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Chips in on a Merger: The Arm-Nvidia Case

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Abstract

This paper analyzes the Nvidia-Arm vertical merger through the lens of the recent literature in Industrial Organization. It explores potential competitive concerns surrounding market foreclosure, technological access, and exclusionary behavior, considering the dynamic semiconductor industry's intricacies. Although limited public information is available due to the parties halting the merger during phase two, I propose four theories of competitive effects addressing issues such as vertical foreclosure in dynamic markets, stifling of innovation due to hold-up concerns, and the ecosystem effects of the merger. This discussion sheds light on the potential impact of this merger in the semiconductor industry on competition in innovative high tech markets such as CPUs, datacenters, gaming consoles, and assisted driving.

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1 Introduction

This paper aims to discuss the Nvidia-Arm case from the perspective of industrial organization, focusing on recent advances in the theoretical and empirical literature on vertical integration. I analyze the potential competitive effects stemming from the merger, including issues related to market foreclosure, access to critical technologies, and the potential for exclusionary behavior. By examining the industry's dynamic nature, the impact on downstream markets, and the conglomerate and ecosystem effects associated with the merger, the paper seeks to shed light on the complexities of this case and its implications for competition in the semiconductor technology industry.

The merger case between Nvidia and Arm was analyzed by various antitrust agencies in different countries including the UK Competition and Markets Authority (CMA), the European Commission, and the US Federal Trade Organization (FTC), which issued initial reports raising concerns that the merger could have anticompetitive effects, primarily related to restricted competitors' access to Arm's technology.[1]

In Europe, the European Commission started an in-depth investigation; the case went to phase 2 in the UK, and in the US, the Federal Trade Commission sued to block the merger. However, following the initial reports from the competition authorities, Nvidia renounced purchasing Arm, alleging large regulatory hurdles. The case was suspended before the EC and CMA investigations concluded and before the FTC trial started. Because the merger was abandoned before the authorities made official decisions, the amount of public information published is limited. In this paper, I discuss the Nvidia-Arm case based on the limited information that was made public.

Nvidia and Arm operate at different stages of the semiconductor production chain. Arm specializes in supplying IP designs for semiconductor production, primarily serving semiconductor suppliers producing central processing units (CPUs) and system-on-chip (SoC) developers. Initially focused on the mobile industry, Arm expanded into other applications requiring higher processing power. Nvidia, on the other hand, gained prominence as a leading graphics processing unit (GPU) designer, with applications ranging from video games to artificial intelligence. Over time, Nvidia diversified its product portfolio to include processor products for various functions.

After summarizing the main conclusions of the authorities and Nvidia's arguments and response to their anticompetitive concerns, I propose two main theories of harm that relate to the primary concerns raised in the initial investigations. These concerns were that the vertical integration would lead to vertical foreclosure either through refusal to supply Nvidia's rivals or supply at degraded conditions and risk of stalled innovation because Nvidia's rivals would be wary of sharing sensitive information with Arm, fearing it would leak to Nvidia. I also present a theory of pro-competitive effects of the merger that captures the main arguments used by Nvidia to defend the transaction. I then describe an additional theory of price effects of the

[1] Other countries also investigated the potential merger, e.g., China, Japan, and Korea

merger. Remark that price effects did not concern the authorities in this case. However, as the theory aligns with some relevant case characteristics, its applicability in this and other related contexts is worth considering.

The first theory of harm is based on Fumagalli and Motta (2020) and shows how vertical foreclosure can be optimal when there is the threat of entry because it affects the future market structure, allowing integrated firms to increase future profits. This theory relates to the dynamic context in which the merger would occur: an industry that experiences fast technological change and innovations and the entry and exit of firms and products.

The second theory of harm is based on Allain et al. (2016). It shows how vertical integration can lead to hold-up concerns associated with incentives of downstream rivals to share sensitive information with the integrated upstream firm. This theory speaks to the fact that innovation in the different markets where Arm is active depends on information sharing between downstream firms and Arm so that Arm can provide the appropriate technical support and develop designs that answer the different firms' specific needs.

The third theory emphasizes the merger's potential pro-competitive benefits and reflects Nvidia's main arguments to defend the vertical integration with Arm. It considers that firms such as Arm and Nvidia and their competitors are typically part of digital ecosystems in the sense that their products and services interconnect through technical compatibility and demand side complementarities (Bowman et al., 2023). In the context of ecosystems, it can be relevant to think of merger effects not only on product market competition but also across and within ecosystems. The theory is based on Condorelli et al. (2023). It develops the idea that if the merger had fostered the creation of a new ecosystem, the competition between ecosystems and the potential for consumer hold-up would have countered foreclosure incentives and kept prices low.

