentives of the input supplier and gives rise to foreclosure via quality degradation: the integrated supplier profitably worsens the input provided to rivals so as to advantage its downstream subsidiary, thereby creating hold-up problems for independent rivals.

Exclusionary incentives may also follow cross-market data-driven mergers (see, for instance, Google-Fitbit discussed in Section B). Condorelli and Padilla (2024) show that acquiring a firm in a data-rich market can motivate exclusionary strategies in that market to protect dominance in a data-intensive market where those data are exploited. Data harvested in the data-rich market raises profitability in the data-intensive market (for example by improving product quality), turning firms active in the former into credible entrants in the latter. By gaining control of data, exclusion both builds the acquirer's advantage and prevents rivals from developing a similar advantage, thereby entrenching dominance in the data-intensive market.

Acquisitions by dominant incumbents may also aim to eliminate potential competitors, an issue that has attracted considerable attention since acquisitions of start-ups are common phenomena in digital markets. When the target could develop substitute products to those of the acquirer, the acquisition may suppress future competition and affect the target's innovative effort or research direction, an issue addressed in the next Section.

At the same time, many digital acquisitions involve complementary products that enrich an incumbent's ecosystem and increase user surplus, which supports a more favorable assessment. Still, such acquisitions may raise market power if they deny rival platforms access to independent apps that would improve the ecosystems, thereby creating an application barrier to entry.

5. The effects of mergers and acquisitions on innovation

The impact of mergers on innovation has drawn significant attention from both enforcers and academics over the past decade, largely due to high-profile mergers in sectors such as telecommunications, pharmaceuticals, agricultural products, and the digital industry. A landmark case in this context is the 2017 merger between Dow and DuPont, which led the European Commission to apply a comprehensive innovation theory of harm and impose extensive remedies, including the divestiture of substantial parts of DuPont's global R&D organization.

The debate about the effects of mergers on innovation is closely

related to the broader issue of how competition affects innovation, a topic that has generated a rich literature rooted in two seminal contributions. On the one hand, Schumpeter (1942) argued that market power can stimulate innovation by enhancing firms' ability to appropriate the returns from their R&D investments. On the other hand, Arrow (1962) contended that monopoly power may hinder innovation because the profits monopolies deriving from existing products reduce their incentives to innovate relative to firms operating in competitive markets, a phenomenon known as the "replacement effect". Together, these pioneering contributions highlight that competition can have conflicting effects on innovation.

The general literature on the relationship between competition and innovation, building on Schumpeter and Arrow, provides valuable insights into how mergers affect firms' incentives to innovate. However, it is not directly applicable to merger analysis because it does not address a key aspect of mergers: the ability of merging firms to coordinate their decisions.²⁴ This limitation has given rise to a distinct literature that specifically examines the impact of mergers on innovation. We begin by discussing general considerations emerging from this literature, before turning to the specific case of start-up acquisitions, which is particularly relevant in digital markets.

5.1. General considerations

Much of the literature on horizontal mergers and innovation emphasizes two key channels through which mergers affect incentives to innovate:²⁵

- Cannibalization: This channel captures the effect of one firm's innovation on the expected sales of the other merging firm(s).
- Market power: This channel reflects the impact of increased market power on firms' incentives to innovate, in particular through changes in their ability to appropriate the returns from innovation.

Consider first the cannibalization channel. When a firm introduces a new or improved product, it negatively affects the sales of other firms selling substitutes. For instance, in the case of competition for developing new products, an increase in one firm's innovation efforts raises the probability that its (successful) rivals face competition, thereby reducing their expected sales. A merger between two firms allows the merged entity to internalize this negative externality, which may give it incentives to reduce the R&D efforts of both merging firms (Federico, Langus and Valletti, 2017).²⁶

Consider now the market power channel. The literature on the relationship between concentration and market power has highlighted that ex-post market power enhances incentives to innovate because it increases the innovator's ability to capture the social value of the innovation, while ex-ante market power may reduce incentives to innovate due to a lack of competitive pressure (Aghion et al., 2005). Given that a merger raises both ex-ante and ex-post market power, the implications for innovation in merger cases are ambiguous in general.

