Value Migration and Defense Strategies*

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Abstract

In many industries, firms adopt external technologies that improve their products but also generate complementary revenues for the technology developer. In this paper, we study a formal model to examine how competition between adopters affects the distribution of value created by such technologies and how adopters can respond to potential value migration—i.e., a shift in value capture from the firms to the developer. We find that value migration depends on the structure of value creation: it occurs when the technology primarily creates value at the consumer level, but not when it creates value foremost at the developer level. In the former case, sellers are in a Bertrand supertrap (prisoners' dilemma): adoption is strategically necessary but reduces sellers' profits. We then study two strategic responses: Defend investments, where sellers develop their own technologies, and embrace investments, where sellers enhance the developer's technology. Defend investments improve sellers' outside options and reduce value migration. Interestingly, this only occurs if the developer's technology exists; instead, without the technology, defend investments dissipate profits. Embrace investments have heterogeneous effects: improvements that increase consumer value intensify competition and exacerbate value migration, whereas improvements that increase complementary revenues can mitigate it. We also find that defend investments are particularly effective if the rival uses embrace investments in complementary revenues. Finally, we study competition between developers and show that it does not necessarily benefit sellers: when consumers are tied to specific technologies, systems competition can exacerbate rather than alleviate value migration.

Keywords: Value migration; technology adoption; systems competition.

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1 Introduction

The digital economy has created a growing class of technologies that improve established products while also generating complementary revenues for their developers. Examples include digital mapping platforms, operating systems, and online payment systems. These technologies create value for firms that integrate them into their products ('adopters') as they make the products more attractive to consumers, but also for developers because they provide valuable data, advertising revenues, or increased demand for complementary goods and services.[1] As these technologies have become increasingly central to firms, adopters fear that developers may appropriate a disproportionate share of the value created, thereby reducing their profits. Anticipating such 'value migration', adopters pursue strategies to protect their share of the jointly created value.[2]

The automotive industry is a case in point. Modern vehicles increasingly rely on external infotainment systems such as Apple's CarPlay and Google's Android Auto. These technologies enhance the driving experience by integrating navigation, entertainment, and app-based services into the car interface, while giving technology providers access to data and digital-service revenues. Accenture (2022) points out that consumers increasingly consider the availability and quality of in-car software when choosing a vehicle, with digital services expected to account for roughly 40% of auto industry revenue by 2040, but that car manufacturers are "ill-prepared to build and deliver services enabled by software." In response to this challenge, automakers are pursuing different strategies. For instance, Volvo and Honda are working with Google to customize the Android Auto OS for several of their models (McKinsey, 2025; Medium, 2025), while Toyota, Ford, and BMW have developed their own infotainment systems while continuing to make Apple CarPlay and Android Auto available to consumers (Dent, 2026).

Similar dynamics can be observed in other industries. For instance, in the television industry, several manufacturers, such as TLC, Hisense, and Sony, have included Smart TV operating systems from different developers (i.e., Roku, Google, or Amazon) into their products.[3] This allows consumers to directly access streaming apps and smart home controls, and at the same time enables developers to obtain revenues via digital advertising and promotional placements.[4] Some TV producers (e.g., Samsung and LG) have reacted by using their own system, whereas adopting companies usually work with developers to ensure seamless connection.

[1] For instance, mapping platforms such as Google Maps enable firms to incorporate navigation and location search into their products while generating revenues for the platform provider through advertising and consumer location data. Similarly, operating systems such as Android increase the value of smartphones, while generating platform revenues via commissions and advertising.

[2] The term 'value migration' was popularized by Slywotzky (1996), who uses it to describe the shift of value from outdated to new business technologies. In a similar spirit, we use it to denote the loss of profits that adopters suffer due to the existence of an external technology.

[3] This is often not done via a plug-in version but the operating system is directly integrated in the TV.

[4] See e.g. LongYield (2022) and Investopia (2026).

In this paper, we use a formal model to examine the strategic trade-offs that competing sellers face when deciding whether to adopt a product-enhancing technology and how to respond to potential value migration. Two competing sellers can independently adopt the technology of an external developer. Adoption of the technology enables the developer to capture complementary revenues. Each seller negotiates bilaterally with the developer to use the technology, and faces an exogenous cost if it decides to adopt it. Adoption decisions depend on the effects of the technology on product-market and complementary revenues, on the bargaining power of sellers vis-a-vis the developer, and on the adoption cost.

We ask three main questions. First, under what conditions does the adoption of a product-enhancing technology benefit adopters, and when does it lead to value migration toward the developers? Second, with respect to the strategies that adopters can use to protect their share of the jointly created value, is it beneficial to protect against value migration by investing either in an own technology and be in a better bargaining position or by embracing the external technology and collaborate with the developer? Third, how does the presence of multiple developers and potential competition between them affect value migration?

Our first result is that value migration crucially depends on the *structure of value creation*, that is, whether the technology primarily creates value at the consumer side (i.e., it improves the quality of the adopters' products) or at the developer side (i.e, it increases complementary revenues such as advertising, data, or commissions). In particular, improvements in product quality are (partially) competed away by adopters. A seller that does not adopt, while its rival does, falls behind, so each seller adopts to avoid a competitive disadvantage. Since adoption by the rival lowers a seller's outside option in its negotiation with the developer, the latter may capture more than the incremental value of the technology. Therefore, if the technology creates value mainly for consumers, adopters are caught in a 'Bertrand supertrap' (Cabral and Villas-Boas, 2005). Instead, if value creation is primarily on the developer side, the developer's complementary revenues are protected from competition. Because they are shared between the developer and each adopter through bargaining, adopters capture part of them.

Our contribution is not to show that value migration can happen,[5] but to show that its occurrence and significance depends on *where* in the ecosystem value is created. Consumer-side value increases value migration, whereas developer-side value tends to reduce it. A key difference to the standard supertrap result is that the cost of adoption is not exogenous: it is determined in negotiations with the developer, and therefore responds to the structure of value creation and to the strategies adopters use to improve that position.

We then study strategies adopters can take to protect against value migration. We consider

[5]Related forms of value migration and profit-reducing technology adoption are already present in the supertrap, technology-licensing, and ecosystem literatures. We provide a detailed literature review in the next section.

two types of responses: (i) *defend strategies*—i.e., developing an internal system that reduces a firm's dependence on the developer's technology—and (ii) *embrace strategies*—i.e., investing to improve the performance of the developer's system or the complementary revenues it generates.

Regarding defend strategies, we find that developing an internal technology reduces both the likelihood and magnitude of value migration. Although the internal technology is inferior compared to that of the developer and may not be finally used, its availability strengthens a seller's threat point in the negotiation with the developer.

Importantly, we show that the presence of the external developer is *essential for the success* of the investment in an internal system and changes its strategic function. Without the developer, investments in internal systems are dissipated through product-market competition, leaving sellers worse off. Instead, with the developer, the same investment opportunity improves sellers' disagreement payoffs and weakens the developer's disagreement payoff, thereby raising sellers' equilibrium profits. Moreover, the possibility that sellers develop their own internal systems can even *benefit the developer*. By strengthening the firm's bargaining position, it makes adoption of the superior external technology more likely. The structure of value creation is also central to this result: high complementary revenues make broader adoption more valuable to the developer, whereas a high consumer-side value tends to have the opposite effect.

Regarding embrace strategies, the structure of value creation again determines whether an investment benefits adopters. Investments that increase the value of the developer's system for consumers intensify competition in the product market and lower each seller's outside option, generating an additional supertrap on top of the one that arises without such investments. They therefore exacerbate value migration. Instead, investments that increase the developer's complementary revenues have two opposing effects. They expand the surplus that sellers share with the developer, and this surplus is not dissipated by competition. However, they also increase the value the developer obtains in case of disagreement with a seller—i.e., its outside option. If the value the system creates for consumers is not too large, the first effect dominates, and sellers then benefit from investing in developer value.

We also study the *interaction* between defend and embrace strategies across sellers. We find that a seller's defend investment is a *strategic complement* to its rival's investment in the developer's complementary revenues. The reason is that the former increases the number of consumers the developer loses if it fails to reach an agreement with the seller, whereas the latter raises the value of each of these consumers to the developer. The two therefore reinforce each other in weakening the developer's outside option. By contrast, a seller's defend investment is a *strategic substitute* to its rival's investment in the consumer value of the developer's system. If the rival offers a better system, the product-market return to improving the internal system, which the seller only uses if negotiations fail, is lower. As a consequence, where one seller's embrace investment creates value

determines both the other seller's incentive to defend and the effectiveness of its defend strategy.

Finally, we examine whether competition between technology developers mitigates value migration. We distinguish between consumers who are tied to a particular technology—e.g., because they already use devices of a specific developer—and consumers who can use either technology. We refer to the former as 'captive' and to the latter as 'free' consumers. We show that systems competition benefits adopters only if the share of free consumers is sufficiently large. Free consumers weaken each developer's bargaining position, because a seller that fails to reach an agreement with one developer can still serve these consumers through the other developer. Captive consumers, by contrast, imply that the developer is indispensable for reaching a segment of the market. We show that competition makes a seller's loss from disagreement concave in the resulting quality disadvantage, which implies that the sum of the seller's losses from separate disagreements with two smaller technology providers can exceed its loss from disagreement with a single larger provider. Fragmentation can therefore strengthen developers' aggregate bargaining position even though each developer is individually smaller. This mechanism allows us to separate between two dimensions of the demand structure: the *fragmentation* of consumers across systems, which strengthens developers' bargaining positions, and the *competitive intensity* between systems, which weakens them.

Overall, the paper highlights a fundamental tension in digital technology adoption. Due to the two-sided nature of these technologies, value migration is governed by the *structure* of value creation: Value embodied in the consumer product is exposed to downstream competition and can weaken sellers' disagreement positions, whereas complementary revenue that accrues to the developer is shared with sellers through bargaining. This explains why technologies with similar total value can have sharply different distributional consequences. This mechanism determines the effectiveness of sellers' strategic responses: defend investments strengthen alternatives to agreement, whereas the consequences of embrace investments depend on whether they increase consumer value or developer-side revenue. Relatedly, competition between systems benefits sellers only if competition for free consumers is sufficiently strong to outweigh the bargaining pressure created by fragmented captive demand.

The paper is organized as follows: The remainder of the introduction relates the paper to the existing literature. Section 2 presents the model. Section 3 determines the conditions for value migration. Section 4 analyzes strategic responses. Section 5 considers developer competition. Section 6 concludes and discusses managerial implications. The Appendix contains the proofs of all results (Appendix A) and two additional analyses (Appendices B and C).

1.1 Literature review

Our paper relates to several strands of literature.

First, we contribute to the literature that studies investment opportunities (e.g., cost-reducing or product-enhancing technologies) that are individually profitable but lower firms' profits if available to all competitors. Cabral and Villas-Boas (2005) show multiple instances in which such "Bertrand supertraps" (prisoners' dilemmas) arise and study the consequences.[6] Abolfathi, Fosfuri and Santamaria (2022) analyze a model in which firms can offer complementary products in addition to their basic one and find that a supertrap can be avoided only if switching costs are sufficiently low. Several papers show that such supertraps are particularly pertinent in online markets. Specifically, Ofek, Katona and Sarvary (2011) analyze a model in which competing retailers can each decide whether to operate an online channel and find that the equilibrium can be asymmetric, with the retailer that operates an online channel earning lower profits. Pang and Etzion (2012) show that if firms can offer complementary online services that exhibit network externalities, they often bundle them with their original products although this strategy leads to fiercer competition and lower prices in equilibrium.[7] The general logic also underlies the literature on licensing an innovation to competing firms (Katz and Shapiro, 1986; Kamien and Tauman, 1986; Arora and Fosfuri, 2003): because each firm's payoff when it does not acquire the technology is lower if its rivals do, the owner of the technology can extract more than the increase in profits the technology generates.

Our analysis builds on this insight but differs in several respects. First, in these papers the value of the technology materializes in the product market, where it is subject to competition. In our setting, the technology also creates value that accrues directly to the developer, and we show that the split between the two forms of value determines whether adopters gain or lose. Second, we analyze the effectiveness of strategies to escape or mitigate the trap. In particular, whereas the cost of adoption is exogenous in the supertrap literature, in our model it results from bilateral negotiations with the developer, which allows us to study how adopters can change the terms of adoption through their strategic responses.[8] For instance, we find that the value of a defend option is tied to the presence of the external technology: the same investment opportunity dissipates profits without the developer but raises profits with it.

Second, our paper is related to the literature that studies how bargaining affects the relationship

[6] Early contributions to this literature are Fudenberg and Tirole (1984), who classify how investment can make a firm tougher or softer in competition, and Bulow, Geanakoplos and Klemperer (1985), who study how a firm's actions in one market can affect rivals' behavior in another market.

[7] Costa, Cool and Dierickx (2013) determine conditions under which even the existence of a unique resource, that is, only one firm can make an investment, can be detrimental for profits due to a change in subsequent product-market competition. See also Hannah, Tidhar and Eisenhardt (2021) for a general discussion of such a scenario.

[8] In this respect, our paper is related to Chatain (2013) and Asmussen (2015), who study how the pricing of resources (e.g., new technologies) by suppliers affects adoption and profitability of competing final-product firms.

between value creation, value appropriation, and investment. Chatain (2011) argues in a formal model that a supplier's competitive advantage depends not only on the value it creates but also on how this value is divided with the buyer through bargaining, and tests the resulting predictions with data from law firms in the United Kingdom. Dukes, Gal-Or and Srinivasan (2006) show how the gains from cost reductions are shared along value chains in which firms negotiate at each layer. John and Ross (2022) study how complementors' incentives are affected by the bargaining power of a platform and find that such power, which usually allows the platform to capture value, can weaken complementors' investment incentives and thereby lower value creation.[9] More recently, Chatain and Plaksenkova (2026) analyze how different types of complementarities shape incentive alignment. They show that multi-sided bargaining among orchestrators, complementors, and buyers typically distorts participants' investments relative to the ecosystem's optimum.[10]

Our paper differs from these studies in two important ways. First, we explicitly determine how value appropriation depends on where in an ecosystem value creation occurs. Specifically, we distinguish between value embodied in sellers' products and value captured by the developer through complementary revenues and show that two forms of value differ in their exposure to downstream competition. Second, we are able not only to explain how bargaining affects investment incentives but also to study which strategies allow adopters to protect their share of value, and under which conditions each strategy is effective.

In this respect, our analysis of defend strategies connects to the resource-based view of competitive advantage (Barney, 1991; Peteraf, 1993) and to the role of complementary assets in profiting from innovation (Teece, 1986).[11] We complement this view by considering the development of internal capabilities to influence the bargaining with technology providers.[12]

Third, our paper also contributes to the literature on platform ecosystems, which studies how complementarities and platform governance determine value capture of participants (Parker and Van Alstyne, 2005; Gawer and Cusumano, 2002; Iansiti and Levien, 2004; Adner and Kapoor, 2010; Adner, 2017; Jacobides, Cennamo and Gawer, 2018). Work on industry architectures shows that value tends to accrue to firms that control bottlenecks, and that firms act to reshape industry architectures in their favor (Jacobides, Knudsen and Augier, 2006). Jacobides and Tae (2015) document how value shifts across segments of a sector toward such bottlenecks. Several papers in

[9] Zhu and Liu (2018) and Wen and Zhu (2019) find empirically that complementors respond strategically to the power of platform owners, for instance by adjusting their innovation and pricing when facing the threat of platform entry.

[10] Reisinger, Schmidt and Stieglitz (2021) study how a complementor can take competition to the system level by launching an integrated system, thereby gaining leverage over its remaining complementor through margin squeezing or managed self-cannibalization.

[11] See also Adegbesan (2006) and Schmidt and Keil (2013).

[12] This part of our analysis is therefore related to papers showing that firms choose technologies to shape their bargaining positions and improve their terms of trade (e.g., Katz, 1987, and Inderst and Wey, 2003).

this literature examine the potentially adverse effects of platform-complementor relationships. For instance, Mantovani and Ruiz-Aliseda (2016) show that firms may endogenously form innovation ecosystems with complementors, which nevertheless leaves them worse off relative to the no-ecosystem case,[13] Panico and Cennamo (2022) determine how user preferences can generate a trade-off between innovation of complementors and the size of the ecosystem, and Hagiu and Wright (2026) show that agents joining a platform can reduce the outside options of other agents, which allows the platform to create a trap in which all agents join despite being worse off.[14]

None of these papers analyzes the questions our paper focuses on. In particular, this literature is not concerned with the questions how the nature of value creation in a ecosystem affects value capture of the different parties and how firms can react to potential value migration by pursuing defend or embrace strategies.