Finally, I present a theory of harm based on Bourreau et al. (2011) showing how the merger could lead to higher consumer prices. This theory captures relevant features of the industry and markets where Nvidia and Arm are active and, therefore, could be relevant for other similar and related cases. For example, in many relevant markets, such as CPUs for PCs and datacenters, vertical integration between Nvidia and Arm would result in a market structure in which only vertically integrated firms would produce the intermediate product. In this setting, there could be partial foreclosure in the downstream market even when the upstream market is competitive.

I believe the two first theories, Fumagalli and Motta (2020) and Allain et al. (2016), are the most relevant for the case. The threat of entry downstream and upstream comes out clearly in the public reports and Nvidia's statement. However, a deeper investigation involving internal documents and submissions from involved parties would be helpful in thoroughly evaluating this theory, particularly in analyzing how downstream entry could facilitate upstream entry by increasing its expected profitability. Additionally, the critical role of sensitive information sharing between upstream and downstream firms arises as a central fact of the case. Given the challenges in verifying information leakages, downstream firms may lose confidence in an integrated Arm, leading to the hold-up concerns described in Allain et al. (2016). Concerning Condorelli et al. (2023), the need for more established literature on the ecosystem effects of

mergers makes it hard to appraise its relevance for this case thoroughly. I find the theory of harm based on Bourreau et al. (2011) convincing for post-merger scenarios where the upstream product is produced only by fully integrated firms. However, it is not especially fit for the Arm-Nvidia case as initial investigations did not stress price effects as likely harmful effects of this merger.

The paper is organized as follows. In the next section, I describe the main characteristics pertinent to the industry in which Arm and Nvidia are active. Section 3 presents the arguments and conclusions of the antitrust agencies and Nvidia, following the initial investigations. In section 4, I present the theories of competitive effects for the proposed vertical merger based on the recent literature on industrial organization that addresses the main concerns of the authorities and the main defense arguments of Nvidia. In that section, I explain how each theory fits this case. The last section concludes.

2 Industry background

In this section, I outline key features of the high-tech industry where Nvidia and Arm operate. This complex industry contains firms producing multiple products for various markets. Innovation plays a crucial role. However, this paper does not delve into an exhaustive, in-depth description of the industry's intricate technical aspects. Instead, I concentrate on essential characteristics crucial for comprehending the conclusions reached by the parties and agencies regarding the proposed vertical merger and the theories of harm I propose later. The industry background described in this section is based on information in the reports by agencies (CMA, 2021; EC, 2021; FTC, 2021), Nvidia's initial submission, and information available on Nvidia and Arm's websites.

2.1 Upstream

The semiconductor technology industry plays a vital role in today's business and consumer landscape, extending its influence to various sectors such as datacenters, the Internet of Things, autonomous driving, and infotainment. Arm, owned by Japanese-based Softbank, develops designs for semiconductor chips and sells the intellectual property to design and produce these chips to its customers. It has more than 1,000 licensees, ranging from startups to established technology firms, active in several downstream markets. Arm's business model is to produced licensable chip IP design centered around upfront fees and royalties, and it actively seeks input from its licensees to innovate its designs. Furthermore, Arm collaborates closely with licensees on the development of design features, often involving sharing confidential and commercially sensitive information. Remarkably, Arm estimates that approximately 70% of the global population interacts with technology based on its IP(CMA, 2021).

Arm supplies chip designs for different uses. Its traditional domain is mobile phones, but it has expanded to other markets, with its processors increasingly found in laptops, desktops, and data center servers. Notably, most chip suppliers vying to provide System-on-Chips for advanced driver assistance systems rely on Arm-based chip designs, including Nvidia, one of

the world's largest chip suppliers and a long-standing Arm licensee. Arm-based computer processors, which encompass three main types – central processing units (CPUs), graphics processing units (GPUs), and data processing units (DPUs) – are integral components in various high-tech devices. CPUs, in particular, are essential for executing primary computer instructions in laptops, smartphones, data centers, and advanced driver assistance systems. In CPUs, Arm and the x86 architecture, used by Intel and AMD, dominate the instruction set architecture (ISA) landscape.