²⁴ Relatedly, mergers generate asymmetries by directly increasing the market power of the merging firms, whereas traditional studies on competition and innovation focus on industry-wide changes in competitive intensity that affect all firms symmetrically, such as variations in the number of firms or in product substitutability.

²⁵ See Lefouili and Madio (2026) for a survey of this literature.

²⁶ This can be seen as an extension of the Arrow replacement effect to the case of a multi-product firm. However, the overall effect of internalizing externalities is not always straightforward, as it depends on the R&D technology. For instance, if the returns to R&D are not rapidly diminishing, it may be profitable after the merger to concentrate all research resources on one firm and to shut down the research lab of the other firm, thereby avoiding the cost of wasteful duplication. In this case, the merger can lead to an increase in innovation (Denicolò and Polo 2018).

However, in many commonly studied settings, this effect boosts merging parties' innovation incentives (Federico, Langus and Valletti, 2018).²⁷

The potential tension between the cannibalization effect and the market power effect implies that mergers may either undermine or boost innovation incentives.²⁸ Bourreau, Jullien and Lefouili (2026) show that absent spillovers and efficiencies, the effect of a merger on innovation is likely to be negative if the innovation externality between merging firms is large relative to the price externality. When the opposite holds, the impact of the merger on innovation can be either positive or negative. More precisely, they establish that the comparison between the price diversion and innovation diversion ratios plays a key role in determining the impact of a merger on quality-enhancing innovation.²⁹ If the innovation diversion ratio is larger, a merger is likely to negatively impact innovation, thus exacerbating the standard adverse effect of a merger on prices. In this case, larger merger-specific efficiencies would be required for the merger to be considered beneficial to consumers (compared to a scenario with fixed innovation). Conversely, if the price diversion ratio is larger, production efficiency gains that are sufficient to eliminate concerns about the merger's impact on prices (holding innovation fixed) also address concerns about the adverse effects of the merger on innovation.

Mergers between suppliers of zero-price services. A distinctive feature of the digital economy is the prevalence of free services. These services operate under business models that rely either on advertising or on monetization of collected user data, allowing the value generated by consumers to cover the costs of acquiring them. Typically, these services would find it profitable to charge negative prices but are constrained by a price floor of zero. The analysis of the impact of a merger on innovation in this context depends on the nature of competition. If competition is primarily driven by innovation, the key question is whether the negative effect on innovation through the cannibalization channel is outweighed by spillovers or potential merger-induced efficiencies. This scenario is discussed in Salinger (2019), who introduced the concept of "Net Innovation Pressure (NIP)," by analogy to the "Upward Pricing Pressure (UPP)" for pricing. However, in many cases, competition among firms offering free services revolves around factors other than innovation. For example, firms may adjust the intensity and intrusiveness of advertising, which affects the level of nuisance experienced by users. In this case, the "price" can be understood as the monetary equivalent of the nuisance. Under this interpretation, the insights from the analysis of mergers in environments with positive monetary prices and innovation extend naturally to settings with zero monetary prices.

Spillovers and synergies. Technological spillovers refer to the phenomenon where improvements made by one company can benefit other companies by enhancing their technological capabilities. Through mechanisms such as imitation or the exchange of researchers, knowledge generated by one firm can be partially appropriated by others. Spillovers are well-documented in the literature, and empirical studies show that their impact may be larger than the negative "business stealing" effect of innovation (Bloom et al., 2013).

A key feature of (involuntary) spillovers is that they constitute

positive innovation externalities. Therefore, their internalization by merging firms may increase their incentives to invest in R&D. Moreover, the merged entity not only internalizes pre-existing spillovers but typically increases the level of (voluntary) spillovers between the merging firms. This results from the nature of the knowledge generated or used in the R&D process: it can often be shared, though it may be protected by intellectual property rights or confidentiality. From an economic perspective, such knowledge can be viewed as an excludable public good. By eliminating a motive for exclusion, a merger between two firms allows each one to make greater use of the knowledge produced by the other one. For instance, positive effects arise when a (process) innovation can be applied post-merger to the production units of both merging firms, thereby increasing its value and strengthening incentives to innovate (Denicolò and Polo, 2021).