On a high level, our paper relates to the literature that studies value creation and value capture in general competitive environments (Brandenburger and Stuart, 1996; MacDonald and Ryall, 2004; Chatain and Zemsky, 2011). In particular, MacDonald and Ryall (2018), show that entry can benefit or harm incumbents depending on how it changes value creation and the productive alternatives available to firms. Our paper studies a related ambiguity in a technology-adoption environment, where a developer's technology increases the value created but also changes competition and bargaining positions of firms. However, our paper departs from this literature by studying how the structure of value creation in an ecosystem affects value capture, and by considering what strategies adopters can use to mitigate value migration. In addition, this literature usually employs concepts from cooperative game theory, whereas we use a non-cooperative model of product-market competition.

Finally, our result in the analysis of systems competition that value migration depends on the share of captive versus free consumers, is related to the role of curvature in the literature on firm size in bilateral bargaining (Chipty and Snyder, 1999; Inderst and Wey, 2003). However, the strategic implications for competition between technology systems, and in particular the distinction between the fragmentation of consumers across systems and the competitive intensity between systems, have not been studied in this literature.

[13] He, Kuksov and Narasimhan (2012) analyze a situation in which firms can choose whether to generate interoperability among their own consumers or between their own consumers and those of the rival, and find that this can lead to a Bertrand supertrap.

[14] Hagiu and Wright (2015) determine the conditions under which it is optimal for a firm to operate as a platform rather than as a reseller.

2 The Model

We consider a model with three firms, 1, 2, and D. Firms 1 and 2 are *sellers* offering products to consumers. Firm D is a *developer* of a technology (system) that increases consumers' valuations when included in a seller's product.[15]

We model demand following the Hotelling specification. There is a continuum of consumers of mass 1. Consumers are distributed uniformly along a unit segment, with sellers located at the extremes. A consumer located at point $x \in [0, 1]$ has valuations

$$u_{1x} \equiv v_1 - p_1 - t\,x, \qquad \text{and} \qquad u_{2x} \equiv v_2 - p_2 - t\,(1-x),$$

for products 1 and 2, where v_i is the gross utility (value) for product $i \in \{1, 2\}$, p_i is its price, and $t > 0$ is a transportation cost parameter.

Product i's value is $v_i = \underline{v}$ if it does not include D's system and $v_i = \underline{v} + \Delta$ if it does, where $\Delta \geq 0$. We assume $\underline{v}$ is large enough so that the market is covered in equilibrium, and $\Delta < 3t$ to ensure interior solutions.[16]

If i includes D's system into its product, we say it *adopts* the system. Adoption implies a fixed *adoption cost* of $K \geq 0$ for the seller. For simplicity, we assume other costs (fixed or variable) are equal to zero.[17]

If D's system is included in a product, D obtains a complementary revenue $\sigma \geq 0$ per each consumer using that product. This revenue represents the two-sided nature of the technology where the developer does not only create value via the improvement of the sellers' products but also via data-related or advertising revenue.[18]

We consider the following two-stage model. In the first stage, each seller i negotiates independently with D about the inclusion of D's system in i's product.[19] In the second stage, the outcomes of the negotiations are publicly observed and each seller chooses its price. Each consumer then decides from which firm to buy.

In the first stage, the outcome of a negotiation is determined by the Nash Bargaining Solution

[15] For a model of technology adoption with a single buyer but two developers, see e.g. Cabral and Dezsö (2008).

[16] This is a reasonable assumption e.g. in the car industry in many countries, where most people have a car and decide mainly about from which firm to buy the car.

[17] Introducing constant marginal costs would not affect our results.

[18] The technology is two-sided in that it improves consumers' valuations while also generating complementary revenues for its developer. This differs from a two-sided market in the sense of Rochet and Tirole (2003, 2006) and Armstrong (2006), where a platform intermediates between two user groups and transaction volume depends on the allocation of charges between them. Instead, we study how the two sources of value affect adoption and the division of surplus through developer–seller bargaining.

[19] In Appendix B, we briefly consider the case in which D has the possibility to commit to include its system exclusively in the product of a single seller and auctions the exclusivity contracts. We determine conditions for such exclusivity to be optimal and show that value migration then occurs for a larger parameter range.

with a bargaining coefficient of $\omega \in (0,1)$ for D and $1-\omega$ for the seller. If firms reach an agreement, we denote the net payment from i to D by f_i.[20] If firms do not reach agreement, there is no payment and D's system is not included in the seller's product. The negotiation between a seller and D takes the outcome of D's negotiation with the other seller as given. This structure—known as "Nash-in-Nash" bargaining—is standard in models of vertical relations and wage bargaining (see Horn and Wolinsky, 1988; Dobson and Waterson, 2007; Inderst and Wey, 2007; Collard-Wexler, Gowrisankaran and Lee, 2019, for example).[21] If a seller is indifferent between adopting and not adopting, we assume that it adopts. The equilibrium concept for the two-stage game is subgame-perfect Nash equilibrium.

3 Baseline Analysis

We solve the game by backward induction. In the second stage (pricing), there are three possible outcomes from the first stage (negotiation): neither seller adopts D's system, only one seller adopts it, or both do.

If no seller adopts the system, product market competition works as in the classic Hotelling model, which leads to an equilibrium price $p^{NN} = t$, a quantity $q^{NN} = 1/2$, and a product-market revenue $R^{NN} = t/2$ for each seller, and zero complementary revenue for D. The superscript NN stands for a second-stage equilibrium in which both sellers do "*N*ot adopt" D's system.

If only one seller adopts, say 1, the two firms offer different gross utilities to consumers. The respective demands are

$$q_1(p_1,p_2) = \frac{1}{2} + \frac{p_2 - p_1 + \Delta}{2t} \quad \text{and} \quad q_2(p_2,p_1) = \frac{1}{2} + \frac{p_1 - p_2 - \Delta}{2t}.$$

Equilibrium prices are $p^{AN} = t + \Delta/3$ and $p^{NA} = t - \Delta/3$, where the superscript AN denotes that the seller under consideration *A*dopts the system whereas its rival does *N*ot adopt (the reverse holds for the superscript NA). Equilibrium quantities are $q^{AN} = (3t + \Delta)/(6t)$ and $q^{NA} = (3t - \Delta)/(6t)$,

[20] In Appendix C, we analyze the case in which the contract between between a seller and the developer consists of a two-part tariff (i.e., a fixed and a per-unit fee) instead of a fixed fee only. Following the vertical relations literature (see, e.g., O'Brien and Shaffer, 1992; Rey and Vergé, 2004), we assume that contracts are unobservable to rivals. (Observability does not matter with fixed fees only, as this fee does not affect product prices in equilibrium). We show that value migration occurs in that case as well and can even be more severe than with fixed fees.

[21] The Nash-in-Nash solution nests the main alternative protocols for bilateral negotiations. With $\omega = 1$, it coincides with the outcome in which D makes take-it-or-leave-it offers that each seller evaluates taking its rival's adoption as given, while with $\omega = 0$, it coincides with sellers making take-it-or-leave-it offers to D (see Collard-Wexler, Gowrisankaran and Lee, 2019 for a non-cooperative foundation of Nash-in-Nash bargaining).

leading to product-market revenues of

$$R^{AN} = \frac{(3t + \Delta)^2}{18t}, \qquad R^{NA} = \frac{(3t - \Delta)^2}{18t},$$

and a developer revenue of $\sigma\, q^{AN}$.

Finally, if both sellers adopt, product-market competition plays out in the same way as in the case in which no firm has reached an agreement. Thus, equilibrium quantities are $q^{AA} = 1/2$ and revenues are $R^{AA} = t/2$ for each firm, where the superscript AA represents that both firms Adopt. Developer revenue is σ because in this case all consumers have access to D's system.[22]

Before moving to the negotiation stage, we present a preliminary result on sellers' adoption incentives. Because of Nash bargaining, in each negotiation a firm obtains its outside option (its profit if no agreement is reached) plus a fraction of the bargaining surplus (the difference between the joint value created when the firms reach an agreement and the sum of their outside options). A necessary condition for two firms to reach an agreement is that the bargaining surplus is positive. Otherwise, the firms can generate larger profits without an agreement.

Suppose that i's rival, j, does not adopt D's system. If i and D reach an agreement, they generate a total value of $\sigma\, q^{AN} + R^{AN} - K$ (i.e., the sum of developer and product-market revenues net of the adoption cost K). If they fail to reach an agreement, each firm obtains its outside option, which is 0 for D and R^{NN} for i. The bargaining surplus is therefore

$$S^{AN} \equiv \sigma\, q^{AN} + R^{AN} - K - R^{NN},$$

and two firms will reach an agreement if and only if $S^{AN} \geq 0$.

Suppose next that j adopts D's system. If i and D reach an agreement, they generate a total value of $\sigma + R^{AA} - K$. If they do not reach an agreement, D obtains $\sigma\, q^{AN}$ and i obtains R^{NA}. The bargaining surplus is therefore

$$S^{AA} \equiv \sigma + R^{AA} - K - \sigma\, q^{AN} - R^{NA},$$

and they will reach an agreement if and only if $S^{AA} \geq 0$.

The effect of j's adoption on i's incentives to adopt is

$$S^{AA} - S^{AN} = \sigma \left(1 - 2q^{AN}\right) + \left[\left(R^{AA} + R^{NN}\right) - \left(R^{AN} + R^{NA}\right)\right] < 0.$$

[22] We note that due the assumption that the market is covered, equilibrium product prices and revenues do not depend on Δ when both sellers adopt. However, the industry revenue is still larger than in case in which no seller adopts because of the complementary revenue that the developer obtains.

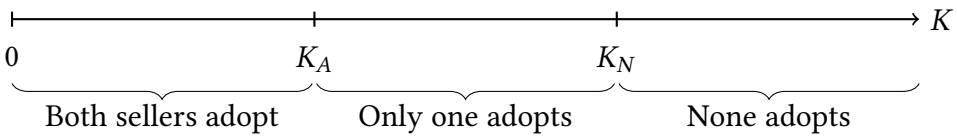


Figure 1: Equilibrium adoption as function of adoption cost K

The first term is negative because the market share of a firm with a quality advantage is higher than 1/2. The second term is negative because industry revenues are larger if firms are heterogeneous with respect to the values they offer to consumers compared to the case where they offer the same values. This holds true because such heterogeneity dampens competition between sellers. Since the difference $S^{AA} - S^{AN}$ is negative, adoption becomes more profitable if the rival does not adopt. Thus, *adoption decisions are strategic substitutes.* The intuition for this result is that adoption by j has two negative effects on the bargaining surplus between i and D: first, it lowers the increase in developer revenue from reaching an agreement, and, second, it lowers the increase in i's product-market revenue in case of an agreement.

The effect of an agreement on the bargaining surplus determines adoption incentives. In equilibrium, both sellers adopt if $S^{AA} \geq 0$, only one adopts if $S^{AN} \geq 0$ and $S^{AA} < 0$, and neither adopts if $S^{AN} < 0$. Lemma 1 expresses equilibrium adoption decisions in terms of thresholds

$$K_A \equiv \sigma\left(\frac{3t-\Delta}{6t}\right) + \Delta\left(\frac{6t-\Delta}{18t}\right) \quad \text{and} \quad K_N \equiv \sigma\left(\frac{3t+\Delta}{6t}\right) + \Delta\left(\frac{6t+\Delta}{18t}\right),$$

which are represented graphically in Figure 1.

Lemma 1 (Equilibrium adoption)**.** *There exist thresholds $K_A \geq 0$ and $K_N \geq K_A$ such that in equilibrium:*

(i) if $K \leq K_A$, both sellers adopt D's system;

(ii) if $K_A < K \leq K_N$, only one seller adopts D's system;

(iii) if $K > K_N$, no seller adopts D's system.

Proof. See Section A.1 in Appendix A.

Lemma 1 shows that if adoption costs are high, no seller adopts D's system; if adoption costs are low, both sellers adopt; and for intermediate costs, there is an asymmetric outcome in which only one of the sellers adopts. This intermediate range arises because adoption decisions are strategic substitutes, which implies that the cost threshold for both sellers to adopt is lower than the threshold for just one of them to adopt.

We next examine how adoption affects sellers' profits. Adopting D's system creates value in two ways: (i) it increases the value of seller's products to consumers, and (ii) it generates complementary revenues. However, adoption by a seller reduces its rival's demand and weakens its outside option in bargaining. The question is therefore whether sellers ultimately benefit from the existence of D's system.

To make this notion precise, we define value migration as the loss of sellers' profits arising from D's existence. Value migration can be defined individually or collectively. Let M_i be the *individual* value migration from seller i to D, and let M be the *total* value migration from both sellers to D. Individual value migration is the difference between a seller's profit when D is not present in the market and its profit when D is present. Collective value migration is the difference between sellers' joint profit without D and the joint profit when D is present. Formally,

$$M_i \equiv \frac{t}{2} - \pi_i \quad \text{and} \quad M \equiv t - (\pi_1 + \pi_2) = M_1 + M_2,$$

where π_i is the equilibrium profit of seller i.

If $M_i \geq 0$, i's profit decreases after D enters the market, and thus there is individual value migration. If $M_i < 0$, i gains from D's existence and there is no value migration. Likewise, if $M \geq 0$, there is aggregate value migration, and if $M < 0$, there is no aggregate value migration (although there may be individual value migration for one seller).

Consider the case in which both sellers adopt, i.e., $K \leq K_A$. Proposition 1 characterizes value migration based on the following threshold:

$$K_V \equiv \max\left\{\sigma\left(\frac{3t-\Delta}{6t}\right) - \frac{\omega}{1-\omega}\,\Delta\left(\frac{6t-\Delta}{18t}\right), 0\right\} < K_A.$$

Proposition 1. *Suppose $K \in [0, K_A]$ so that both sellers adopt in equilibrium. If $\Delta > 0$, there exists a threshold $K_V < K_A$ such that if $K \in (K_V, K_A]$, there is individual and aggregate value migration (i.e., $M_i > 0$ and $M > 0$). In this range, value migration M increases with product-improvement value Δ and developer bargaining power ω, decreases with per-user developer revenue σ, and increases (decreases) with horizontal differentiation t if $\frac{\Delta}{\sigma} > (<) \frac{3(1-\omega)}{\omega}$.*

Proof. See Section A.2 in Appendix A.

Proposition 1 shows that the introduction of D's system can indeed lead to value migration. The reason for this result is that, if both sellers adopt, the gains from system adoption are competed away, but sellers adopt to avoid having a competitive disadvantage. When negotiating with each seller, the developer extracts more value than it creates via its system—i.e., a Bertrand supertrap

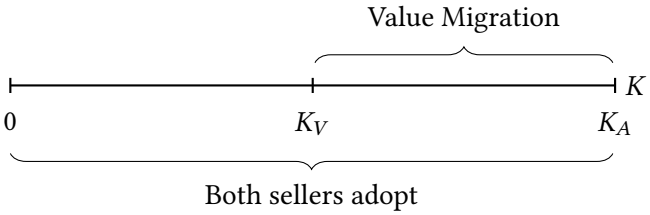


Figure 2: Value migration when both sellers adopt

occurs. Importantly, value migration may arise even if the adoption cost K is zero, because payments to D may be positive. Figure 2 illustrates the relation between thresholds K_A and K_V.

The comparative statics analysis shows that *value migration is more severe if the system creates value at the consumer level and less severe if it creates value at the developer level.* As consumer value Δ increases, sellers' outside options when not adopting become smaller, which increases value migration. Instead, if developer value σ increases, complementary revenues increase, and given that a part of this revenue is shared with sellers, value migration falls.

The analysis also shows that as ω increases, the share of the bargaining surplus captured by D rises, which increases value migration. Finally, the transportation cost t is a measure of the degree of differentiation between sellers' products. An increase in t therefore affects the difference in sellers' product-market revenues with and without an agreement and D's complementary revenue via the share of consumers using D's system in case it reaches an agreement with only one seller. For the first effect, value migration rises with t, whereas for the second effect, value migration falls with t. The overall effect therefore depends on Δ/σ, which is a measure of the importance of the first effect relative to the second.