Unlike Arm, which licenses its IP to various manufacturers, the x86 ecosystem is maintained and advanced by Intel and AMD only (it is not licensable to other firms). The term "x86" refers to a family of ISAs originally developed by Intel. Intel produces a wide range of processors based on the x86 architecture, designing and manufacturing its own chips. AMD, the other major manufacturer of x86 processors, has a historical cross-licensing agreement with Intel that allows it to design and manufacture its own x86-based processors. Both Intel and AMD are vertically integrated, handling both the design and manufacturing of their processors.

Other CPU IP licensors are RISC-V, MIPS, and Power Architecture. RISC-V, an open-source alternative that emerged from the University of California, Berkeley, is viewed as less suitable for complex applications and lacks a comprehensive software ecosystem, making it a minor player compared to Arm. MIPS has a diminishing market presence, being active only in certain niche markets. Power Architecture, originally developed by IBM, is a competitor in high-performance computing and specific embedded applications. These licensors are small compared to Arm, who has a strong position in the licensable chip design market.[2] For example, Arm is the leading supplier of CPU IP for SmartNICs with almost 100% share of supply. Concerning the Internet of Things, the market share of devices using Arm-based technology amounts to 65%. The constraint posed by the other CPU IP licensors is weak, and there are significant barriers to switching CPU IP licensors as different IP designs "speak different languages", which results in different associated ecosystems FTC (2021).

2.2 Downstream

Nvidia is one of the largest chip suppliers globally, competing across various computer markets and steadily expanding into new sectors. The company has established itself as an Arm licensee for an extended period, leveraging its software and design expertise. Nvidia is fabless, that is, it designs its products but, not owning factories, contracts out their production. It specializes in designing GPUs, application programming interfaces for data science and high-performance computing, and system-on-a-chip units tailored for the mobile computing and automotive markets. Moreover, it has emerged as a dominant hardware and software supplier for artificial intelligence applications. In the GPU market, Nvidia holds an 83% market share in graphics cards, where its customer segments predominantly consist of gamers and professionals who heavily rely on visualization tools in their respective domains, such as architecture, engineering

[2]Arguably, Arm's position is weaker if we consider the whole market of chip design, irrespective of whether they are licensable or not, due to the prevalence of the x86 technology.

and construction, media and entertainment, automotive, scientific research, and manufacturing design.[3] The competitive landscape within the GPU market involves firms such as AMD, Intel, Sapphire (which utilizes AMD chips), and Apple GPUs as a newcomer in the gaming market and persistent entry of new products that directly compete and potentially challenge Nvidia's dominant position[4].

Nvidia has also become a relevant player in the AI-enabled platforms and systems industry. For example, it has built and launched the Cambridge-1 supercomputer in the UK for medical research. It has also recently developed the Omniverse platform, a cloud-computing platform for creating and operating 3D metaverse applications. Moreover, it announced plans to develop Earth-2, which should be the world's largest and most powerful supercomputer dedicated to climate science. Remark that although Nvidia is a long-term Arm licensee, it is also an Intel client. Notably, the Nvidia supercomputers and the Omniverse were developed within the x86 Intel ecosystem.

3 What the parties had to say

3.1 The conclusions of the competition authorities

The FTC sued to block Nvidia's acquisition of Arm on December 2, 2021. A trial was scheduled for August 2022, but in February 2022, Nvidia announced it was abandoning the takeover. Meanwhile, the European Commission opened an in-depth investigation under the EU Merger Regulation and, in the UK, the CMA moved to a phase 2 investigation in November 2021, with a 24-week deadline to issue a final report. However, the takeover was canceled before the conclusion of the EC's investigation and the release of CMA's final report.

The three authorities closely cooperated throughout the investigation, reaching similar conclusions expressed in their initial reports and press releases.[5] They identified significant competition concerns related to the merged business.[6] These concerns centered around potential harm to Nvidia's rivals through foreclosure strategies, such as limiting access to Arm's CPU intellectual property and hindering interoperability between related products, ultimately benefiting Nvidia's downstream activities and increasing its profits. The concerns rose from evidence consistent with a dominant position of Arm in the licensable chip IP design market (see section 2.1 for more details).

The theory of harm argues that Nvidia and Arm had different incentives concerning Arm's downstream markets before the merger. Arm's incentive was to expand the use of its processor technology, as its profits typically increased when its licensees achieved more sales. On the other hand, Nvidia competed against many of Arm's licensees and profited from diverting

[3]The GPU market seemed not to be the focus of concern of the antitrust authorities in the case of a merger with Arm. I mention it here because Nvidia is best known for its GPUs.