The existence of potential complementarities between merging firms' assets is another channel through which a merger can increase incentives to innovate. Importantly, such complementarities may arise not only in R&D assets (Ferrett and Davidson, 2007) but also in production assets (Bourreau, Jullien and Lefouili 2024). In the latter case, the resulting reduction in marginal production costs raises margins, thereby strengthening the merging parties' incentives to innovate in order to expand demand.³⁰

5.2. Acquisition of start-ups

We now discuss how acquisitions of start-ups by incumbents affect the innovation incentives of both the acquired and acquiring firms.

Innovation for buyout. A central concept in this context is *innovation for buyout*, which describes situations where start-ups develop innovations with the objective of being acquired. The prospect of an acquisition increases a start-up's incentives to invest in innovation whenever an incumbent is willing to pay a buyout price higher than what the start-up could gain on its own. This occurs, for instance, if the acquirer is better positioned to realize the market potential of the innovation. Additionally, the possibility of start-ups being acquired can stimulate innovation by attracting venture capital funding, as investors often view acquisitions as a primary exit strategy.³¹ Finally, start-up acquisitions can promote the diffusion of innovation by facilitating technology transfer in sectors, such as digital industries, where licensing intellectual property is particularly challenging (Cabral, 2021).

Protection of market power. However, the acquisition of start-ups can also negatively impact innovation and competition. A key concern is that incumbents may acquire emerging competitors and discontinue their innovative projects—a practice known as *killer acquisition* (Cunningham, Ederer and Ma, 2021).³² Note that such discontinuation may occur either because the start-up's innovation would benefit the incumbent, but the cost of developing it turns out to be higher than the potential gain, or because the acquisition offers no direct benefit to the incumbent but allows it to prevent a rival from acquiring the start-up (Bryan and Hovenkamp, 2020).³³ Importantly, even if the start-up project is developed by the acquirer, the acquisition may still harm consumers because of standard adverse price effects resulting from the

²⁷ In particular, when the innovative products of the merging firms are only imperfect substitutes, coordination of marketing decisions, such as prices or product positioning, allows the merged entity to reduce cannibalization. The ex-post internalization of sales externalities resulting from a merger raises the appropriability of multiple innovations and may boost incentives to innovate (D'Annunzio, Jullien, Lefouili and Madio 2026).

²⁸ This is, for instance, established by Moraga-Gonzalez and Motchenkova (2026) in a unified framework where R&D investments may affect both the probability of innovation success and the payoff conditional on success, and competition is captured in a general form.

²⁹ The price diversion ratio is the percentage of sales that is diverted to the other product when the price of a given product increases. The innovation diversion ratio is the percentage of sales that is diverted from the other product when the innovation level of a given product increases.

³⁰ See Régibeau and Rockett (2019) for a comprehensive discussion of merger-related efficiencies in innovation-intensive industries.

³¹ See Ederer and Pellegrino (2023), Alezra and Berquier (2024), and Eisfeld (2025).

³² Cunningham, Ederer and Ma (2021) provide empirical evidence for killer acquisitions in the pharmaceutical sector. Malek, Seldeslachts and Veugelers (2025) also study acquisitions in the pharmaceutical sector and show that most terminated acquired projects were still at a very early stage of development, that is, far from product-market entry.