It is important to note that sellers do not always lose from the existence of D's system. Although product-market revenues are unaffected, the system generates complementary revenues, and part of these revenues are transferred to sellers when they negotiate with D. If $K < K_V$, D makes a positive payment to sellers which more than compensates the adoption cost.

We also point out that the assumption of sellers competing on a Hotelling line is not crucial for our results. This assumption simplifies the exposition because the market is covered, which implies that adoption of D's system by one or both sellers does not lead to demand expansion. Our qualitative results also hold if adoption increases demand not only via stealing business from the rival, but also by gaining consumers who would not buy without system adoption.[23] Note, however, that for e.g. the automobile and the television market, the assumption that the choice of whether or not to adopt the system does not affect the overall size of the market but mainly sellers' market shares, is reasonable.

[23]We verified this, for instance, with the well-known linear demand system $p_1 = v - q_i - \gamma q_j$, $i, j = 1, 2$, $j \neq i$, where $\gamma \in (0, 1)$ is in inverse measure of the degree of product differentiation.

We next turn to the case in which only one seller adopts, i.e. $K \in (K_A, K_N]$. Proposition 2 characterizes value migration based on the following threshold:

$$\widetilde{K}_V \equiv \max\left\{K_A,\ \sigma\left(\frac{3t+\Delta}{6t}\right) - \frac{\omega}{1-\omega}\,\Delta\,\left(\frac{6t+\Delta}{18t}\right) + \frac{\Delta^2}{(1-\omega)9t}\right\}.$$

Proposition 2. *Suppose $K \in (K_A, K_N]$ so that only one seller adopts in equilibrium. The adopter benefits from the availability of D's system, whereas the non-adopter loses (i.e., there is individual value migration for the non-adopter). There exists a threshold $\widetilde{K}_V < K_N$ such that if $K \in (\widetilde{K}_V, K_N]$, there is aggregate value migration (i.e., $M > 0$). In this range, value migration M increases with horizontal differentiation t and developer bargaining power ω, decreases with per-user developer revenue σ, and increases (decreases) with product-improvement value Δ if $\Delta <$ (>) $[6\omega t - 3(1-\omega)\sigma]\,/[2(2-\omega)]$.*

Proof. See Section A.3 in Appendix A.

If only one seller adopts D's technology, the adopter is strictly better off relative to the no-adoption baseline model, while the non-adopter is worse off. Proposition 2 shows that the latter effect may dominate for the industry, resulting in collective value migration.

As in the case in which both sellers adopt, value migration decreases with σ, since a higher σ raises the surplus from agreement. In contrast to the previous case, the effect of Δ is non-monotonic: An increase in Δ raises the profit of the adopter but lowers the profit of the non-adopter. For Δ large enough, the first effect dominates, and value migration falls with Δ.

4 Strategic Responses to Value Migration

We now study how sellers can respond to the presence of an external technology provider to mitigate or avoid value migration. We consider two types of strategies. Under a *defend* strategy, sellers invest in internally-developed systems to strengthen their bargaining position vis-a-vis the developer. Under an *embrace* strategy, they invest in complementary dimensions that enhance the performance and monetization of the developer's system when it is integrated into their products.

4.1 Defend strategy

Suppose that each seller can invest in an own internal system, which can be used if the seller fails to reach an agreement with D. Given seller i chooses an investment y_i, the value of product i with

the internal system is $v_i = \underline{v} + y_i$. The investment cost is

$$\frac{1}{2\lambda_y} y_i^2,$$

where $\lambda_y > 0$ measures the effectiveness of investment. We assume that a seller does not obtain complementary revenues from the use of its own system. As in the baseline model, D captures complementary revenues from a seller's users only if its system is used.

The timing is as follows. In the first stage, each seller chooses its investment y_i. In the second stage, the game proceeds as in the baseline model, with sellers negotiating with D and subsequently competing in prices.

To focus on the case in which the development of an internal system is used to improve a seller's bargaining position, we assume that λ_y and K are small enough, so that adoption of D's system is optimal for both firms in equilibrium. The condition on λ_y places an upper bound on the seller's incentive to invest in its own system. The restriction on K ensures that adoption costs are sufficiently low. Formally, we assume that λ_y is below a threshold $\bar{\lambda}_y$, which we give in Section A.4 of the Appendix. There, we show that, for any $\lambda_y \leq \bar{\lambda}_y$, there exists a threshold $K_A^y > 0$ such that both sellers adopt in equilibrium whenever $K \leq K_A^y$.

In an adoption equilibrium, seller i's payoff is

$$\pi^{AA}(y_i) = R^{NA}(y_i) + (1-\omega)\, S^{AA}(y_i) - \frac{y_i^2}{2\lambda_y},$$

where $R^{NA}(y_i) = (3t + y_i - \Delta)^2 / (18t)$ is its downstream revenue in case it does not adopt (and uses its own system) whereas the rival adopts. Therefore, $R^{NA}(y_i)$ constitutes the seller's outside option. S^{AA} is the bargaining surplus to be shared between seller i and D and is given by

$$S^{AA}(y_i) = \frac{t}{2} + \sigma - K - R^{NA}(y_i) - \sigma q^{AN}(y_i),$$

where $q^{AN}(y_i) = 1/2 + (\Delta - y_i)/(6t)$ is the quantity sold by seller $-i$ in case of no adoption by seller i. The optimal investment solves $\max_{y_i \geq 0} \pi^{AA}(y_i)$. In the symmetric equilibrium, we obtain

$$y^{AA}(\lambda_y) = \frac{\lambda_y \left[6\omega t + 3(1-\omega)\sigma - 2\omega\Delta\right]}{2(9t - \omega\lambda_y)}.$$

The equilibrium investment level $y^{AA}(\lambda_y)$ is strictly positive for all $\omega \in (0,1)$, that is, even if sellers' bargaining power goes to zero or one. In case their bargaining power is close to zero, this result is perhaps expected, as an investment in an own system increases a seller's outside option in the negotiation with D. However, in case sellers' bargaining power approaches one, they can

appropriate almost all surplus in the negotiation, and such an increase in the outside option does not raise the surplus. Investment in an own system is nevertheless profitable because it lowers D's outside option. This is due to the fact that D's complementary revenue when not reaching an agreement with seller i depends on the quantity of seller $-i$, which is falling in case seller i offers a higher value to consumers.

To study value migration, we use the same concept as in the baseline model, and compare sellers' equilibrium profits with the profits they would obtain if D would not be present. Note that in this case, sellers are able to invest to develop their own systems. Without D, given investments, equilibrium revenues are then $R_i(y_i, y_{-i}) = (3t + y_i - y_{-i})^2/(18t)$, and seller i's optimal investment solve

$$\max_{y_i \geq 0} \; R_i(y_i, y_{-i}) - \frac{1}{2\lambda_y} y_i^2,$$

which leads to equilibrium investments of $y^{\not D} = \lambda_y/3$ and equilibrium profits of $\pi^{\not D} = t/2 - \lambda_y/18$. Since equilibrium profits fall in λ_y, the possibility to invest harms sellers, because it places them in a prisoners' dilemma: sellers compete away product improvements, which implies that investments lead to business stealing only, and joint profits would be higher without investment. Value migration is then given by $\widehat{M} \equiv 2\,\pi^{\not D} - 2\pi(y^*)$, where $\pi(y^*)$ is the equilibrium profit of each seller.

As in the case of Proposition 1, we can determine the conditions for value migration to occur in case firms have the possibility to invest (i.e., $\widehat{M} > 0$). As we show in part (ii) of Proposition 3, this occurs if and only if $K > K_V^y$, where

$$K_V^y \;\equiv\; \max\left\{ \frac{36t(3(1-\omega)(3t-\Delta)\sigma - \omega\Delta(6t-\Delta)) + \lambda_y\left(36t^2(1+\omega^2) + 9\sigma^2(1-\omega)^2\right) - 4\lambda_y^2 t\omega}{72t(9t-\lambda_y\omega)(1-\omega)}, 0 \right\}.$$

Another benchmark, which we consider in part (iii) of the proposition, is the one in which both sellers obtain $t/2$ when D is not present (i.e., the profits without D in the benchmark model). For this part, we use the threshold K_B^y given by:

$$K_B^y \equiv \;\max\left\{ \frac{\left((36\sigma(1-\omega) + 4\lambda_y\omega^2 - 24\omega\Delta)t^2 - (12\sigma\Delta(1-\omega) - 4\omega\Delta^2)t + \lambda_y\sigma^2(1-\omega)^2\right)}{8t(9t-\lambda_y\omega)(1-\omega)}, 0 \right\}.$$

We can then state the following results:

Proposition 3. *If both sellers adopt in equilibrium (i.e., $K \leq K_A^y$), the following holds:*
(i) The existence of a defend strategy benefits sellers (seller's equilibrium profits increase with λ_y).
(ii) In case value migration occurs, the defend strategy strictly lowers it. Moreover, $K_V^y \geq K_V$ for all $\lambda_y > 0$, that is, there exists a range of K such that value migration occurs without the defend strategy but not with the strategy.

(iii) Finally, if $K \leq K_B^y$, then sellers' profits with a defend strategy are larger than $t/2$ (the profit without D and internal systems).

Proof. See Section A.4 in Appendix A.

The proposition first states that the possibility to invest in an own system raises seller profits in an equilibrium in which both sellers adopt D's system. If only one seller had the investment option, this result would be immediate (by revealed preference, if the seller chooses a positive investment, it must be better off). With symmetric investment opportunities, however, the conclusion is not automatic. When D is absent, sellers' investments mainly generate business stealing and are competed away in the product market. As a result, seller profits would fall with λ_y in the benchmark without D. Instead, when D is present, the investment in internal systems benefits sellers.

This result arises for two reasons. First, investing in an own system, despite the fact that it does not generate complementary revenues, increases a seller's outside option. In case i does not reach an agreement with D but $-i$ does, the reduction in i's demand is smaller. This implies that the seller can claim a larger share in the negotiation with D. Second, the outside option of D is also lower. Specifically, if D only reaches an agreement with $-i$, then i's demand, and therefore the data revenue generated for D, is smaller than in a situation in which i does not possess its own system. Taken together, these effects help sellers obtain a larger fraction in the negotiation with D, thereby reducing value migration. The main difference with respect to the benchmark case is therefore that, as both sellers adopt D's system in equilibrium, an increase in y_i only strengthens seller i's bargaining position with D, but does not negatively affect seller $-i$'s profit.

Part (ii) follows from (i). Since sellers' equilibrium profits increase in λ_y, if value migration occurs,[24] it is reduced and also arises for a smaller range of parameters.

Part (iii) shows that sellers' profits with the defend strategy can even be larger than in the case without adoption in the benchmark model. This allows us to derive a strategic implication about the presence of D. In particular, this presence is essential for the success of the investment in an own system and therefore changes its strategic function. It is evident from the statement that, without D, the possibility to invest in an own system is to the detriment of sellers as profits are dissipated via competition, whereas the possibility benefits sellers once D is present. Therefore, the possibility to invest allows sellers to *benefit* from the presence of the developer in a situation in which they would have been *worse off* without this possibility.[25] In fact, the opportunity to invest in an own system allows sellers to participate to such a large extent at the value created

[24] As we show in the proof of Proposition 3, value migration occurs if $\lambda_y < 3\Delta$.

[25] Mathematically, in the former case profits with the investment possibility are below $t/2$, but in the latter case, they are above $t/2$.

by D's system that it overturns the prisoners' dilemma situation that would arise without D's presence.

Interestingly, the possibility to invest in an own system *creates* value for consumers if there is no (superior) outside system, but, due to the dissipation via competition, does not allow the sellers to *appropriate* this value. Instead, with the presence of a superior system, the investment possibility does not create value, but allows sellers to appropriate part of the value of the outside system. This appropriated value can be so large that the strategy of own investment benefits them.

The preceding discussion focuses on the profits of the sellers. Since the possibility to invest in an own system improves the sellers' bargaining position against the developer, a potential conclusion is that the developer is hurt from this possibility. Perhaps surprisingly, this is not necessarily the case. Defining

$$\tilde{\lambda}_y \equiv \frac{9t\left(2(1+\omega)(3t-\Delta)+3\sigma(1-\omega)\right)\left(2\Delta+3\sigma-6t\right)}{9\sigma^2(1-\omega)+12\sigma\omega(3t-\Delta)-4\omega(3t-\Delta)^2},$$

we obtain the following result:

Proposition 4. *For $\lambda_y \in [0, \tilde{\lambda}_y]$, the sellers' defend strategy increases the adoption region (i.e., $K_A^y \geq K_A$) if and only if $\sigma > 2(3t-\Delta)/3$.*[26] *In that case, there exists a $\tilde{K} > K_A$ and $\hat{\lambda}_y \leq \tilde{\lambda}_y$, such that for $K \in [K_A, \tilde{K}]$, $\lambda_y \in [0, \hat{\lambda}_y]$, and $\Delta < 3\sigma(1-\omega)/\omega$, D benefits from the sellers' defend strategy.*

Proof. See Section A.5 in Appendix A.

The intuition behind this result is as follows: First, the possibility to invest in own system can lead to a decrease or an increase in the adoption region. The former occurs if such an investment is particularly effective, so that sellers prefer to use the own system instead of adopting that of the developer. Formally, in the baseline model, adoption occurs for all $K \leq K_A$, whereas with the investment possibility adoption in the region $K \leq K_A$ only occurs if additionally $\lambda_y \leq \bar{\lambda}_y$.

However, the adoption region can also increase in case sellers can invest in an own system. The precise range for this to occur is given in Proposition 4. The reason is that sellers obtain a larger share of the negotiation surplus. In particular, if the complementary revenue of D is sufficiently high (i.e., $\sigma > 2(3t-\Delta)/3$), sellers benefit more from adopting D's system as compared to the baseline model. This is due to the diminished outside option of D, which implies that sellers receive a larger share of this surplus. Thus, the possibility to defend via an own system can even raise adoption incentives.

As the region in which both sellers adopt may increase, the defend strategy can also benefit the developer. In particular, while the share of the bargaining surplus for the developer always

[26] Indeed, $\tilde{\lambda}_y < \bar{\lambda}_y$ for $\sigma > 2(3t-\Delta)/3$.

shrinks, there is now a countervailing force, which is that it is adopted by both sellers instead of only one. This effect can be sufficiently large so that the developer in facts benefits.

As we show in the proof of Proposition 4, this occurs if K is slightly above K_A and Δ is relatively small. The intuition for these thresholds is that, first, if K is relatively small, the surplus in case both sellers adopt is rather large, and, second, if Δ is relatively small, D adds rather little value in case of single adoption. We note, however, that the condition for Δ to be sufficiently small is only sufficient and D may benefit from the possibility of a defend strategy even for larger values of Δ.

4.2 Embrace strategy

We now study an alternative response: to *embrace* the developer's technology by investing to increase value creation within the ecosystem. In particular, suppose each seller i can choose investments (x_i, r_i), such that, if the seller adopts D's system, the value of its product to consumers becomes $v_i = \underline{v} + \Delta + x_i$, while the developer obtains complementary revenues of $\sigma + r_i$ for each consumer who purchases seller i's product. To focus on the strategic aspects of the investments, we assume an additive relationship between the costs of the two investments. In particular, the investment cost function is

$$\frac{1}{2\lambda_x}x_i^2 + \frac{1}{2\lambda_r}r_i^2,$$

with $\lambda_x, \lambda_r > 0$ measuring the effectiveness of investments. To ensure interior solutions and that second-order conditions are fulfilled, we assume that the transport-cost parameter t is sufficiently large relative to λ_x and λ_r. Concretely, $t > \lambda_x(1-\omega)/9 + \Delta$ and $t^2 > \lambda_x(1-\omega)\left[4t + \lambda_r(1-\omega)\right]/36$.

We consider a timing in which sellers choose investments in the first stage, and then the game proceeds as in the baseline model. As in the previous subsection, we focus on the case in which both sellers adopt in equilibrium, which implies that K is below a certain threshold. We provide the concrete value in the proof of Proposition 5 in the appendix.