[4]https://linuxhint.com/nvidias-competitors-gpus; https://finance.yahoo.com/news/nvidia-is-on-top-of-the-world-but-its-rivals-are-gaining-steam-181437845.html

[5]The FTC published that they also coordinated closely with the CMA and the EC, Japan, and South Korea.

[6]CMA (2021), EC (2021), and FTC (2021)

demand from competitors towards its own products. The agencies believe that the merger would alter Arm's incentives in the direction of foreclosure strategies. These strategies could involve withholding critical inputs from rivals, delaying or degrading access to inputs or service support, or changing terms relating to input availability to disadvantage competitors and increase input costs.

The agencies found that the impact of potential foreclosure strategies would be substantial in several global markets, including the supply of CPUs, interconnected products, and System-of-Chips in datacenters, internet-of-things devices, and automotive applications. They identified foreclosure strategies that would reinforce each other, possibly lessening competition. Such an outcome would stifle innovation and lead to more expensive or lower-quality products.

The agencies also raised concerns that the merger could slow down innovation because ARM customers might be reluctant to share confidential information crucial to enhance ARM designs.

Furthermore, in the datacenter sector, the CMA identified both vertical and conglomerate effects, as the merger could restrict access to CPUs, network interface controllers, and GPUs, impacting data transfer efficiency and server performance.[7] In the IoT, automotive, and gaming console sectors, the CMA report observed vertical effects to be predominant, with concerns about limited access to system-of-chips for applications in these markets.

3.2 The arguments of Nvidia

A substantial part of Nvidia's pro-integration arguments was based on the notion of ecosystems.[8] Nvidia defends the idea that the merger would be an opportunity to expand Arm's ecosystem, enabling it to compete with the x86/Intel ecosystem, implying more choice for customers, and encouraging innovation and entry of new products across the board. Nvidia insists that post-merger Arm would have more incentives and opportunities to increase R&D dramatically. They also argue that Nvidia's investments in Arm in the UK are seen as an opportunity to deconcentrate CPU markets, traditionally dominated by Intel's x86 CPUs. Moreover, the merger was expected to accelerate Arm's roadmaps for mobile, IoT, and other areas Arm has traditionally served.

Responding to foreclosure concerns raised by competition authorities, Nvidia defends that any foreclosure attempts could severely damage Nvidia's investment in Arm because it would undermine the creation of ecosystem network effects crucial to Arm's success in datacenters, reduce customer incentives to buy into the Arm ecosystem, hinder Nvidia's ability to benefit from downstream risk diversification, and jeopardize customer trust and commitment to the Arm ecosystem in the datacenter market and other markets.

[7] The EC press release does not mention conglomerate effects as described here but classic input foreclosure scenarios.

[8] "Technology ecosystems are product platforms defined by core components made by the platform owner and complemented by applications made by autonomous companies in the periphery. These ecosystems offer solutions comprising a larger system of use than the original platform owner created and solve important technical problems within an industry. In successful technology ecosystems, it is easy to connect to or build upon the core solution in order to expand the system of use and allow new and even unanticipated end uses" $https : //cio - wiki.org/wiki/IT_Ecosystem$

Additionally, Nvidia defended that if it merged with Arm, it would be unable to foreclose competitors, citing intense competition from Intel and RISC-V as a deterrent. It points out that the authorities, specifically the CMA, overlooked the role of Arm's long-term licensee contracts and its influential architectural licensees. These contracts ensure that Arm cannot foreclose its licensees for an extended period, thereby preventing any significant threat of foreclosure. Additionally, they emphasize the time frames related to Arm's licensing, highlighting that licenses are guaranteed up to 7 years, and there is no way to nullify them before the original agreed deadline. They also highlight that Arm's licensees have perpetual manufacturing rights, allowing them to continue producing, using, and selling chips designed during the license term.

Regarding licensing revenues and downstream sales, Nvidia argues that Arm would forego immediate licensing revenues if it attempted to foreclose new intellectual property. In contrast, the impact on downstream sales would take years to materialize. This is because the licensees use Arm technology today to develop products that will only be marketed downstream in many years.

Nvidia also argued that post-merger, they would not have the ability to decrease technical compatibility between Arm-based downstream products, such as CPUs and SmartNICs, that compete with Nvidia's products. Nvidia explained that Arm's customers make their own CPUs and control chip interfaces, and compatibility is determined by the chip itself, not Arm's products.