³³ In some cases, the objective is to hire specialized talent. In this case, the merger may also lead to inefficient talent allocation due to the use of preemptive strategies by the acquirers (Benkert, Letina and Liu 2025).

suppression of a competitor (Motta and Peitz, 2021), or because the acquisition gives the acquirer incentives to halt its own innovation efforts to avoid duplication, a phenomenon called *reverse killer acquisition* by Caffarra, Crawford and Valletti. (2020).³⁴ Finally, the acquisition of a start-up can strengthen the dominance of the acquirer, which may affect future market entry. Specifically, as the acquirer's dominance grows, the returns to innovation for new entrants decrease (whether they are acquired or not). This may reduce start-ups' incentives to invest in innovation (Denicolò and Polo, 2025). In extreme cases, this may even lead to the creation of a *kill zone*, where market entry becomes unprofitable (Kamepalli, Rajan and Zingales, 2020; Teh, Banerjee and Wang, 2026).

Recent research highlights the benefits of accounting for new factors when evaluating acquisitions of start-ups. One such factor is the acquisition price (Fumagalli, Motta and Tarantino, 2023). A low acquisition price may indicate that the target start-up is not viable on its own—and thus has limited bargaining power—whereas a high price may reflect the start-up's potential to enter the market and compete effectively with the acquiring firm. Another factor that competition authorities could consider is the acquirer's history of past acquisitions (Denicolò and Polo, 2025). The more acquisitions an incumbent has completed, the more dominant it becomes, making future entry increasingly difficult. This mechanism, referred to as the *entrenchment-of-monopoly effect*, may outweigh the *innovation-for-buyout effect* in the long run. As a result, competition authorities may wish to adopt a stricter stance toward acquisitions when an acquirer has achieved a high degree of dominance through a history of repeated acquisitions.³⁵

The *entrenchment-of-monopoly effect* can arise regardless of whether the acquired party is a competitor or a complementor to the acquirer, although the underlying mechanisms may be different. In the former case, the increase in the firm's dominance may result, for instance, from consumer inertia, which leads to an increase in the incumbent's base of captive consumers following an acquisition, thereby undermining the contestability of the market (Denicolò and Polo, 2025). In the latter case, it may follow from firms' ability to offer bundles of integrated products, thereby potentially expanding ecosystems. When acquisitions increase differences in ecosystem size, competition between ecosystems to acquire start-ups weakens, reducing the acquisition price and thereby start-ups' incentives to innovate. This concern is particularly relevant in the case of market leaders in *access-point* markets (where users start their online journeys) who are able to steer users in these markets towards their products in other markets (Heidhues, Köster and Köszegi, 2024). This logic relates to the ecosystem theory of harm used by the European Commission to prohibit the proposed acquisition of eTraveli by Booking.com in 2023. In that case, discussed in Section B, the Commission considered that the inclusion of eTraveli's service within Booking's ecosystem would channel significant additional traffic to Booking's hotel OTA service.

Direction of innovation. Some acquired start-ups may not be direct or potential competitors to incumbents, but they provide input that may give a competitive advantage to the acquirer. When developing its innovation, the start-up chooses a direction that maximizes its exit value. In the context of acquisitions, the start-up may face a trade-off between creating significant value for one of the incumbents (Bryan and Hovenkamp, 2020) and inducing an intense bidding race between potential acquirers (Bedre Defolie et al., 2026). This suggests that the acquisition of start-ups can affect not only the pace of innovation but also its direction. The prospect of acquisition may influence the

direction of innovation for additional reasons. For instance, start-ups may distort their innovation portfolios in order to increase expected acquisition rents (Dijk, Moraga-González and Motchenkova, 2024). Moreover, acquirers may also distort their own innovation portfolios in anticipation of acquiring a start-up (Dijk, Moraga-González and Motchenkova, 2025).

Empirical evidence. There is a rapidly expanding empirical literature on start-up acquisitions in the digital sector, particularly by large technology firms.³⁶ Affeldt and Kesler (2021a) provide early evidence on the effects of Big Tech acquisitions. They study the impact of GAFAM acquisitions of mobile apps on both the acquirers' strategies and the acquired apps. Using a comprehensive dataset of GAFAM acquisitions from 2015 to 2019, they identify over 50 acquisitions involving apps distributed through the Google Play Store and find that roughly half of the acquired apps are discontinued. The discontinued apps are typically smaller, updated less frequently, and less privacy-intrusive than apps that continue to operate.³⁷ The same authors also examine the effects of the same set of acquisitions on rivals. Specifically, Affeldt and Kesler (2021b) show that, following acquisitions, competitors reduce their innovative efforts in the affected markets. They also find that competitors reallocate innovative effort toward unaffected apps, and that entry declines in the affected markets after the acquisition.