Seller i's payoff in an adoption equilibrium is

$$\pi^{AA}(x_i, r_i, x_{-i}, r_{-i}) = R^{NA}(x_{-i}) + (1-\omega)\, S^{AA}(x_i, r_i, x_{-i}, r_{-i}) - \frac{1}{2\lambda_x}x_i^2 - \frac{1}{2\lambda_r}r_i^2,$$

where $R^{NA}(x_{-i}) = (3t - \Delta - x_{-i})^2/(18t)$ is seller i's downstream revenue if it does not adopt, and

$$S^{AA}(x_i, r_i, x_{-i}, r_{-i}) = \frac{(3t + x_i - x_{-i})^2}{18t} + \sigma + \left[r_i\left(\frac{1}{2} + \frac{x_i - x_{-i}}{6t}\right) + r_{-i}\left(\frac{1}{2} + \frac{x_{-i} - x_i}{6t}\right)\right] -$$

$$-K - R^{NA}(x_{-i}) - (\sigma + r_{-i})q^{AN}(x_{-i}),$$

is the bargaining surplus to be shared between seller i and D, where $q^{AN}(x_{-i}) = 1/2 + (\Delta + x_{-i})/(6t)$.

In the first stage, each seller chooses investments $x_i \geq 0, r_i \geq 0$ to maximize $\pi^{AA}(x_i, r_i, x_{-i}, r_{-i})$.

It is straightforward to show that the two investments x_i and r_i are strategic complements. The intuition is that raising the quality of D's system increases a seller's demand, which in turn makes investment in the complementary revenue more profitable, as D obtains it for a larger number of consumers. Instead, if the rival seller invests more in the improvement of D's system, the opposite effect occurs as then the rival receives more demand. Therefore, r_i and x_j are strategic substitutes. The same holds for x_i and x_j, as the marginal benefit from investment in product value is lower if the rival's product is more valuable as well.[27]

Despite these strategic interactions, the equilibrium investments are remarkably simple and given by

$$x^* = \frac{(1-\omega)\lambda_x}{3} \quad \text{and} \quad r^* = \frac{(1-\omega)\lambda_r}{2}.$$

Both investments are decreasing in the bargaining power of the developer, ω, as this implies that sellers can appropriate less value of their investments, and are increasing in the effectiveness of the respective investment, λ_x and λ_r. Despite this similarity, the next proposition shows that their effects on sellers' profits are sharply different:

Proposition 5. *An increase in λ_x decreases sellers' equilibrium profits, that is, embrace investments that increase consumer-side value reduce sellers' value capture.*
By contrast, an increase in λ_r increases sellers' equilibrium profits if and only if

$$\Delta + x^* = \Delta + \frac{(1-\omega)\lambda_x}{3} < \frac{3t}{2},$$

that is, embrace investments that increase the developer's complementary revenues raise sellers' value capture if and only if the consumer-side value ($\Delta + x^*$) generated by the system is sufficiently small.

Proof. See Section A.6 in Appendix A.

As λ_x increases, sellers invest more to improve the system's value for consumers. However, these improvements are competed away in the product market. Moreover, the increase in the rival seller's investment lowers each seller's outside option and raises the developer's one, which implies that the developer is able to appropriate a larger share of the surplus in the negotiation. This leads to a reduction in sellers' profits. Therefore, such investments lead to a Bertrand supertrap on top of that in the baseline model.

By contrast, investments that increase the developer's complementary revenues have an ambiguous effect. If the consumer-side value of the system including equilibrium investments,

[27] There is no direct relation between r_i and r_{-i} because if D obtains a larger complementary revenue from $-i$, this has no direct effect on the revenue from i.

$\Delta + x^*$, is sufficiently small, an increase in λ_r raises sellers' profits. In this case, the additional complementary revenue expands the total surplus generated under adoption without substantially intensifying product-market competition. However, if $\Delta + x^*$ is large, increases in λ_r primarily strengthen the developer's bargaining position, as a seller that does not adopt is confronted with a developer that has a high outside option. This allows the latter to appropriate a larger share of the surplus, thereby reducing sellers' profits.

The implications for value migration follow directly from the effects on equilibrium profits. Since sellers' profits in the absence of the developer are unaffected by embrace investments, any change in profits under adoption translates one-to-one into a change in value migration. In particular, investments in consumer-side value always increase value migration, as they reduce sellers' profits. By contrast, investments in developer-side revenues reduce value migration if $\Delta + x^* < 3t/2$, and increase it otherwise. Thus, while some embrace strategies can mitigate or even avoid value migration, others may exacerbate it.

As in the previous section, the introduction of embrace strategies has an ambiguous effect on the likelihood of adoption. On one hand, the ability to invest in complementary dimensions increases the total value created when the developer's technology is adopted, which tends to make adoption more attractive. On the other hand, this effect is offset by two countervailing forces. First, as both sellers can enhance the value of the developer's system, the relative advantage from adoption is reduced, because improvements in product quality are at least partly competed away. Second, stronger rival-side investments increase the developer's outside option in bargaining, which weakens each seller's position and reduces its share of the surplus. As a result, the net effect of embrace strategies on adoption incentives is not clear-cut: while they increase the value created under adoption, they also intensify competition and shift bargaining power to the developer.

4.3 Defend and embrace strategies

Finally, we examine the interaction between the two types of strategic responses. Suppose each seller i can choose investments (y_i, x_i, r_i) such that, if the seller adopts D's system, the value of its product to consumers becomes $v_i = \underline{v} + \Delta + x_i$ and the developer captures complementary revenues of $\sigma + r_i$ from i's consumers, while if seller i relies on its own system instead, the value of its product is $v_i = \underline{v} + y_i$. In line with the previous analysis, investment costs are

$$\frac{1}{2\lambda_y} y_i^2 + \frac{1}{2\lambda_x} x_i^2 + \frac{1}{2\lambda_r} r_i^2.$$

As in the previous sections, we consider a timing in which sellers first choose investments and then the game proceeds as in the baseline model, and focus on parameters such that both sellers

adopt in equilibrium. To gain an understanding of the strategic relation between the two types of investments, we focus in the remainder of this section on the interaction between the defend investments and the rival's embrace investments.[28]

First, an increase in x_{-i} reduces the optimal defend investment y_i, that is, x_{-i} is a strategic substitute to y_i. The reason is that an increase in x_{-i} lowers the effect of an increase in y_i on the product-market revenue of seller i in case of disagreement. This in turn diminishes i's outside option in its negotiation with D, thereby leading to a decrease in the optimal defend investment. This result arises because product-market revenues are convex in valuation differences.

Second, an increase in r_{-i} increases the optimal defend investment y_i, that is, r_{-i} is a strategic complement to y_i. An increase in r_{-i} raises the value of seller $-i$'s consumers for D. Thus, an increase in y_i leads to a larger loss for D if it does not reach an agreement with i because fewer consumers then buy from seller $-i$. This induces i to increase its defend investment. These effects are behind the results in the following proposition.

Proposition 6. *Equilibrium defend investments decrease with λ_x and increase with λ_r. Moreover, $\left(\partial^2\pi^*\right)/\left(\partial\lambda_y\partial\lambda_x\right) < 0$ and $\left(\partial^2\pi^*\right)/\left(\partial\lambda_y\partial\lambda_r\right) > 0$, that is, the benefit of the defend strategy for sellers falls with λ_x and rises with λ_r.*

Proof. See Section A.7 in Appendix A.

Given the discussion preceding Proposition 6, the intuition for the two results is easy to grasp. First, if both sellers have the option to invest to make D's system more valuable, they will do so in equilibrium. However, this renders the defend strategy less effective in the sense that as λ_y increases—i.e., the defend strategy becomes more important—the profit gain for sellers and also the equilibrium defend investment are lower the larger is λ_x.

By contrast, in equilibrium both sellers also invest to raise D's complementary revenue, but this makes the defend strategy even more effective. In other words, as λ_y increases, sellers' profits rise more when λ_r is larger. The reason is that greater importance of λ_r not only increases the joint surplus but, via the effect described above, helps sellers to lower D's outside option via investing more in the own system.

5 Systems competition

We have so far focused on the case of a single developer. However, in many markets sellers can integrate multiple developer systems into their products, and these systems may differ in the value they provide to consumers. For example, in the car industry, manufacturers may include Apple's

[28] As the model in this section is a combination of the two previous ones, several results that do not relate to the interaction of the investment types, indeed carry over.

CarPlay, Google's Android Auto, or both. In this section, we study how competition between such systems affects value creation and value migration.

Suppose that two developers, A, B, provide systems that can improve sellers' products. Sellers can include both systems in their products. To focus on the new effects that competition between developers brings, we assume that the adoption cost of either system is zero (i.e., $K = 0$).

There are three types of consumers: a mass $\alpha \geq 0$ of consumers only values A's system, a mass $\beta \geq 0$ only values B's system, and a mass $\gamma = 1 - \alpha - \beta \geq 0$ values either system. We refer to the former two types of consumers as captive consumers, and to the latter type as free consumers. The utility of captive consumers increases by Δ only if their preferred system is included in a seller's product. The utility of free consumers increases by Δ if either system is included (and does not increase further if a second system is included).[29]

An example of this setting is given by the automobile industry, where iPhone and Android users can only interact with a compatible entertainment system (e.g., an iPhone user does not benefit from having access to Android Auto). Free consumers represent individuals who can switch systems or purchase a new device after buying the car. In other industries, they may represent multi-homing consumers.

We assume $\Delta < t$ to guarantee interior solutions. The remaining details of the model are as in Section 2. In particular, developers do not differ in terms of product enhancement (Δ), complementary revenues (σ), or bargaining power (ω). If a product has both systems available, we assume that free consumers purchasing this product split evenly between the two systems, so each developer obtains 1/2 of the complementary revenue related to these consumers.

The timing is as follows. In the first stage, each seller i negotiates independently with each developer j about the inclusion of j's system in i's product. In the second stage, the outcomes of the negotiations are publicly observed and each seller chooses its price. Each consumer then decides from which firm to buy.

As in the baseline model, we assume negotiations between sellers and developers follow the Nash-in-Nash framework. In particular, when negotiating the terms of their supply contract, seller i and developer j take the outcomes of the other negotiations as given, and their respective payoffs are given by the Nash bargaining solution.

We solve the model in detail in Section A.8 of Appendix A. Here, we present the main intuitions and conclusions. Given that $K = 0$, both sellers adopt both systems in equilibrium. We focus on how value is distributed among sellers and developers, and how this distribution is affected by market characteristics.

In particular, our analysis shows that the effect of systems competition on sellers depends on the interplay between two forces: market *fragmentation* and *competitive intensity*. Fragmentation

[29] For all three types, consumers are uniformly distributed along the unit segment.

refers to how consumers are distributed across systems in equilibrium. To formalize this notion, we define the equilibrium market share of systems A and B as

$$s_A \equiv \alpha + \frac{\gamma}{2} \quad \text{and} \quad s_B \equiv \beta + \frac{\gamma}{2} = 1 - s_A,$$

respectively. These market shares combine a system's captive consumers and half of the free consumers (who split evenly across systems in equilibrium). Fragmentation is maximal when $s_A = 1/2$ and decreases as s_A approaches 0 or 1. Competitive intensity, in turn, is captured by the share of free consumers γ: for any given level of fragmentation, a larger γ means that more consumers can be reached through either system, thereby increasing the degree to which the systems compete head-to-head.

We first study the role of competitive intensity holding the degree of fragmentation constant, that is, we consider a change in γ, keeping s_A fixed.[30]

Proposition 7. *For $s_A \in (0,1)$, there exists a threshold $\hat{\gamma}(s_A) \in (0,1)$ such that value migration is more severe with two developers as compared to the case with one developer if and only if $\gamma < \hat{\gamma}(s_A)$. Thus, systems competition benefits sellers if and only if the share of free consumers is sufficiently large.*

Proof. See Section A.8 in Appendix A.

The proposition shows that, perhaps counter-intuitively, the presence of multiple developers does not always benefit sellers. The existence of multiple developers has two effects. On one hand, free consumers weaken developers' bargaining positions, because if a developer and a seller fail to reach an agreement, the seller can still increase the valuations of free consumers by including the other system. On the other hand, each developer is indispensable for the seller to increase the product's valuation for the developer's captive users. Because product-market revenues are convex in quality differences, negotiating with two smaller developers over a given quality improvement is worse for sellers than negotiating with one larger developer.

The share of free consumers determines which force dominates. If γ is large, the first force prevails, and sellers benefit from the existence of multiple developers. In the extreme case where $\gamma = 1$, developers compete head-to-head and the value they create accrues entirely to sellers. Instead, if γ is small, the second force dominates and sellers obtain lower profits with multiple systems, thereby exacerbating the problem of value migration.

[30] Since $\gamma = 1 - \alpha - \beta$, a change in γ necessarily affects also α and/or β. To disentangle the effect of competitive intensity from fragmentation, we consider an adjustment of α and β in response to a change in γ so that market shares stay constant. We note that e.g. holding α or β fixed and adjusting only one other variable yields analogous results.

We next turn to the role of fragmentation, holding competitive intensity fixed. As before, let $\hat{\gamma}(s_A) \in (0,1)$ denote the threshold such that value migration is more severe with two developers than with one if $\gamma < \hat{\gamma}(s_A)$. The next proposition characterizes how fragmentation shapes this threshold:

Proposition 8. *The threshold value $\hat{\gamma}(s_A)$ increases with the degree of fragmentation: It is largest if $s_A = 1/2$ and falls as s_A moves toward 0 or 1.*

Proof. See Section A.9 in Appendix A.

Keeping competitive intensity fixed, an increase in fragmentation decreases sellers' profits. This result is based on two effects. First, because product-market revenues exhibit increasing returns to quality differences, sellers are worse off negotiating with more symmetric developers than with more asymmetric ones, as they can keep a smaller share of the surplus. Second, if the share of users is rather balanced between systems, the impact of a disagreement between seller i and the developer of the system on the seller's product price p_i is also not particularly large. This implies that the system retains a rather large share of consumers via its agreement with seller j. As a consequence, the outside option of the developer is relatively large, and sellers therefore obtain a smaller share of the surplus as compared to the case in which one system has a large share of users.

Figure 3 illustrates the regions of the (s_A, γ) space in which sellers gain or lose compared to the single-developer benchmark. By construction, the feasible set must satisfy $\frac{\gamma}{2} \leq s_A \leq 1 - \frac{\gamma}{2}$, which defines the triangular region of admissible (s_A, γ) combinations.

Summarizing the previous results, fragmentation shifts bargaining power toward developers, whereas competitive intensity shifts bargaining power toward sellers. As a result, sellers benefit from systems competition only if the competitive intensity is sufficiently high to offset the additional bargaining pressure created by fragmentation. If the share of free consumers is small, sellers prefer to negotiate with a single large developer rather than with multiple smaller ones.

Overall, our results contradict the common view that system competition necessarily benefits complementors (i.e., sellers in our case): its effects depend on the structure of demand, and may harm complementors if consumers are not sufficiently mobile across systems.

6 Conclusion and Managerial Implications

This paper studies how firms can benefit from a product-enhancing technology without ceding an excessive share of the resulting value to its developer. We first show that the occurrence and extent of value migration depends crucially on *where* in the ecosystem value is created. In particular, if the

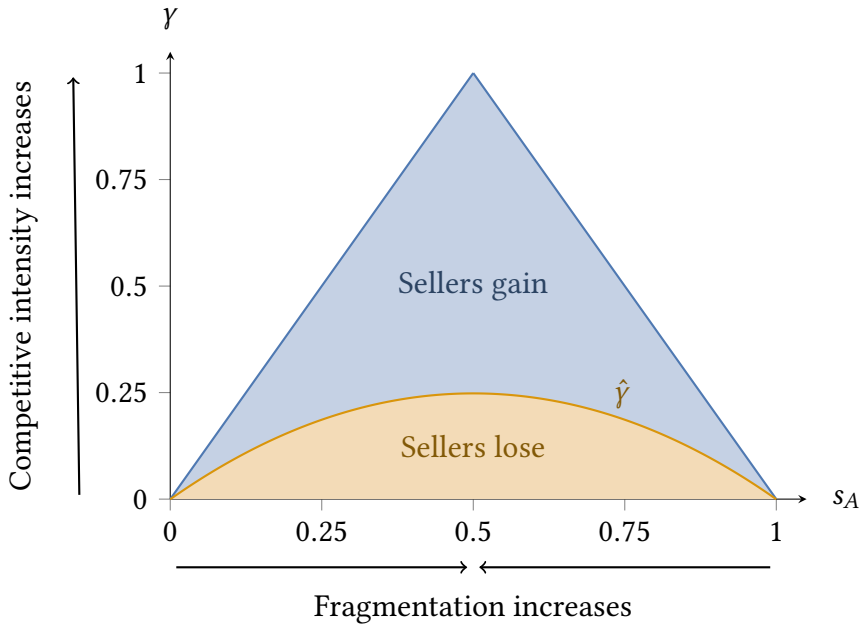


Figure 3: Regions in which sellers gain and lose from systems competition

technology mainly creates value by improving products and benefiting consumers, competition between sellers may render adoption strategically necessary, which allows the developer to capture a disproportionate share of the surplus, thereby leading to value migration. Instead, if the technology mainly creates value by allowing the developer to obtain complementary revenues, value migration is less of a problem.