4 What does the economic literature have to say?

In this section, I present two possible theories of harm for the vertical merger between Nvidia and Arm based on the recent industrial organization literature. These theories address two central concerns raised by the competition authorities, i.e., input market foreclosure by Arm, who would have an incentive to stop supplying Nvidia's rivals (or supply at degraded conditions), and a negative effect on innovation because Nvidia's rivals would be reluctant to share confidential information with Arm. I also present a theory of "no harm" that formed the basis of the defendant's arguments. Moreover, despite initial investigations not identifying potential anticompetitive price effects, I examine an additional theory that could fit the case, and that shows how vertical integration could lead to consumer price increases.

4.1 Evolving industries

In this section, I propose a theory of harm relating to one of the authorities' primary concerns, which was that the merger could create input foreclosure incentives. They were concerned that Arm would have incentives to stop supplying its designs to Nvidia's rivals or would degrade the quality of the supplied designs and services. In static settings, it is hard for vertical integration to result in foreclosure because the upstream monopolist can get higher profits by serving efficient downstream rivals and extracting rents from them instead of excluding them. This is the well-known Chicago critique. To get foreclosure due to vertical integration, one typically needs frictions that limit the rent extraction in the downstream market, e.g., commitment

problems (Hart and Tirole, 1990). However, Nvidia and Arm are active in a dynamic high-technology sector marked by continuous evolution, innovation, and the emergence of novel application markets. There is also potential entry of firms and products due to the rapidly evolving technology. Hence, it is appropriate to consider a theory of harm for the vertical merger between Nvidia and Arm where dynamics play a crucial role. In dynamic contexts, vertical foreclosure can be optimal because, although it leads to profit loss today, it affects future market structure, increasing the integrated firm's future profits as in Fumagalli and Motta (2020).

In Fumagalli and Motta (2020), an integrated monopolist faces the threat of downstream entry and the threat of future upstream entry.[9] It may be optimal to foreclose downstream competitors, even if it means losing profits in the current period. Why? There are two possible cases. First, by foreclosing the downstream competitor and maintaining a monopoly in the downstream market, the downstream integrated subsidiary can extract higher rents from the more efficient upstream future rival, increasing total profits. This is in the case where upstream future entry is unavoidable. Second, in cases where, e.g., entry costs are high, lack of competition in the downstream market following foreclosure of the downstream unintegrated entrant makes upstream entry unprofitable. In this case, the current profit loss due to foreclosure of the downstream unintegrated firm is compensated by defending the integrated firm's monopoly both downstream and upstream.

Which of these cases is more likely in the Arm-Nvidia merger? The issue is whether weaker downstream competition significantly reduces upstream profitability—enough to make upstream entry unprofitable given the entry costs—or whether upstream entry is inevitable regardless of downstream competition. In either scenario, the key ingredient for a theory of harm is that future entry in the upstream market is likely, irrespective of whether it would occur anyway or depends on the success of entry in the vertically related market. This information is often found in internal documents, party submissions, and specialized trade publications. Notably, one of Nvidia's arguments in defense of the merger was the potential threat of future entry in the upstream market. However, the analysis by Fumagalli et al. (2020) suggests that Nvidia's argument might backfire, as the threat of entry could indicate possible anticompetitive effects of the merger rather than supporting it.

4.2 Hold-up and effect on Innovation

The competition authorities were concerned that the merger would negatively affect innovation incentives because, due to fear of being exposed to Nvidia, its rivals would restrain sharing confidential information relevant to developing microprocessor technology that matches downstream firms' needs. More generally, innovation could suffer post-merger if an integrated Arm had incentives to offer services with degraded quality to Nvidia's rivals. Allain et al. (2016) provide the theoretical framework clarifying the mechanisms behind these concerns raised by the

[9]The mechanisms work the same if there is a threat of entry in the upstream market today and a threat of entry in the downstream market in the future.

authorities. The main specification in the paper considers a duopoly in the upstream market, which is a good description of the markets in which Arms is active. Also, in their environment, the downstream firm requires services from the upstream supplier for investment to be successful. This feature also relates to the downstream firms in this case: for their investments to succeed, they need Arm chip technology tailored to their specific requirements for performance, power, and cost. Additionally, they require training and support in chip design and production to minimize risks and shorten development time.[10]

The crucial idea in the paper is that vertical integration can also be a source of hold-up instead of a solution to the hold-up problem (e.g., Grossman and Hart, 1986). A downstream firm is held up when part of the return of its investments can be appropriated by an upstream firm with which it trades. Hold-up concerns can arise when the upstream firm has bargaining power due to market power or because the downstream firm's investment is relationship specific, and contracting cannot take place after investments are sunk or contracts are complete.