A related contribution is Eisfeld (2025), who studies the impact of start-up acquisitions in the enterprise software industry on entry. She distinguishes between strategic acquirers (already active in the enterprise software industry), financial acquirers (such as private equity firms), and industry outsiders (such as manufacturing firms adopting software). On the one hand, she finds that a higher expected probability of exit through acquisition generally increases the profitability of entry and encourages start-up formation. On the other hand, she provides evidence that large-transaction acquisitions by strategic acquirers tend to be followed by lower subsequent entry in the affected markets. Her counterfactual merger simulations show that a prohibition of all acquisitions would reduce start-up entry by about 16% in the average market, whereas selectively blocking high-value acquisitions by strategic acquirers could increase entry, albeit modestly, by up to 1.5% in the affected markets.

Alezra and Berquier (2024) study how acquisitions affect acquired firms' innovation output across multiple sectors, including the digital sector, and find that acquisitions are associated with a significant decline in patent output. Barsy and Gautier (2024) also examine post-acquisition innovation in digital markets, focusing on the development of technologies owned by acquired firms. They find that acquisitions are followed by an initial boost in technological development, which slows down after about 1.5 years. Relatedly, Ederer, Seibel and Simcoe (2025) study the effects of 1200 acquisitions by major technology firms on innovation. They show that innovation typically rises prior to an acquisition but persists afterward only when additional acquisitions occur. Moreover, acquired patents receive significantly more citations post-acquisition than comparable patents, suggesting that acquisitions by digital incumbents often amplify the diffusion and visibility of acquired technologies.

³⁶ See Teh and Wang (2026) for a recent survey of the literature on start-up acquisitions and innovation.

³⁷ Relatedly, Gautier and Lamesh (2021) examine 175 GAFAM acquisitions over the period 2015–2017 and find that in >60% of the acquisitions in their sample, the products were discontinued. Gautier and Maitry (2024) extend this analysis to 329 GAFAM acquisitions over the period 2005–2021 and examine acquirers' decisions to maintain or discontinue products, distinguishing between products kept under their original brand, integrated into the acquirer's ecosystem, no longer available, or killed by the acquirer. They find that 12% of the acquisitions in their sample can be considered as killer acquisitions. In contrast, Ivaldi, Petit and Unekbass (2025) consider 12 transactions involving GAFAM and a few other large tech players and find no evidence of killer acquisitions.

³⁴ For further theoretical insights into the impact of start-up acquisitions on the acquirer's incentives to innovate (in addition to the entrant's incentives), see Letina, Schmutzler and Seibel (2024) and Dijk, Moraga-González and Motchenkova (2025).

³⁵ This issue is specifically addressed in the new US Horizontal Merger Guidelines, namely in Guideline 8 (*When a Merger is Part of a Series of Multiple Acquisitions, the Agencies May Examine the Whole Series*).

The literature also examines the impact of digital acquisitions on venture-capital investment. Gugler et al. (2025) find that acquisitions by large digital firms are associated with increases in patenting activity in affected technology classes but sharp declines in venture-capital investment among start-ups that are technologically close to the acquirer. These negative effects on VC investment are more pronounced in earlier periods and for transactions characterized by greater opacity, such as undisclosed deal values. In contrast, Jin, Leccese and Wagman (2023) find that acquisitions increase VC investment and start-up funding in related business areas, and do not find significantly different effects for acquisitions by large digital platforms relative to other acquirers.