We analyze two broad classes of strategies through which firms may respond to value migration. First, defend strategies—i.e., developing an internal alternative to the developer's technology—improve the sellers' outside options in negotiations with the developer and reduce value migration. In fact, developing an own system is only an effective strategy due to the existence of the external technology but would be profit-reducing without it. As the strategy allows sellers to capture a larger part of the created value, such an investment may also increase the likelihood of adoption and, perhaps surprisingly, even benefit the technology developer. Second, embrace strategies, which improve the developer's system, have heterogeneous effects. Investments that increase consumer value intensify competition in the product market and thereby exacerbate value migration. By contrast, investments that increase complementary revenues expand the bilateral surplus, but also raise the outside option of a developer in each negotiation. The former effect, however, dominates if the consumer-side value of the system is relatively small. Such investments then mitigate value migration. Moreover, they are a strategic complement to the defend strategy.

We also study competition between multiple technology developers. Contrary to the common view that developer competition benefits adopters, we show that the presence of multiple devel-

opers does not always reduce value migration. When consumer demand is fragmented across technologies, sellers must negotiate with multiple developers to serve all consumers, which can increase the developers' bargaining positions and exacerbate value migration. The benefits of developer competition therefore depend on the share of consumers who value multiple systems and on the distribution of consumers across technologies.

Understanding how technological complementarities reshape bargaining and value capture is increasingly important in industries in which digital platforms mediate interactions between producers and consumers. Managers therefore face the challenge of deciding not only whether to adopt external technologies but also how to organize their relationships with technology providers. By highlighting the mechanisms through which enabling technologies affect bargaining positions and value capture, our framework offers several managerial implications.

First, firms typically collaborate closely with technology providers to integrate external technologies into their products. Our analysis suggests that such collaborations are most beneficial when they focus on expanding complementary sources of value, such as data, digital services, or other ancillary revenues, rather than exclusively on further improving the final product. The reason is that improvements in product quality may be competed away, whereas complementary revenues are largely insulated from such competition.

Second, collaboration with a technology provider can be particularly effective when combined with investments in an in-house alternative. At first sight, these strategies may appear contradictory because one emphasizes cooperation while the other strengthens independence. However, an internal technology need not replace the external one to be valuable. Even if it is ultimately not used, it improves the firm's outside option in negotiations with the technology provider and thereby enables the firm to capture a larger share of the value created through collaboration.

Third, managers should be aware that competition between developers does not necessarily strengthen their bargaining position. When consumers are attached to different technology ecosystems, firms may need to negotiate with multiple providers in order to serve the market effectively. Fragmentation can then weaken rather than strengthen the firm's bargaining position. In such a situation, it could be profitable to have one developer as the main collaborator to lower the extent of fragmentation.

We conclude by outlining two directions for future research. First, our analysis considers symmetric sellers, implying that value migration affects both adopters in the same way if they adopt the technology. Extending the framework to heterogeneous firms—for example, firms that differ in product quality or customer base—allows to examine how value migration varies across firms and whether the optimal balance between defend and embrace strategies depends on a firm's competitive position. It could shed light on whether larger firms are better able to resist value migration than smaller rivals.

Second, our analysis focuses on the strategic responses of adopters. Another promising direction is to examine the strategic choices of technology developers. Developers may invest in technologies that increase product quality or complementary revenues, design alternative pricing and licensing schemes, or negotiate more sophisticated contracts, such as exclusivity arrangements.[31] Studying how these strategic choices interact with adopters' responses could deepen our understanding of value creation and value appropriation in digital ecosystems.

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[31] Our analysis of exclusive contracting in Appendix B is a first step in this direction.

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Appendix

A Proofs of lemmas and propositions

A.1 Proof of Lemma 1.

From the expressions derived in the text, the bargaining surpluses can be written as

$$S^{AN} = K_N - K \quad \text{and} \quad S^{AA} = K_A - K,$$

where

$$K_A \equiv \sigma\left(\frac{3t-\Delta}{6t}\right) + \Delta\left(\frac{6t-\Delta}{18t}\right) \quad \text{and} \quad K_N \equiv \sigma\left(\frac{3t+\Delta}{6t}\right) + \Delta\left(\frac{6t+\Delta}{18t}\right).$$

Moreover, $K_N \geq K_A$ since

$$K_N - K_A = \frac{\sigma\Delta}{3t} + \frac{\Delta^2}{9t} \geq 0.$$

An agreement is reached if and only if the corresponding surplus is non-negative. Therefore:

(i) if $K \leq K_A$, then $S^{AA} \geq 0$ and both sellers adopt;

(ii) if $K_A < K \leq K_N$, then $S^{AA} < 0$ but $S^{AN} \geq 0$, so exactly one seller adopts;

(iii) if $K > K_N$, then $S^{AN} < 0$, so no seller adopts.

A.2 Proof of Proposition 1.

Suppose $K \in [0, K_A]$. From Lemma 1, both sellers adopts in equilibrium. The equilibrium payoff of each seller is then

$$\pi^{AA} = \frac{(3t-\Delta)^2}{18t} + (1-\omega)\left[\sigma + \frac{t}{2} - K - \sigma\left(\frac{1}{2} + \frac{\Delta}{6t}\right) - \frac{(3t-\Delta)^2}{18t}\right].$$

Since a seller obtains a profit of $t/2$ without D's existence,

$$M_i = \frac{t}{2} - \frac{(3t-\Delta)^2}{18t} - (1-\omega)\left[\sigma + \frac{t}{2} - K - \sigma\left(\frac{1}{2} + \frac{\Delta}{6t}\right) - \frac{(3t-\Delta)^2}{18t}\right].$$

Because the equilibrium is symmetric, the thresholds for individual and total value migration coincide. Setting M_i equal to zero and solving for K then yields the threshold K_V. If $\Delta > 0$, the threshold is strictly smaller than K_A. Given that M increases with K, for $K > K_V$, there is individual and total value migration.

Inspection of the formula for M_i shows that value migration decreases with σ and increases with ω. Differentiating with respect to Δ we obtain

$$\frac{\partial M_i}{\partial \Delta} = \frac{2\omega(3t-\Delta)+3(1-\omega)\sigma}{18t} > 0,$$

so M_i increases with Δ. Differentiating with respect to t we obtain

$$\frac{\partial M_i}{\partial t} = \Delta \frac{\omega\Delta - 3(1-\omega)\sigma}{18t^2},$$

which is positive if

$$\frac{\Delta}{\sigma} > \frac{3(1-\omega)}{\omega},$$

and negative if the inequality is reversed.

A.3 Proof of Proposition 2.

Suppose $K \in (K_A, K_N]$, which implies $\Delta > 0$ (otherwise $K_A = K_N$). From Lemma 1, only one seller adopts in equilibrium. The adopter's profit is

$$\pi^{AN} = \frac{t}{2} + (1-\omega)\left[\sigma\left(\frac{1}{2}+\frac{\Delta}{6t}\right) + \frac{(3t+\Delta)^2}{18t} - K - \frac{t}{2}\right],$$

and the non-adopter's profit is

$$\pi^{NA} = \frac{(3t-\Delta)^2}{18t}.$$

The adopter benefits from D's existence and the non-adopter loses from it because $\Delta > 0$ implies

$$\pi^{NA} < \frac{t}{2} < \pi^{AN}.$$

Total value migration is

$$M = t - \pi^{AN} - \pi^{NA} = \Delta\left(\frac{6t-\Delta}{18t}\right) - (1-\omega)\left[\sigma\left(\frac{3t+\Delta}{6t}\right) + \Delta\left(\frac{6t+\Delta}{18t}\right) - K\right]. \tag{1}$$

Threshold $\widetilde{K}_V$ is the value of K such that $M = 0$. Given that M increases with K, if $K > \widetilde{K}_V$, there is aggregate value migration. Moreover, $K_N - \widetilde{K}_V = (\Delta(6t-\Delta))/(18t(1-\omega)) > 0$, which implies that the range $K \in [\widetilde{K}_V, K_N]$ is never empty.

Inspection of (1) shows M increases with ω and decreases with σ. Differentiating with respect to t we obtain

$$\frac{\partial M}{\partial t} = \frac{\Delta(\Delta(2-\omega)+3\sigma(1-\omega))}{18t^2} > 0$$

so M increases with t. Differentiating with respect to Δ we obtain

$$\frac{\partial M}{\partial \Delta} = \frac{6t\omega - 2\Delta(2-\omega) - 3\sigma(1-\omega)}{18t},$$

so M increases with Δ if

$$\Delta < \frac{6\omega t - 3(1-\omega)\sigma}{2(2-\omega)}$$

and decreases with Δ if the inequality is reversed.

A.4 Proof of Proposition 3.

We start by deriving the conditions such that in equilibrium both sellers adopt. Fix $\lambda_y > 0$ and consider the symmetric candidate equilibrium in which both sellers adopt D's technology. To determine whether this is an equilibrium, we compare seller i's (on-path) payoff with its payoff from an (off-path) deviation in which it does not adopt while seller $-i$ does. In both cases, due to the adoption of $-i$, seller i's payoff depends only on its own investment y_i but not on the rival's investment y_{-i}.

As stated in the main text, seller i's payoff if both sellers adopt is

$$\pi^{AA}(y_i, \lambda_y, K) = R^{NA}(y_i) + (1-\omega)\, S^{AA}(y_i, K) - \frac{y_i^2}{2\lambda_y},$$

with $S^{AA}(y_i, K) = \sigma + R^{AA} - K - \sigma q^{AN}(y_i) - R^{NA}(y_i)$, and its payoff if it does not adopt is

$$\pi^{NA}(y_i, \lambda_y) = R^{NA}(y_i) - \frac{y_i^2}{2\lambda_y}.$$

Let $y^{AA}(\lambda_y)$ and $y^{NA}(\lambda_y)$ denote the optimal investment levels in the AA and NA cases, respectively. From the first-order conditions of the respective maximization problems, we obtain[32]

$$y^{NA}(\lambda_y) = \frac{\lambda_y(3t - \Delta)}{9t - \lambda_y},$$

and

$$y^{AA}(\lambda_y) = \frac{\lambda_y\left[6\omega t + 3(1-\omega)\sigma - 2\omega\Delta\right]}{2(9t - \omega\lambda_y)}.$$

The equilibrium condition for AA to be sustained as an equilibrium is

$$\pi^{AA}(y^{AA}(\lambda_y), \lambda_y, K) \geq \pi^{NA}(y^{NA}(\lambda_y), \lambda_y).$$

[32]The second-order conditions are fulfilled if $9t > \lambda_y$. As we show below, this always holds if $\lambda_y < \bar{\lambda}_y$.

As $\lambda_y \to 0^+$, investment becomes prohibitively costly and therefore $y^{AA}(\lambda_y), y^{NA}(\lambda_y) \to 0$. It follows that $K_A(\lambda_y) \to K_A(0)$, where $K_A(0) \equiv \lim_{\lambda_y \to 0} K_A(\lambda_y) = K_A > 0$ is the threshold of the baseline model. By continuity, if λ_y is sufficiently small, the threshold $K_A(\lambda_y)$ is positive and defined by the indifference condition

$$\pi^{AA}(y^{AA}(\lambda_y), \lambda_y, K_A(\lambda_y)) = \pi^{NA}(y^{NA}(\lambda_y), \lambda_y).$$

Since K enters linearly in S^{AA}, π^{AA} is linearly decreasing in K, and therefore $K_A(\lambda_y)$ is uniquely defined. Explicitly solving for $\pi^{AA}(\lambda_y, K)$ and $\pi^{NA}(\lambda_y)$ yields

$$\pi^{AA}(\lambda_y, K) = \frac{9t^2 + t\left(9\sigma(1-\omega) - 6\Delta\omega\right) + \omega\Delta^2 - 3\sigma\Delta(1-\omega)}{2\left(9t - \omega\lambda_y\right)} - (1-\omega)K - \frac{\lambda_y(1-\omega)\left(4\omega t^2 - \sigma^2(1-\omega)\right)}{8t\left(9t - \omega\lambda_y\right)}$$

and

$$\pi^{NA}(\lambda_y) = \frac{(3t-\Delta)^2}{2\left(9t - \lambda_y\right)}.$$

Denoting $K_A(\lambda_y) \equiv K_A^y$, we obtain

$$K_A^y = \frac{36t^2\left(3\sigma(3t-\Delta) + \Delta(6t-\Delta)\right) + \lambda_y^2\left(4t^2\omega - \sigma^2(1-\omega)\right) - 3\lambda_y t\left(12t^2(1+\omega) - 3\sigma^2(1-\omega) + 4\sigma(3t-\Delta)\right)}{8t\left(9t - \omega\lambda_y\right)\left(9t - \lambda_y\right)}.$$

We next determine the threshold $\bar{\lambda}_y$, such that K_A^y is strictly positive for $\lambda_y < \bar{\lambda}_y$. Using the Envelope Theorem, we can totally differentiate the indifference condition above to get

$$\frac{\partial \pi^{AA}}{\partial \lambda_y} + \frac{\partial \pi^{AA}}{\partial K} K_A'(\lambda_y) = \frac{\partial \pi^{NA}}{\partial \lambda_y}.$$

Since $\partial \pi^{AA}/\partial K = -(1-\omega) < 0$, the sign of $K_A'(\lambda_y)$ is opposite to the sign of

$$\frac{\partial \pi^{NA}}{\partial \lambda_y} - \frac{\partial \pi^{AA}}{\partial \lambda_y}.$$

Given that y_i does not affect the profit of seller $-i$, we can use the Envelope Theorem to obtain

$$\frac{\partial \pi^{AA}}{\partial \lambda_y} = \frac{(y^{AA})^2}{2\lambda_y^2} \quad \text{and} \quad \frac{\partial \pi^{NA}}{\partial \lambda_y} = \frac{(y^{NA})^2}{2\lambda_y^2}.$$

Hence, $K_A'(\lambda_y) > 0$ if and only if $y^{AA}(\lambda_y) > y^{NA}(\lambda_y)$. A direct comparison shows that $y^{AA}(\lambda_y) >$

$y^{NA}(\lambda_y)$ if and only if

$$\sigma > \frac{2}{3}(3t-\Delta) \quad \text{and} \quad \lambda_y < \frac{9\,t}{\sigma}\left(\sigma - \frac{2}{3}(3t-\Delta)\right).$$

As a result, $K_A'(\lambda_y) < 0$ for λ_y large enough. Therefore, $K_A(\lambda_y) < 0$ for λ_y sufficiently large. Using the formula for K_A^y, the explicit value of λ_y such that $K_A^y = 0$ if $\lambda_y = \bar{\lambda}_y$ is[33]

$$\bar{\lambda}_y = \frac{3t\left[12t^2(1+\omega) - 3\sigma^2(1-\omega) + 4\sigma(3t-\Delta)\right]}{2\left(4t^2\omega - \sigma^2(1-\omega)\right)}$$

$$-\frac{3t\sqrt{\left(4t^2+\sigma^2\right)\left(36t^2(1+\omega)^2 - 16\omega\Delta(6t-\Delta) + 9\sigma^2(1-\omega)^2 + 24\sigma(1-\omega)(3t-\Delta)\right)}}{2\left(4t^2\omega - \sigma^2(1-\omega)\right)}.$$[34]

Hence, for $\lambda_y > \bar{\lambda}_y$, the equilibrium in which both firms adopt does not exist. As a consequence, the equilibrium in which both sellers adopt exists if and only if $\lambda_y \leq \bar{\lambda}_y$ and $K \leq K_A^y$.