In the paper's main setup, two downstream duopolists must decide to invest before contracting with upstream firms. For investment to succeed, the downstream firms need service from an upstream supplier. The authors show that, in vertically separated markets, competition in the upstream market prevents hold-up. However, under vertical integration between a downstream firm and an upstream supplier, there are both ex-ante and ex-post incentives to degrading conditions for the rival downstream firm.

Ex-ante, the upstream integrated supplier may commit to dissipate instead of to appropriate part of the investment return, disadvantaging non-integrated downstream rivals. To dissipate investment returns, the integrated supplier could, for example, share sensitive information, degrade the quality of provided services, or limit access to inputs.

The paper illustrates an ex-ante hold-up mechanism relevant to the Nvidia-Arm case. Suppose downstream firms are in a race to innovate. Innovation requires close cooperation and sensitive information sharing with the upstream supplier, who provides technological support to the downstream firms. If sensitive information leaks, the integrated downstream subsidiary can imitate the innovation, decreasing the innovation investment incentives of the independent downstream firm. Thus, if the integrated firm can pre-commit to leaking sensitive information, the downstream rival is ex-ante held up by the non-integrated upstream supplier. The key to operationalizing this theory of harm would be to check to what extent Arm could pre-commit to sharing sensitive information or, more generally, to degrading service quality.

However, even without pre-commitment, there could be ex-post hold-up concerns when the quality of service provided by the upstream supplier is unverifiable or only partially contractible.[11] An integrated supplier may then degrade the input supplied to its rival to increase the profits of its downstream subsidiary. Hence, vertical integration makes the integrated firm less reliable, leading the independent downstream firm to be held up by the rival upstream firm.

For the ex-post hold-up concern to arise, service quality must be unverifiable. This is likely

[10] See the content presented in https://www.arm.com/support

[11] Partially contractible because the quality can be verified ex-post with a certain probability through, for example, audits or court litigation.

the case with regard to the services provided by Arm. These services include IP chip design, client support for chip design and production, and safeguarding from commercially sensitive data leakages. Contracting to prevent Arm from sharing sensitive information with Nvidia, e.g., informally, poses evident challenges. Arm could sign a non-disclosure agreement with the downstream firms. However, checking whether the NDA was respected would likely require ex-post investigation or litigation, implying that the information sharing is only partially contractible. Similarly, drafting a contract to ensure Arm does not degrade technical compatibility for rivals is problematic because it is hard to measure and compare compatibility across different downstream firms or against a benchmark. Also, Arm could easily hide behind arguments about technological limitations. In this context, the prospect of a hold-up by the other upstream firm could discourage investment from rival firms, impeding innovation, as highlighted by competition authorities.

4.3 Ecosystem effects

The notion of ecosystem effects, as outlined in Condorelli et al. (2023), formed the basis of the defendant's arguments. An "ecosystem" in this context refers to a supply-chain framework for producing multiple final products. The potential for consumer hold-up sets ecosystems apart from traditional supply chains. This means that final clients make long-term decisions about which ecosystem to join before the prices of final products are determined.

Due to the inability to predict future prices, consumers risk being held up and relying on signals, such as downstream market structure, to gauge their future consumer surplus. These signals are crucial in their decision-making process when engaging with a particular ecosystem.

When ecosystem effects are present, an integrated upstream firm may find it advantageous to enter into contracts with downstream competitors, even those offering close substitutes. This approach enables the firm to preserve within-ecosystem competition, as it is often impractical to secure long-term contracts with final customers during the development phase of downstream products.[12] By committing to keep within-ecosystem prices low, the integrated firm can attract consumers to its ecosystem. Condorelli et al. (2023) argue that this strategy could benefit the upstream firm more than foreclosing downstream rivals.

In summary, ecosystem effects introduce the potential for consumer hold-up in supply chains. Consumers rely on signals about their future consumer surplus to choose an ecosystem, and within-ecosystem competition helps the integrated upstream firm attract consumers by promising low prices. These dynamics emphasize the importance of understanding and considering ecosystem effects in analyzing the impact of mergers and competition.