6. Concluding remarks and policy suggestions

Market definition and competitive constraints

Assessing digital mergers requires a departure from the traditional, sequential approach to merger analysis, which starts with market definition and then proceeds to assess market power and competitive conditions. Digital operators are, in most cases, platforms connecting different sides and groups of agents, and exploiting cross-side externalities. A useful distinction is between marketplaces (easing the interaction of demand and supply) and attention platforms (offering content to users and their attention to advertisers). In platform markets, relevant market definition, business-model identification, competitive conditions, and merger effects are deeply interconnected and must be examined jointly.

Market definition should begin, as in traditional markets, with a comprehensive mapping of the platform's core and ancillary services, and identification of the close substitutes offered by competitors. However, to properly characterize the competitive constraints of the undertaking, the analysis should consider the interaction among sides and groups of agents served, as well as pricing strategies (including zero-price services), network effects, and data usage.

Understanding the platform's business model—how products are bundled, monetized, and supported by data—is essential to identifying competitive constraints. Competition may come from firms with similar business models or from partial overlaps on specific products or market sides. On supply side substitution, particular attention must be paid to business-model flexibility and potential competition, including the platform's ability to expand into new services or leverage data across markets.

Market power

Traditional indicators such as market shares and concentration measures remain useful screening tools, but they must be interpreted within the business model of the platform and by considering all sides jointly: quite often, digital operators charge one side and supply the services to the other side for free. Market power, then, is exerted on the paying side but constructed by large market shares on the other. Moreover, it is important to distinguish dominance in core services and ancillary ones, and the relationship among services within the ecosystem.

Evaluating competitive conditions requires moving beyond a checklist of factors toward a coherent theory of harm, integrating elements such as network effects, switching costs, interoperability, brand advantages, data access, and mitigating forces like differentiation and multi-homing.

Effects of mergers on competition

Merger effects in digital markets may replicate the traditional conjecture, whereby a merger increases market power and prices, shrinking output and consumers' surplus. However, non-standard effects may also arise, in particular when some distinguished features of platform markets, such as multi-homing and cross-side externalities, play an important role. Since standard predictions on prices and output may not hold, merger assessment must be case-specific, forward-looking, and grounded in the particular features of the platforms and markets involved.

The effects of a merger may be non-exclusionary (distorting competition within the market) or exclusionary (weakening or eliminating competition for the market). These effects often unfold dynamically over time, especially where network effects are strong, with an initial contraction of competitors, followed over time by their exit or marginalization.

To assess the merger's impact on competition for the market, the enforcer should start from the parties' pre-merger conduct—tying, vertical restraints, rebates, exclusivity, and similar practices associated in case law with foreclosure. Whether these practices are already used, or deliberately avoided, helps predict post-merger incentives. If the parties already employ such practices, this suggests they are feasible and potentially profitable under current market conditions; the parties' small scale may simply have reduced antitrust exposure. After the merger, the same conduct may become more harmful because the merged entity is larger and better able to foreclose rivals. Conversely, practices not observed pre-merger may become attractive once assets and control are consolidated.

This predictive exercise turns on three merger-driven changes: (i) a larger bundle of assets under unified control, making exclusion more effective; (ii) internal governance replacing contractual imperfections, increasing strategic flexibility; and (iii) reduced transparency of internal decisions, weakening ex-post monitoring by the enforcer. These factors indicate whether existing conduct will intensify or new foreclosure strategies will emerge.

In network markets, combining user bases can tip the market and facilitate foreclosure, including through subtle degradation of interoperability that is hard to detect amid product changes. In vertical settings, integration can enable preferential dealing with an internal affiliate—practically difficult to replicate through contracts pre-merger.

Finally, identifying these risks informs remedies: authorities may prohibit practices that entrench the merged entity, whether already present or newly enabled by the merger. Remedy design can also draw on the DMA (Arts. 5–6), which codifies lessons from digital antitrust enforcement and provides a benchmark for coherent behavioral commitments.