Turning to the first statement of Proposition 3, we can use the formula for $\pi^{AA}(\lambda_y, K)$ to get

$$\frac{\partial \pi^{AA}(\lambda_y, K)}{\partial \lambda_y} = \frac{\left(2\omega(3t-\Delta) + 3\sigma(1-\omega)\right)^2}{8\left(9t - \omega\lambda_y\right)^2} > 0.$$

Therefore, the defend strategy benefits sellers as each sellers' profit is strictly larger for $\lambda_y > 0$ than for $\lambda_y = 0$.

We next turn to statement (ii). As shown above, the equilibrium seller profit $\pi^{AA}(\lambda_y, K)$ is strictly increasing with λ_y. Instead, as determined in the main text, if D would not be present, then $\pi^{\not D} = t/2 - \lambda_y/18$, which is strictly falling with λ_y. Because value migration is defined as $\pi^{\not D} - \pi^{AA}(\lambda_y, K)$, it follows that value migration falls with λ_y.

To determine the threshold value for value migration to occur, we solve $\pi^{\not D} - \pi^{AA}(\lambda_y, K) = 0$ for K. Doing so yields that value migration only occurs if $K \geq K_V^y$, where K_V^y is defined in the main text. To determine the conditions at which value migration occurs in case both firms adopt, we compare K_V^y with K_A^y. This yields

$$K_A^y - K_V^y = \frac{\left(18t - \lambda_y - 3\Delta\right)\left(3\Delta - \lambda_y\right)}{18(1-\omega)(9t-\lambda_y)},$$

[33] The numerator of K_A^y evaluated at $\lambda_y = 9t$ equals $-36t^2(3t-\Delta)^2 < 0$, while its denominator equals 0. Hence $K_A^y \to -\infty$ as $\lambda_y \to 9t$. Since K_A^y is continuous on $[0, 9t)$ and equals $K_A > 0$ at $\lambda_y = 0$, it follows that $\bar{\lambda}_y \in (0, 9t)$.

[34] At $\omega = \omega^* \equiv \sigma^2/(4t^2+\sigma^2) \in (0,1)$, both the numerator and the denominator are zero. Using the rule of L'Hopital, $\bar{\lambda}_y$ is then given by

$$\bar{\lambda}_y\big|_{\omega=\omega^*} = \frac{54\,t^2\left(3\sigma\left(3t-\Delta\right) + \Delta\left(6t-\Delta\right)\right)}{18t\left(3t^2 + \sigma\left(3t-\Delta\right)\right)}.$$

which is strictly positive if $\lambda_y < 3\Delta$. Comparing K_V^y with K_V from the baseline model yields that if both values are positive then

$$K_V^y - K_V = \frac{\lambda_y \left[9\sigma^2(1-\omega)^2 + 12\sigma\omega(1-\omega)\left(3t-\Delta\right) + 36t^2(1+\omega^2) - 4\Delta\omega^2\left(6t-\Delta\right) - 4t\lambda_y\omega\right]}{72t\left(9t-\omega\lambda_y\right)\left(1-\omega\right)}.$$

This difference is strictly positive. To see this note that the sign of this difference is determined by the sign of the term in square brackets. This term is strictly decreasing in λ_y. Inserting $\lambda_y = 9t$, which is above that admissible value of λ_y given by $\bar{\lambda}_y$, the last term becomes $-36t^2\omega$. The first two terms in the square bracket are positive. The last terms evaluated at $\lambda_y = 9t$ can be written as $36t^2(1-\omega+\omega^2) - 4\Delta\omega^2\left(6t-\Delta\right)$, which is weakly larger than $36t^2(1-\omega) > 0$ because $9t^2 > \Delta(6t-\Delta)$. It follows that the difference $K_V^y - K_V$ is strictly positive if $K_V^y > 0$ and zero otherwise.

Finally, we turn to statement (iii). Building the difference between $\pi^{AA}(\lambda_y, K)$ and $t/2$, we obtain that the former is larger if and only if $K \leq K_B^y$, where K_B^y is defined in the main text. Comparing K_B^y with K_A^y, yields that sign $\left\{K_B^y - K_A^y\right\}$ = sign $\left\{\left[t\lambda_y - \Delta(6t-\Delta)\right] / \left[2(9t-\lambda_y)(1-\omega)\right]\right\}$. Therefore, if $\lambda_y > \Delta(6t-\Delta)/t$, then K_B^y is even larger than K_A^y, which implies that the firms' equilibrium profits with the defend strategy are larger than $t/2$ for the entire range in which firms adopt.

A.5 Proof of Proposition 4.

Comparing K_A^y with K_A yields

$$K_A^y - K_A = \frac{\lambda_y \left[9t\left(3\sigma+2\Delta-6t\right)\left(2(3t-\Delta)(1+\omega)+3\sigma(1-\omega)\right)\right]}{72t\left(9t-\omega\lambda_y\right)\left(9t-\lambda_y\right)}$$

$$-\frac{\lambda_y \left[\lambda_y\left(12t\omega\left(3\sigma+2\Delta-3t\right)+9\sigma^2(1-\omega)-4\Delta\omega(\Delta+3\sigma)\right)\right]}{72t\left(9t-\omega\lambda_y\right)\left(9t-\lambda_y\right)}. \tag{2}$$

Solving $K_A^y - K_A = 0$ for λ_y, there are two solutions, which are given by $\lambda_y = 0$ and

$$\lambda_y = \tilde{\lambda}_y \equiv \frac{9t\left(3\sigma+2\Delta-6t\right)\left(2(3t-\Delta)(1+\omega)+3\sigma(1-\omega)\right)}{12t\omega\left(3\sigma+2\Delta-3t\right)+9\sigma^2(1-\omega)-4\Delta\omega(\Delta+3\sigma)}. \tag{3}$$

It is evident from (2) that for λ_y slight above zero, $K_A^y - K_A > 0$ if and only if $3\sigma+2\Delta-6t > 0$. This is because the second term on the right-hand side is a multiple of $\left(\lambda_y\right)^2$ and therefore becomes negligibly small for λ_y in the positive vicinity of zero, whereas the first term is a multiple of λ_y, thereby dominating the second term. The sign of the first term is given by the sign of the term in the first parentheses—i.e., $3\sigma + 2\Delta - 6t$. This is due to the fact that the term in the second parentheses is strictly positive because $3t - \Delta > 0$ and $\omega \in (0,1)$, whereas the denominator

is strictly positive because $9t - \lambda_y > 0$ and $9t - \omega\lambda_y > 0$. Therefore, for $3\sigma + 2\Delta - 6t > 0$ or $\sigma > 2(3t - \Delta)/3$, the range in which both sellers adopt is larger if λ_y is slightly positive than if it is zero.

Moreover, for $\sigma > 2(3t - \Delta)/3$, $\tilde{\lambda}_y$ is strictly positive. The reason is that the numerator and the denominator are both strictly positive. First, the numerator from the arguments given above. Second, turning to the denominator, at $\sigma = 2(3t - \Delta)/3$, it is equal to $4(3t - \Delta)^2 > 0$, and its derivative with respect to σ is $18\sigma(1-\omega) + 12\omega(3t - \Delta)$, which is also strictly positive. Therefore, if $\sigma > 2(3t - \Delta)/3$, both the numerator and the denominator of the right-hand side of (3) are strictly positive, which implies that $\tilde{\lambda}_y > 0$. In addition, one can show that $\bar{\lambda}_y > \tilde{\lambda}_y$ for $\sigma > 2(3t - \Delta)/3$. Therefore, if the latter inequality holds, $K_A^y - K_A \geq 0$ for $\lambda_y \in [0, \tilde{\lambda}_y]$, which implies that the defend strategy increases the adoption region.

Instead, for $\sigma \leq 2(3t - \Delta)/3$, we have $K_A^y - K_A \leq 0$ for λ_y in the positive vicinity of zero. In that case, the numerator of $\tilde{\lambda}_y$ is negative, whereas the denominator, due to argument given above, is still positive if σ is close to $2(3t - \Delta)/3$. In that case, the two solutions for λ_y that solve the equation $K_A^y - K_A = 0$, are 0 and negative, respectively. This implies that $K_A^y - K_A \leq 0$ for all positive values of λ_y. If, instead, σ is sufficiently small, the denominator is negative as well, which implies that $\tilde{\lambda}_y$ is strictly positive. However, $\tilde{\lambda}_y$ is then strictly larger than $\bar{\lambda}_y$. In particular, at $\sigma = 0$,

$$\bar{\lambda}_y - \tilde{\lambda}_y = -\frac{3\left(3t^2(1+\omega) + t\sqrt{9t^2(1+\omega)^2 - 4\Delta\omega(6t - \Delta)}\right)}{2t\omega} < 0,$$

and the difference $\bar{\lambda}_y - \tilde{\lambda}_y$ falls in σ as the denominator of $\tilde{\lambda}_y$ goes to zero as σ approaches $2(3t - \Delta)/3$. As a result, for $\sigma \leq 2(3t - \Delta)/3$, the range of K in which both sellers adopt, shrinks with the possibility of a defend strategy. This proves the first statement of the proposition.

We next turn to the second statement and consider the profit of D for the region $\sigma > 2(3t - \Delta)/3$ and $\lambda_y \in [0, \tilde{\lambda}_y]$. In the baseline model without a defend strategy (i.e., $\lambda_y = 0$), only one seller adopts, and D's profit is given by

$$\frac{\omega\left(3t(2\Delta + 3\sigma) + \Delta(3\sigma + \Delta) - 18tK\right)}{18t}. \tag{4}$$

Instead, in case with defend strategy, both sellers adopt, and D's profit is

$$2\omega\left(\frac{t}{2} + \sigma - K - \frac{\left(6t(3t - \Delta) + \lambda_y\sigma(1-\omega)\right)^2}{8t\left(9t - \omega\lambda_y\right)^2}\right) + \frac{(1-\omega)\sigma\left(6t(3t + \Delta) - \lambda_y\sigma(1-\omega) - 4t\lambda_y\omega\right)}{2t\left(9t - \omega\lambda_y\right)} - \sigma. \tag{5}$$

We can now compare these two profits. Building the difference between (5)—i.e., D's profit with defend strategy and both sellers adopting—and (4)—i.e., D's profit without defend strategy

and only one seller adopting—yields that the sign of this difference evaluated at $K = K_A$ is given by the sign of

$$108t^2\Delta\left(3\sigma(1-\omega)-\Delta\omega\right)-\lambda_y\left(18t-\omega\lambda_y\right)\left(4\omega^2t(3t-2\Delta)+12\omega\sigma t(1-\omega)+3\sigma^2(1-\omega)^2\right). \quad (6)$$

Taking $\lambda \longrightarrow 0^+$, the difference is given by $108t^2\Delta\left(3\sigma(1-\omega)-\Delta\omega\right)$, which is strictly positive if

$$\Delta < \frac{3\sigma\left(1-\omega\right)}{\omega}. \quad (7)$$

Due to continuity of the profit functions, this difference is also positive if λ_y is strictly positive but sufficiently low.

Bringing these arguments together, by continuity, there exists a $\tilde{K} > K_A$ and $\hat{\lambda}_y \leq \tilde{\lambda}_y$, such D's profit with the defend strategy and double adoption is larger than its profit without the defend strategy and single adoption if $K \in [K_A, \tilde{K}]$, $\lambda \in [0, \tilde{\lambda}_y]$, and (7) holds.

A.6 Proof of Proposition 5.

Equilibrium investments. If both firms adopt, seller i obtains a product-market revenue of

$$R_i^{AA} = \frac{(3t + x_i - x_j)^2}{18t},$$

while the developer obtains a complementary revenue of

$$(\sigma + r_i)\, q_i^{AA} + (\sigma + r_j)\, q_j^{AA} = (\sigma + r_i)\, \frac{3t + x_i - x_j}{6t} + (\sigma + r_j)\, \frac{3t + x_j - x_i}{6t}$$

If seller i does not adopt, it obtains

$$R_i^{NA} = \frac{(3t - \Delta - x_j)^2}{18t},$$

while the developer obtains a complementary revenue of

$$(\sigma + r_j)\, q_j^{AN} = (\sigma + r_j)\, \frac{3t + \Delta + x_j}{6t}.$$

In the second stage, investments are given. Therefore, adoption of both sellers is an equilibrium if

$$R_i^{NA} + (1-\omega)\, S_i^{AA} \geq R_i^{NA} \quad \Longleftrightarrow \quad S_i^{AA} \geq 0, \quad i = 1, 2,$$

where

$$S_i^{AA} = R_i^{AA} + (\sigma + r_i)\, q_i^{AA} + (\sigma + r_j)\, q_j^{AA} - R_i^{NA} - (\sigma + r_j)\, q_j^{AN} - K.$$

In the first stage, seller i's optimal investments, anticipating and equilibrium in which both sellers adopt, solve

$$\pi^{AA} \equiv \max_{x_i, r_i \geq 0} R_i^{NA} + (1-\omega)\, S_i^{AA} - \frac{{x_i}^2}{2\lambda_x} - \frac{{r_i}^2}{2\lambda_r}. \tag{8}$$

Instead, if seller i anticipates to not adopt D's system, its optimal investments are zero.

Using the respective formulas for R_i^{NA}, R_i^{AA}, q_i^{AA}, q_j^{AA}, and q_j^{AN} in (8) yields

$$\max_{x_i, r_i \geq 0} \omega\, R_i^{NA} + (1-\omega)\, \left[R_i^{AA} + (\sigma + r_i)\, q_i^{AA} + (\sigma + r_j)\, (q_j^{AA} - q_j^{AN}) - K\right] - \frac{{x_i}^2}{2\lambda_x} - \frac{{r_i}^2}{2\lambda_r} =$$

$$= \omega\, \frac{(3t - \Delta - x_j)^2}{18t} + (1-\omega) \left[\frac{(3t + x_i - x_j)^2}{18t} + (\sigma + r_i)\frac{3t + x_i - x_j}{6t}\right]$$
$$- (1-\omega) \left[(\sigma + r_j)\frac{\Delta + x_i}{6t} + K\right] - \frac{x_i^2}{2\lambda_x} - \frac{r_i^2}{2\lambda_r}.$$

The first-order conditions for interior solutions are

$$\frac{\partial \pi_i^{AA}}{\partial x_i} = (1-\omega) \left[\frac{3t + x_i - x_j}{9t} + \frac{\sigma + r_i}{6t} - \frac{\sigma + r_j}{6t}\right] - \frac{x_i}{\lambda_x} = 0$$

and

$$\frac{\partial \pi_i^{AA}}{\partial r_i} = (1-\omega)\frac{3t + x_i - x_j}{6t} - \frac{r_i}{\lambda_r} = 0.$$

The second-order conditions are satisfied if, first, the second partial derivatives with respect to x_i and r_i are negative and, second, the Hessian determinant is positive. On the former, we obtain

$$\frac{\partial^2 \pi_i^{AA}}{\partial\, (x_i)^2} = \frac{1-\omega}{9t} - \frac{1}{\lambda_x} \quad \text{and} \quad \frac{\partial^2 \pi_i^{AA}}{\partial\, (r_i)^2} = -\frac{1}{\lambda_r}.$$

Therefore, the assumption $t > \lambda_x(1-\omega)/9 + \Delta$ ensures that $\partial^2 \pi_i^{AA} / \partial\, (x_i)^2 < 0$, and $\partial^2 \pi_i^{AA} / \partial\, (r_i)^2 < 0$ is always satisfied. On the latter, we obtain

$$\left(\frac{\partial^2 \pi_i^{AA}}{\partial\, (x_i)^2}\right)\left(\frac{\partial^2 \pi_i^{AA}}{\partial\, (r_i)^2}\right) - \left(\frac{\partial^2 \pi_i^{AA}}{\partial x_i \partial r_i}\right)^2 = \frac{1}{\lambda_x \lambda_r} - \frac{(1-\omega)\lambda_x\, (4t + \lambda_r(1-\omega))}{36t^2 \lambda_x \lambda_r}.$$

The assumption $36t^2 - (1-\omega)\lambda_x\, (4t + \lambda_r(1-\omega)) > 0$ therefore ensures that the Hessian determinant is positive.