Nvidia argued that Arm's primary competitors, Intel and AMD, who use the x86 architecture, are part of an established ecosystem of developers, software, systems, and peripherals. Both Intel and AMD are vertically integrated—they control the design and manufacturing of

[12]Note however that Arm signed long-term contracts with developers. See for example https://www.design-reuse.com/news/17573/arm-samsung.html, and https://www.tomshardware.com/news/apple-inks-new-long-term-arm-license-agreement-till-2040.

their chips, which allows them to generate substantial profits across various levels of their operations and invest heavily in research and development. As a result, Nvidia argues that Arm faces significant ecosystem and economic disadvantages.

Other than Condorelli et al. (2023), the industrial organization literature has seen limited research addressing competition within and across ecosystems.[13] The development of well-formulated theories with testable implications is fundamental for devising strategies to assess the competitive impacts of mergers involving ecosystems. Understanding the ecosystem effects of vertical integration is becoming progressively important for shaping effective competition policies, particularly in the context of mergers, given the relevance of ecosystems in digital markets.

4.4 Another possible theory: price effects

If the Nvidia-Arm merger had occurred, the market structure for CPUs, GPUs, and gaming consoles, for example, would consist of vertically integrated firms only, as depicted in Figure 1. In this scenario, Bourreau et al. (2011) demonstrate that even with upstream competition and public contracts, partial foreclosure equilibria can arise.

Their model features two vertically integrated firms and one unintegrated downstream firm competing with differentiated products on a downstream market. Despite assuming tough competition in the upstream market (linear price, homogeneous goods, identical constant marginal costs), equilibria with prices above marginal cost exist. Specifically, one integrated firm might supply the unintegrated firm at a monopoly price, while the other refrains from making an upstream offer. The intuition to this result is as follows.

Suppose Firm 1 in Figure 1 is the upstream supplier of the unintegrated downstream firm (Others). Does Firm 2 have an incentive to undercut Firm 1 in the upstream market? This depends on the downstream market. As the upstream supplier, Firm 1 has incentives to set higher downstream prices, because part of its resulting lost demand diverts towards Others, increasing 1's upstream revenue. Hence, the upstream supplier sets higher downstream prices than its integrated rival, Firm 2. This softening of competition benefits firm 2 who gains more downstream profits than firm 1. Thus, we cannot definitively determine who earns higher total profits: the upstream supplier extracts more profits in the upstream market, whereas its integrated rival extracts more profits in the downstream market. When deciding whether to undercut the integrated supplier in the upstream market, Firm 2 weighs the gain in upstream profit and the loss in downstream profit resulting from Firm 1 becoming more aggressive in the downstream market. If the softening effect in the downstream market is strong, the loss in downstream profit from becoming the upstream supplier may be substantial, and firm 2 may decide not to undercut its rival in the upstream market. The monopoly outcome is an equilibrium in this instance.

One of the main determinants of the intensity of the competition softening effect in the downstream market is the degree of differentiation downstream. The more differentiated the

[13] See also Bisceglia et al. (2022)

downstream market, the lower the diversion ratios and the lower the incentive of the upstream supplier to increase prices. The softening effect in this case is weak, with upstream competition driving prices to marginal cost. Conversely, when downstream products are close substitutes, the softening effect is strong, and the monopoly outcome is an equilibrium.[14]

Hence, the key to make this theory of harm operational is to show that the softening effect post-merger is likely to be strong, which translates into determining that downstream products are strong substitutes. The degree of differentiation in a market is typically an empirical question. Likely, the most straightforward way to measure diversion ratios or, more generally, substitutability across different products in a downstream market is to collect second-choice data through a survey, such as the ones sometimes conducted by antitrust agencies, especially the CMA.[15] Diversion ratios obtained from second-choice data measure the proportion of lost sales that goes to other products following an infinite price increase (product exit). This measure may differ from diversion ratios associated with marginal price increases depending on the format of consumers' preferences.[16] However, even when both measures differ, they are both still useful in indicating the degree of substitutability between products and, therefore, would provide empirical evidence on how differentiated a certain market is. Alternatively, if downstream prices and quantities data are available, as well as observable product characteristics, then it would be possible to estimate a full demand model (e.g., nested logit) and calculate diversion ratios using the resulting preference parameters estimates. This approach requires more data, is potentially more time-consuming, and is technically more involved. Its advantage, however, is that the estimated preference parameters are useful not only to calculate diversion ratios but also to simulate counterfactual scenarios that could be of policy interest (e.g., merger simulation).

Remark that in its defense, Nvidia insists on the inability to foreclose due to the intense competition Arm faces from Intel and AMD in all relevant antitrust markets (Nvidia, 2021, p.3). This type of argument, i.e., that there is intense competition in the upstream market, is frequently encountered in vertical integration defense arguments. However, the results in Bourreau et al. (2011) show that vertical integration can lead to harmful price effects in the downstream market even when upstream firms have no market power.