The effects of mergers on innovation

A key challenge for competition authorities in assessing the impact of start-up acquisitions on innovation and competition is the uncertainty surrounding the counterfactual scenario where the acquisition does not occur. For instance, a start-up that is not currently a close competitor of the potential acquirer may become one in the future. It is therefore important to consider a wide range of observable factors that can help predict both the counterfactual scenario and the post-merger scenario when evaluating start-up acquisitions. As discussed in Section E, recent literature suggests accounting for the acquisition price as well as the history of past acquisitions (and the resulting degree of dominance of the acquirer). Moreover, given the current standard of proof in merger control, it may be desirable to design a process that allows reverting the burden of proof when there is a significant suspicion of potential competition (as proposed by Crémer, de Montjoye and Schweitzer, 2019).

A key takeaway from the discussion on the role of diversion ratios in Section E is that if an analysis of the merger's unilateral price effects (assuming fixed innovation) shows a negative impact and the innovation diversion ratio exceeds the price diversion ratio, this should be enough to block the merger. Conversely, if the analysis shows no adverse price effects and the price diversion ratio is larger than the innovation diversion ratio, this should be sufficient to approve the merger. The

main challenge in applying these insights in practice lies in measuring the relevant diversion ratios. While many competition authorities have gained experience in calculating and using price diversion ratios in merger control, the innovation diversion ratio is a relatively new concept, and expertise in its measurement is still to be developed.³⁸

Finally, a distinctive aspect of R&D and knowledge production is that they generate spillovers for other market participants. In merger analysis, it is useful to distinguish between involuntary spillovers (those beyond the firms' control) and voluntary spillovers (those managed by the firms), as the latter can be substantially affected by the merger. In particular, each firm in a merger is likely to voluntarily share knowledge with its partner—knowledge it would withhold from a competitor. A lack of involuntary spillovers often results from a firm's ability to prevent its innovations from being imitated. In such cases, there may be room for knowledge sharing between the merging firms, which further boosts the returns on R&D and increases incentives to invest in it (see Denicolò and Polo, 2021). Similarly, potential synergies, such as those arising from R&D complementarities, should also be taken into account as long as they are merger-specific and benefit consumers.

Extension to partnerships and other arrangements

While this paper has focused on full-fledged mergers, many of the insights we discuss could also extend to partnerships and other arrangements that share important similarities with mergers. This is notably the case for certain strategic partnerships observed along the AI stack, which may involve long-term exclusivity agreements, preferential access to key inputs (such as data, compute, or foundation models), or some forms of operational and financial integration that fall short of formal acquisition. Examples include partnerships between large digital incumbents and frontier AI developers, such as cloud-AI agreements combining capital investment, exclusive cloud provision, and privileged access to models.³⁹ Although these arrangements do not entail a transfer of control in the strict legal sense, they could lead to merger-like effects and alter incentives to innovate, affect rivals' access to critical inputs, or reinforce ecosystem advantages. Reflecting these concerns, several competition authorities have scrutinized such partnerships using tools that emphasize de facto control and material influence, rather than formal ownership alone.⁴⁰ This suggests that the analytical framework developed for digital mergers can also provide useful guidance for assessing a broader set of structural arrangements in fast-moving digital and AI markets.

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³⁸ Recent empirical research offers guidance on how to measure the innovation diversion ratio in practice. Notably, Conlon and Mortimer (2021) have developed a methodology using a class of discrete choice models that can empirically assess diversion ratios for both prices and non-price factors such as quality.

³⁹ Prominent examples of partnerships in the AI stack include Microsoft's partnership with OpenAI, Amazon's partnership with Anthropic, and Alphabet's partnership with Anthropic.

⁴⁰ For instance, the CMA opened inquiries into AI partnerships such as Microsoft/OpenAI, Amazon/Anthropic, and Alphabet/Anthropic. Similarly, the FTC launched a broad Section 6(b) inquiry in early 2024 to examine the competitive implications of investments and partnerships involving these same entities. The EC has also assessed whether some of these arrangements could fall within the scope of the EU Merger Regulation and has monitored their competitive implications.

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CRedit authorship contribution statement

Chiara Fumagalli: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Bruno Jullien:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Yassine Lefouilli:** Writing – review & editing, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Michele Polo:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Data availability

No data was used for the research described in the article.

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