Given that the second-order conditions are satisfied, the symmetric investments in the equilibrium in which both sellers adopt are

$$x^* = \frac{(1-\omega)\lambda_x}{3} \quad \text{and} \quad r^* = \frac{(1-\omega)\lambda_r}{2}.$$

Instead, if seller i deviates and does not adopt D's system, its profit is

$$\pi^{NA} = R_i^{NA} = \frac{(3t - \Delta - x^*)^2}{18t}.$$

Demands are interior because of the assumption $t > \lambda_x(1-\omega)/9 + \Delta$.

Adoption threshold. The condition for both sellers to adopt is

$$(1-\omega)\left[\frac{\sigma + r^*}{2} + (\Delta + x^*)\left(\frac{1}{3} - \frac{\Delta + x^* + 3(\sigma + r^*)}{18t}\right) - K\right] - \frac{x^{*2}}{2\lambda_x} - \frac{r^{*2}}{2\lambda_r} \geq 0, \tag{9}$$

from which we obtain the following threshold for adoption:

$$K \leq K_A(\lambda_x, \lambda_r) \equiv \left[\frac{\sigma + r^*}{2} + (\Delta + x^*)\left(\frac{1}{3} - \frac{\Delta + x^* + 3(\sigma + r^*)}{18t}\right)\right] - \frac{1}{2(1-\omega)}\left(\frac{x^{*2}}{\lambda_x} + \frac{r^{*2}}{\lambda_r}\right). \tag{10}$$

Substituting for the equilibrium expressions and simplifying, we obtain

$$\begin{aligned} K_A(\lambda_x, \lambda_r) \quad = \quad & \frac{3\sigma + 2\Delta}{6} - \frac{\Delta(3\sigma + \Delta)}{18t} + \frac{(1-\omega)\lambda_x\left[2\left(3t - 3\sigma - 2\Delta\right) - 3\lambda_r(1-\omega)\right]}{108t} \\ & + \frac{(1-\omega)(3t - 2\Delta)\lambda_r}{24t} - \frac{(1-\omega)^2\lambda_x^2}{162t}. \end{aligned} \tag{11}$$

Therefore, for $K \leq K_A(\lambda_x, \lambda_r)$, adoption of both sellers constitutes an equilibrium. By continuity of the model, if λ_x and λ_r are sufficiently small, $K_A(\lambda_x, \lambda_r)$ is strictly positive.

Effects on seller profit. At a symmetric equilibrium, profit is

$$\pi^* = \omega\,\frac{(3t - \Delta - x^*)^2}{18t} + (1-\omega)\left[\frac{t}{2} + \frac{\sigma + r^*}{2} - (\sigma + r^*)\frac{\Delta + x^*}{6t} - K\right] - \frac{(1-\omega)^2\lambda_x}{18} - \frac{(1-\omega)^2\lambda_r}{8}.$$

This shows that an increase in λ_x is detrimental to sellers because it raises x^*, which lowers the outside option and intensifies product-market competition, and also implies that each seller incurs higher investment cost.

For λ_r, using $r^* = (1-\omega)\lambda_r/2$, we obtain

$$\frac{\partial \pi^*}{\partial \lambda_r} = (1-\omega)^2\left(\frac{1}{4} - \frac{\Delta + x^*}{12t}\right) - \frac{(1-\omega)^2}{8} = (1-\omega)^2\left(\frac{1}{8} - \frac{\Delta + x^*}{12t}\right).$$

Therefore,

$$\frac{\partial \pi^*}{\partial \lambda_r} > 0 \quad \Longleftrightarrow \quad \Delta + x^* < \frac{3}{2}t \quad \Longleftrightarrow \quad \Delta + \frac{(1-\omega)\lambda_x}{3} < \frac{3}{2}t.$$

Thus, increasing the effectiveness of investments that raise developer-side revenues benefits sellers if and only if the consumer-side gains from adoption are not too large.

A.7 Proof of Proposition 6.

If both firms adopt D's system, seller i obtains a product-market revenue of

$$R_i^{AA} = \frac{(3t + x_i - x_j)^2}{18t},$$

while the developer obtains a complementary revenue of

$$(\sigma + r_i)q_i^{AA} + (\sigma + r_j)q_j^{AA} = (\sigma + r_i)\frac{3t + x_i - x_j}{6t} + (\sigma + r_j)\frac{3t + x_j - x_i}{6t}.$$

If seller i does not adopt D's system and instead relies on its own system, while seller j adopts D's system, then seller i obtains a product-market revenue of

$$R_i^{NA} = \frac{(3t + y_i - \Delta - x_j)^2}{18t},$$

while the developer obtains a complementary revenue of

$$(\sigma + r_j)q_j^{AN} = (\sigma + r_j)\frac{3t + \Delta + x_j - y_i}{6t}.$$

In the second stage, investments are given, so adoption is an equilibrium if $S_i^{AA} > 0$, where

$$S_i^{AA} = R_i^{AA} + (\sigma + r_i)q_i^{AA} + (\sigma + r_j)q_j^{AA} - R_i^{NA} - (\sigma + r_j)q_j^{AN} - K.$$

Given that we focus on the equilibrium in which both firms adopt, we assume this condition holds.

In the first stage, the optimal investments solve

$$\begin{aligned}\pi_i^{AA} &\equiv \max_{y_i,x_i,r_i\geq 0} R_i^{NA} + (1-\omega)S_i^{AA} - \frac{y_i^2}{2\lambda_y} - \frac{x_i^2}{2\lambda_x} - \frac{r_i^2}{2\lambda_r} \qquad (12)\\ &= \max_{y_i,x_i,r_i\geq 0} \omega\, R_i^{NA} + (1-\omega)\left[R_i^{AA} + (\sigma+r_i)q_i^{AA} + (\sigma+r_j)\left(q_j^{AA} - q_j^{AN}\right) - K\right]\\ &\qquad - \frac{y_i^2}{2\lambda_y} - \frac{x_i^2}{2\lambda_x} - \frac{r_i^2}{2\lambda_r}\\ &= \max_{y_i,x_i,r_i\geq 0} \omega\,\frac{(3t+y_i-\Delta-x_j)^2}{18t} + (1-\omega)\left[\frac{(3t+x_i-x_j)^2}{18t} + (\sigma+r_i)\frac{3t+x_i-x_j}{6t}\right]\\ &\qquad - (1-\omega)\left[(\sigma+r_j)\frac{\Delta+x_i-y_i}{6t} + K\right] - \frac{y_i^2}{2\lambda_y} - \frac{x_i^2}{2\lambda_x} - \frac{r_i^2}{2\lambda_r}. \qquad (13)\end{aligned}$$

The first-order conditions for an interior solution are

$$\begin{aligned}\frac{\partial \pi_i^{AA}}{\partial x_i} &= (1-\omega)\left[\frac{3t+x_i-x_j}{9t} + \frac{\sigma+r_i}{6t} - \frac{\sigma+r_j}{6t}\right] - \frac{x_i}{\lambda_x} = 0,\\ \frac{\partial \pi_i^{AA}}{\partial r_i} &= (1-\omega)\frac{3t+x_i-x_j}{6t} - \frac{r_i}{\lambda_r} = 0,\\ \frac{\partial \pi_i^{AA}}{\partial y_i} &= \omega\frac{3t+y_i-\Delta-x_j}{9t} + (1-\omega)\frac{\sigma+r_j}{6t} - \frac{y_i}{\lambda_y} = 0. \qquad (14)\end{aligned}$$

As is evident from $\partial\pi_i^{AA}/\partial y_i$, the optimal investment choice y_i is independent of (x_i, r_i). Therefore, the necessary and sufficient conditions for the first-order conditions to constitute an optimum are the same ones as in the previous two subsections—i.e., $t > \lambda_x(1-\omega)/9 + \Delta$, $36t^2 > \lambda_x(1-\omega)\,(4t + \lambda_r(1-\omega))$, and $\lambda_y < \bar{\lambda}_y$ (see the proof of Proposition 3).

Solving for the symmetric equilibrium investments yields

$$x^* = \frac{(1-\omega)\lambda_x}{3}, \qquad r^* = \frac{(1-\omega)\lambda_r}{2},$$

$$y^* = \frac{\lambda_y}{9t - \omega\lambda_y}\left[\omega\left(3t - \Delta - \frac{(1-\omega)\lambda_x}{3}\right) + \frac{3(1-\omega)}{2}\left(\sigma + \frac{(1-\omega)\lambda_r}{2}\right)\right].$$

The first statement the proposition—i.e., $\partial y^*/\partial\lambda_x < 0$ and $\partial y^*/\partial\lambda_r > 0$—follows directly from the equilibrium expression for y^*.

Inserting the equilibrium investments into π_i^{AA} and taking the second derivatives $\left(\partial^2\pi^*\right)/\left(\partial\lambda_y\partial\lambda_x\right)$ and $\left(\partial^2\pi^*\right)/\left(\partial\lambda_y\partial\lambda_r\right)$ yields

$$\frac{\partial^2\pi^*}{\partial\lambda_y\partial\lambda_x} = -\frac{\omega(1-\omega)\left(12\omega(3t-\Delta) + 18\sigma(1-\omega) + 9\lambda_r(1-\omega)^2 - 4\omega(1-\omega)\lambda_x\right)}{36\left(9t - \omega\lambda_y\right)^2}$$

and

$$\frac{\partial^2 \pi^*}{\partial \lambda_y \partial \lambda_r} = \frac{(1-\omega)^2 \left(12\omega(3t-\Delta) + 18\sigma(1-\omega) + 9\lambda_r(1-\omega)^2 - 4\lambda_x\omega(1-\omega)\right)}{16\left(9t - \omega\lambda_y\right)^2}.$$

Because $t > \lambda_x(1-\omega)/9 + \Delta$, the numerator of the fraction is strictly positive, which yields the result.

A.8 Proof of Proposition 7.

Derivation of the equilibrium. We first solve the model with two developers and characterize the resulting equilibrium payoffs. We use backward induction and begin by considering the second stage. Let $v_{ij} \in \{v, v+\Delta\}$ be the valuation of a type j consumer for seller i's product, and let $z_j \equiv v_{1j} - v_{2j}$ be seller 1's valuation advantage or disadvantage for type j consumers. For example, if seller 1 includes system A and seller 2 does not, then $v_{1\alpha} = v + \Delta$, $v_{2\alpha} = v$, and $z_\alpha = \Delta$.

Given system adoption choices, seller demands are

$$\begin{aligned} q_1(p_1,p_2) &= \alpha\left(\frac{1}{2} + \frac{p_2 - p_1 + z_\alpha}{2t}\right) + \beta\left(\frac{1}{2} + \frac{p_2 - p_1 + z_\beta}{2t}\right) + \gamma\left(\frac{1}{2} + \frac{p_2 - p_1 + z_\gamma}{2t}\right) \\ q_2(p_1,p_2) &= \alpha\left(\frac{1}{2} + \frac{p_1 - p_2 - z_\alpha}{2t}\right) + \beta\left(\frac{1}{2} + \frac{p_1 - p_2 - z_\beta}{2t}\right) + \gamma\left(\frac{1}{2} + \frac{p_1 - p_2 - z_\gamma}{2t}\right). \end{aligned}$$

Let $\overline{z} = \alpha\, z_\alpha + \beta\, z_\beta + \gamma\, z_\gamma$ be the average advantage or disadvantage of seller 1. Equilibrium prices are

$$p_1^* = t + \frac{\overline{z}}{3} \quad \text{and} \quad p_2^* = t - \frac{\overline{z}}{3},$$

and equilibrium quantities are

$$q_1^* = \frac{1}{2} + \frac{\overline{z}}{6t} \quad \text{and} \quad q_2^* = \frac{1}{2} - \frac{\overline{z}}{6t}.$$

The respective product-market revenues are then given by

$$R_1^* = \frac{(3t + \overline{z})^2}{18t}, \qquad R_2^* = \frac{(3t - \overline{z})^2}{18t}.$$

Consider now the first stage, and assume that both sellers adopt both systems. We will later show that this holds in equilibrium, given that adoption costs are zero.

Let f_{ij} be the equilibrium payment from seller i to developer j. Consider the negotiation between seller 1 and developer A. Recall that this negotiation takes as given the outcome on the equilibrium path that 2 adopts both technologies and 1 adopts B. Thus, if 1 and A reach an

agreement, $\overline{z} = 0$ and the joint value created is

$$\frac{t}{2} + \sigma\, s_A + f_{2A} - f_{1B},$$ [35]

where $s_A \equiv \alpha + \gamma/2$ is the measure of consumers using A's system when both sellers adopt it. If 1 and A do not reach an agreement, then $\overline{z} = -\alpha\Delta$, and seller 1 obtains

$$R_{1,-A} - f_{1B},$$

while developer A obtains

$$\sigma\, s_{A,-1} + f_{2A},$$

where $R_{1,-A} \equiv \left((3t - \alpha\Delta)^2/(18t)\right)$ is seller 1's product-market revenue if it does not adopt A and

$$\begin{aligned} s_{A,-1} &\equiv \alpha\left(\frac{1}{2} + \frac{p_1 - p_2}{2t} - \frac{z_\alpha}{2t}\right) + \frac{\gamma}{2}\left(\frac{1}{2} + \frac{p_1 - p_2}{2t} - \frac{z_\gamma}{2t}\right) \\ &= \alpha\left(\frac{1}{2} - \frac{2\alpha\Delta}{6t} + \frac{\Delta}{2t}\right) + \frac{\gamma}{2}\left(\frac{1}{2} - \frac{2\alpha\Delta}{6t}\right) \end{aligned} \tag{15}$$

is the measure of consumers using A's system in case 1 does not adopt it.[36]

The bargaining surplus of this negotiation is

$$S_{1A} \equiv \frac{t}{2} - R_{1,-A} + \sigma\left(s_A - s_{A,-1}\right),$$

which is positive because product-market revenue and system market share are larger under agreement. Given that the bargaining surplus is positive for any seller-developer pair, in equilibrium both sellers adopt both systems, as we had assumed.

Seller 1's bargaining payoff in the negotiation with A is $\pi_{1A} = R_{1,-A} - f_{1B} + (1-\omega)S_{1A}$. By definition, this payoff must be equal to the equilibrium product-market revenue minus the sum of payments from 1 to A and B, that is,

$$R_{1,-A} - f_{1B} + (1-\omega)S_{1A} = \frac{t}{2} - f_{1A} - f_{1B}.$$

[35] We include the payments from 2 to A and from 1 to B in this formula for completeness. However, since they are decided in negotiations other than the one between 1 and A, they do not affect f_{1A}.

[36] If seller 1 does not adopt A, only consumers of seller 2 use this system. These consumers comprise of a fraction $1/2 + (p_1 - p_2)/(2t) + (z_\alpha)/(2t)$ of the α-type consumers, and a fraction $1/2\left[1/2 + (p_1 - p_2)/(2t) + (z_\gamma)/(2t)\right]$ of the γ-type consumers.

From this equation, it follows that

$$\begin{aligned} f_{1A} &= \frac{t}{2} - (1-\omega)\, S_{1A} - R_{1,-A} \\ &= \omega \left(\frac{t}{2} - R_{1,-A}\right) - (1-\omega)\, \sigma \left(s_A - s_{A,-1}\right). \end{aligned}$$

The first term of this expression measures the effect of agreement on product-market revenues, and the second term measures its impact on complementary revenues. The payment from 1 to A is positive if the product-market effect is large relative to the complementary-revenue effect, and negative otherwise.

Applying the same steps to the negotiation between 1 and B leads to

$$f_{1B} = \omega \left(\frac{t}{2} - R_{1,-B}\right) - (1-\omega)\, \sigma \left(s_B - s_{B,-1}\right).$$

Given these payments, seller 1's payoff can be written as

$$\begin{aligned} \pi_1 &= \frac{t}{2} - f_{1A} - f_{1B} \\ &= \frac{t}{2} + \omega \left(R_{1,-A} + R_{1,-B} - t\right) + (1-\omega)\, \sigma \left(1 - s_{A,-1} - s_{B,-1}\right), \end{aligned} \tag{16}$$

and given symmetry, seller 2 obtains an analogous payoff. The equation shows that a seller's equilibrium payoff increases with the sum of its outside options, $R_{1,-A} + R_{1,-B}$ and decreases with the sum of developers' outside options, $\sigma \left(s_{A,-1} + s_{B,-1}\right)$.