5 Conclusion

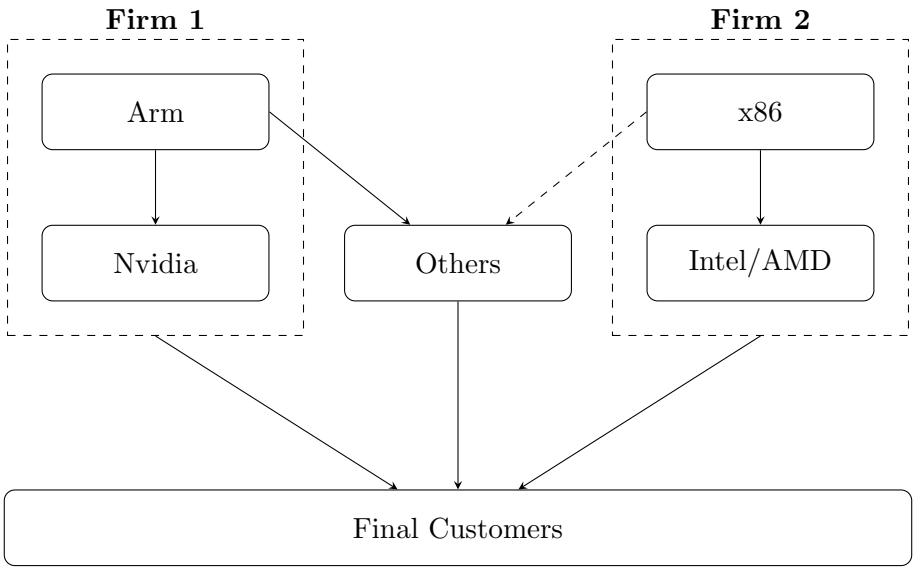
This paper analyses the Arm-Nvidia case from an industrial organization perspective, highlighting the complexities and potential competitive effects associated with vertical integration in the semiconductor industry. Based on the recent literature, I explore the primary concerns raised by antitrust authorities, including market foreclosure, access to critical technologies, and the

[14]The second key determinant of the softening effect is the efficiency of the unintegrated downstream firm. An inefficient downstream competitor sets higher downstream prices, supplies fewer downstream consumers, and demands less intermediate input, which tends to reduce the upstream profits, weakening the incentives to undercut and making partial foreclosure a more likely outcome.

[15]These surveys can be done by phone, asking consumers which product they would substitute if a certain product exited the market.

[16]See Conlon and Mortimer (2021) for details

Figure 1: Market structure post-merger



potential stifling of innovation. I also discuss Nvidia's main defense arguments and examine the possible economic mechanisms behind them.

The theories of harm I present illustrate how vertical foreclosure can influence future market structures, allowing integrated firms to increase future profits by limiting downstream competition. Additionally, they show how the risk of hold-up can repress innovation due to the reluctance of downstream firms to share sensitive information with an integrated upstream supplier.

Nvidia's defense, centered on the potential pro-competitive benefits of creating a new ecosystem to rival established incumbents, offers a counterpoint. This argument suggests that the merger could have enhanced competition across ecosystems, potentially benefiting consumers through lower prices and increased innovation. However, the limited development of ecosystem competition theories in the industrial organization literature calls for further research to adequately assess these claims.

I also explore the potential for price effects which, despite not being a central concern of the authorities, remains an important consideration. The analysis shows that even when there is upstream competition, vertical integration can lead to partial foreclosure equilibria, resulting in higher consumer prices post-merger.

As discussed, there are multiple channels through which anticompetitive effects could arise from the proposed vertical merger. I believe that the theory of harm based on Fumagalli and Motta (2020), where downstream market foreclosure is optimal because it prevents future upstream entry, is compelling. There is indication in the specialized press and also in the document released by Nvidia of threat of entry both upstream and downstream. Nevertheless, it would be helpful to extend the investigation using internal documents and parties submissions, especially to assess the link between entry profitability and the downstream market. The ex-post hold-up theory of Allain et al. (2016) is also very relevant in this case. The sharing of sensitive information between parties arises as an essential ingredient for successful investments

in innovations by the dowsntream firms. As information leakages are difficult to verify, especially when done informally, the downstream firms could loose trust in a integrated Arm. Due to the current lack of alternative chip IP licensors, the hold up concern could lead to total foreclosure in many markets.

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