Using $R_{1,-i} \equiv \left((3t - \alpha\Delta)^2 / (18t)\right.$, the former is given by

$$\begin{aligned} R_{1,-A} + R_{1,-B} &= \frac{(3t-\alpha\Delta)^2}{18t} + \frac{(3t-\beta\Delta)^2}{18t} \\ &= \frac{18t^2 - 6t\Delta(\alpha+\beta) + \Delta^2(\alpha^2+\beta^2)}{18t} \\ &= t - (\alpha+\beta)\frac{\Delta}{3} + (\alpha^2+\beta^2)\frac{\Delta^2}{18t}. \end{aligned}$$

Turning to the latter, from (15) we obtain

$$\begin{aligned} s_{A,-1} &= \alpha\left(\frac{1}{2}-\frac{2\alpha\Delta}{6t}+\frac{\Delta}{2t}\right)+\frac{\gamma}{2}\left(\frac{1}{2}-\frac{2\alpha\Delta}{6t}\right) \\ &= \left(\alpha+\frac{\gamma}{2}\right)\left(\frac{1}{2}-\frac{2\alpha\Delta}{6t}+\frac{\Delta}{2t}\right)-\gamma\,\frac{\Delta}{4t} \\ &= \left(\alpha+\frac{\gamma}{2}\right)\left(\frac{3t-2\alpha\Delta+3\Delta}{6t}\right)-\gamma\,\frac{\Delta}{4t} \\ &= \left(\alpha+\frac{\gamma}{2}\right)\left(\frac{3t+\Delta}{6t}\right)+\left(\alpha+\frac{\gamma}{2}\right)\left(\frac{1-\alpha}{3t}\right)\Delta-\gamma\,\frac{\Delta}{4t}. \end{aligned}$$

The first term measures the effect of disagreement in the baseline model, scaled by the share of consumers using system A. The second term captures that the price effect of non-agreement is smaller, since only α-type valuations are affected. The third term arises because free consumers using seller 2's product do not experience a decrease in quality. Thus, it reflects the fact that the presence of free consumers lowers developer A's bargaining power. Summing across developers, we obtain

$$s_{A,-1}+s_{B,-1} = \frac{3t+\Delta}{6t}+\left[\left(\alpha+\frac{\gamma}{2}\right)(1-\alpha)+\left(\beta+\frac{\gamma}{2}\right)(1-\beta)\right]\frac{\Delta}{3t}-\gamma\,\frac{\Delta}{2t}.$$

Inserting this expressions into (16), seller i's equilibrium payoff can be written as

$$\pi_i(\alpha,\beta,\gamma)=\frac{t}{2}+\omega\left(\frac{\Delta^2\left(\alpha^2+\beta^2\right)}{18t}-\frac{\Delta\left(\alpha+\beta\right)}{3}\right)+(1-\omega)\sigma\left(1-\frac{3t+\Delta}{6t}-\frac{\Delta\left(2\alpha+\gamma\right)\left(2\beta+\gamma\right)}{6t}+\frac{\gamma\Delta}{3t}\right). \tag{17}$$

Using that $\alpha+\beta=1-\gamma$ and $(\alpha-\beta)^2=(2s_A-1)^2$, we can write (17) as a function of γ and s_A to get

$$\pi_i(\gamma,s_A)= \tag{18}$$
$$=\frac{t}{2}+\omega\left(\frac{\Delta^2\left[(1-\gamma)^2+(2s_A-1)^2\right]}{36t}-\frac{\Delta\left(1-\gamma\right)}{3}\right)+(1-\omega)\sigma\left(\frac{1}{2}+\frac{\Delta\left[(2s_A-1)^2-2(1-\gamma)\right]}{6t}\right).$$

For $\alpha=1$, and therefore $\beta=0$ and $\gamma=0$ (or, equivalently, $\beta=1$, and, thus, $\alpha=0$ and $\gamma=0$), $\pi_i(\alpha,\beta,\gamma)$ simplifies to

$$\pi_i(1,0,0)=\frac{t}{2}-\frac{\omega\Delta\left(6t-\Delta\right)}{18t}+\frac{(1-\omega)\sigma\left(3t-\Delta\right)}{6t}, \tag{19}$$

which is equivalent to the seller's equilibrium payoff in the baseline model.

Effect of γ on value migration. We next determine how value migration changes with γ, holding s_A fixed. First, note that both in the baseline model and in the model with system competition,

a seller's payoff without the presence of the system(s) is $t/2$. Therefore, value migration in the model with system competition is $t/2 - \pi_i(\gamma, s_A)$, where $\pi_i(\gamma, s_A)$ is given in (18), whereas value migration in the baseline model is $t/2 - \pi_i(1, 0, 0)$, where $\pi_i(1, 0, 0)$ is given in (19). It follows that value migration is lower in case with competition between systems if $\pi_i(\gamma.s_A) > \pi_i(1, 0, 0)$. After simplifying, this difference is given by

$$\pi_i(\gamma, s_A) - \pi_i(1, 0, 0) \tag{20}$$

$$= \frac{\Delta \left[12\omega t\gamma + 12\sigma(1-\omega)\left(\gamma - 2s_A(1-s_A)\right) - \omega\Delta\left(\gamma(2-\gamma) + 4s_A(1-s_A)\right)\right]}{36t}.$$

We can now analyze how the right-hand side of (20) changes with γ. Because $s_A = \alpha + \gamma/2$ and $s_B = \beta + \gamma/2$, it holds that $\gamma \leq 2\min\{s_A, 1 - s_A\}$. To show that there exists a threshold $\hat{\gamma}$ as stated in the proposition, we show that the above condition does not hold for $\gamma = 0$, but holds for $\gamma = 2\min\{s_A, 1 - s_A\}$, and that the left-hand side is increasing in γ. The existence of a threshold follows then from the mean value theorem.

For the first result, inserting $\gamma = 0$ into (20) yields

$$-\frac{\Delta s_A(1-s_A)(6\sigma(1-\omega) + \omega\Delta))}{9t} < 0.$$

For the second result, suppose $s_A < 1/2$ (the case $s_A > 1/2$ is equivalent). Inserting $\gamma = 2s_A$ into (20) yields

$$\frac{2\Delta s_A\left[\omega\left(3t - \Delta(1-s_A)\right) + 3\sigma s_A(1-\omega)\right]}{9t},$$

which is strictly positive as $3t > \Delta$.

Finally, taking the derivative with respect to γ yields

$$\frac{\Delta\omega\left(6t - \Delta(1-\gamma)\right)}{18t} + \frac{\Delta\sigma(1-\omega)}{3t}.$$

This expression is strictly positive as $3t > \Delta$ by assumption. It follows that there must exist a unique threshold for γ, denoted by $\hat{\gamma}(s_A) \in (0, 1)$, such that value migration with two developers is larger than with one developer if and only if $\gamma \leq \hat{\gamma}(s_A)$.

A.9 Proof of Proposition 8.

To determine how $\hat{\gamma}(s_A)$ changes with s_A, we invoke the Implicit Function Theorem

$$\frac{d\gamma}{ds_A} = -\frac{\frac{\partial(20)}{\partial s_A}}{\frac{\partial(20)}{\partial\gamma}}.$$

From the proof of the previous proposition, $\partial(20)/\partial\gamma > 0$. Taking the derivative of (20) with respect to s_A yields

$$\frac{\partial(20)}{\partial s_A} = \frac{\Delta(2s_A - 1)(6\sigma(1-\omega) + \omega\Delta)}{9t},$$

which is decreasing for $s_A < 1/2$ and increasing for $s_A > 1/2$. It follows that $\hat{\gamma}(s_A)$ attains its maximum at $s_A = 1/2$, increases for $s_A < 1/2$ and falls for $s_A > 1/2$.

B Exclusivity contract

The baseline model assumes that D can reach an agreement with both sellers. In this section, we consider the situation in which D can commit to provide its system to only one seller. This lets D make the sellers compete for access, but means that D forgoes the complementary revenue from consumers who buy from the excluded seller. To isolate this trade-off, we set $K = 0$ and assume $\Delta > 0$.[37]

The timing is as follows. First, D chooses between non-exclusive contracting, in which case the game proceeds as in Section 2, and an exclusive contract. Under exclusivity, D conducts a sealed-bid second-price auction. Each seller $i \in \{1, 2\}$ submits a bid b_i, expressed as a fixed transfer to D. The seller with the highest bid obtains exclusive access to the system and pays the losing bid; ties are resolved randomly.[38] Afterward, sellers then compete in prices.

If seller i wins the auction, the product-market outcome is the same as when only i adopts in the baseline model: the winner obtains R^{AN} and the excluded seller obtains R^{NA}. Each seller's willingness to pay for exclusivity is therefore

$$R^{AN} - R^{NA} = \frac{2\Delta}{3}. \tag{21}$$

Both sellers bid $2\Delta/3$, and the winner pays this amount. The winner earns $R^{AN} - 2\Delta/3 = R^{NA}$, which is also the profit of the excluded seller. Competition for access forces the winner to transfer its entire competitive advantage to D, whose profit is

$$\pi_D^E = \frac{2\Delta}{3} + \sigma\frac{3t + \Delta}{6t}. \tag{22}$$

[37] With $K \in (0, 2\Delta/3]$, the outcome of the auction is the same as described below—i.e., each seller still bids $2\Delta/3 - K$—ans both sellers still earn R^{NA}. Value migration under exclusivity therefore does not depend on K. However, the developer obtains lower profits if K is larger.

[38] Because information is complete, a first-price auction, or competition between sellers in take-it-or-leave-it offers to D, yields the same transfer.

Since each seller earns $t/2$ without D, individual value migration under exclusivity is

$$M_i^E = \frac{t}{2} - R^{NA} = \frac{\Delta(6t-\Delta)}{18t} > 0. \tag{23}$$

Proposition A1. *Suppose $K = 0$ and $\Delta > 0$. If D auctions an exclusive contract, both sellers bid $2\Delta/3$ and earn R^{NA}. There is individual and aggregate value migration, and each seller is strictly worse off than under non-exclusive contracting. If $\omega \leq 1/2$, D strictly prefers the exclusive contract. If $\omega > 1/2$, D prefers the exclusive contract if and only if*

$$\sigma < \bar{\sigma}^E \equiv \frac{2\Delta\left[6t(1-\omega)+\omega\Delta\right]}{3(2\omega-1)(3t-\Delta)}, \tag{24}$$

where $\bar{\sigma}^E$ decreases with t and increases with Δ.

Proof. The difference between the product-market revenues of the winning and losing sellers is given in (21). Bidding $2\Delta/3$ is therefore a weakly dominant strategy in the second-price auction, and the winner pays $2\Delta/3$. The winner earns $R^{AN} - 2\Delta/3 = R^{NA}$, as does the excluded seller. Since the winner serves a share $(3t+\Delta)/(6t)$ of consumers, D obtains (22).

Let $A \equiv t/2 - R^{NA} = \Delta(6t-\Delta)/(18t) > 0$. When $K = 0$, both sellers adopt under non-exclusive contracting, and each pays

$$f^B = \omega A - (1-\omega)\sigma q^{NA},$$

so that D's profit is $\pi_D^B = \sigma + 2\omega A - 2(1-\omega)\sigma q^{NA}$. Hence

$$\pi_D^E - \pi_D^B = \frac{\Delta\left[6t(1-\omega)+\omega\Delta\right]}{9t} + (1-2\omega)\,\sigma\,\frac{3t-\Delta}{6t}. \tag{25}$$

The first term is strictly positive. If $\omega \leq 1/2$, the second term is nonnegative, so (25) is strictly positive. If $\omega > 1/2$, (25) is strictly positive if and only if $\sigma < \bar{\sigma}^E$.

Under non-exclusive contracting, seller i earns $\pi_i^B = R^{NA} + (1-\omega)(A + \sigma q^{NA})$. Thus

$$\pi_i^B - R^{NA} = M_i^E - M_i^B = (1-\omega)\left(A + \sigma q^{NA}\right) > 0,$$

so each seller is strictly worse off, and value migration is strictly larger, under exclusivity. Aggregate value migration is $2M_i^E > 0$.

Finally, for $\omega > 1/2$,

$$\frac{\partial\bar{\sigma}^E}{\partial t} = -\frac{2\Delta^2(2-\omega)}{(2\omega-1)(3t-\Delta)^2} < 0 \quad \text{and} \quad \frac{\partial\bar{\sigma}^E}{\partial\Delta} = \frac{2\left[18(1-\omega)t^2+\omega\Delta(6t-\Delta)\right]}{3(2\omega-1)(3t-\Delta)^2} > 0.$$

■

Under exclusivity, both sellers earn R^{NA}. This is exactly what each seller earns under non-exclusive licensing when D has all the bargaining power ($\omega = 1$). Exclusivity is thus a way for D to capture the entire bargaining surplus, at the cost of forgoing the complementary revenue from the excluded seller's consumers, σq^{NA}, where $q^{NA} = (3t - \Delta)/(6t)$.

This trade-off explains the role of ω. Regarding product-market revenues, exclusivity always benefits D: it obtains $2\Delta/3$ instead of a share ω of each seller's product-market loss from not adopting. Regarding complementary revenues, under non-exclusive contracting each seller obtains a share $1 - \omega$ of the complementary revenue at stake in their negotiation, σq^{NA}, that is, sellers obtain $2(1 - \omega)\sigma q^{NA}$ in total. Instead, under exclusivity D loses σq^{NA}. If $\omega \leq 1/2$, the former exceeds the latter and exclusivity is more profitable for any σ. If $\omega > 1/2$, exclusivity is more profitable only if complementary revenues are not too large.

The comparative statics reflect the structure of value creation. A larger consumer-side value Δ raises sellers' bids and makes exclusivity attractive for a larger range of complementary revenues. The effect of developer-side value σ depends on D's bargaining power: if $\omega > 1/2$, a larger σ favors non-exclusive contracting, because D forgoes more revenue from the excluded seller's consumers. Instead, if $\omega < 1/2$, it favors exclusivity, because under non-exclusive contracting D shares much of this revenue with sellers. An increase in t raises the product-market loss that D exploits under non-exclusive contracting, while leaving the bids unchanged, and raises the market share of the excluded seller and hence the complementary revenue that D forgoes under exclusivity. Both effects make exclusivity less attractive.

C Two-part tariffs

In the main model, sellers and the developer bargain over a fixed fee. In this section, we consider contracts to be two-part tariffs (f_i, w_i), where f_i is a fixed transfer from seller i to D and w_i is a payment per unit sold by seller i. All other elements of the model are as in Section 2. We assume that $\underline{v}$ is large enough so that the market is covered in the relevant subgames, and $0 \leq \Delta + \sigma < 3t$.

In line with the vertical relations literature, we assume that contracts are private, that is, each seller observes whether its rival adopted D's system (i.e., reached an agreement with D), but not the rival's contract. As is well known from e.g. O'Brien and Shaffer (1992) and Rey and Vergé (2004), the equilibrium outcome may then depend on the belief that each seller holds about the outcome in the negotiation of D with the rival seller. A widely-used solution concept is "contract equilibrium", which implies that in any negotiation, D and seller i maximize their bilateral profit.[39] In what follows, we use this concept to determine the equilibrium. As in Appendix B, we focus on

[39] As noted by Rey and Vergé (2004), allowing for multilateral deviations can lead to problems of equilibrium existence. Moreover, it is difficult in our framework in which both parties have bargaining power in the negotiation.

equilibria in which both sellers adopt.

Let $q_i(p_i, p_j)$ denote seller i's demand in case both sellers adopt. Consider the negotiation between i and D, holding fixed the rival's contract (f_j, w_j). Given w_i, seller i sets p_i to maximize $(p_i - w_i)\, q_i(p_i, p_j)$, so

$$q_i + (p_i - w_i)\frac{\partial q_i}{\partial p_i} = 0. \tag{26}$$

The joint payoff of i and D is $(p_i + \sigma)\, q_i + (w_j + \sigma)\, q_j$ plus terms that do not depend on (f_i, w_i). The fixed fee is a pure transfer. Therefore, in the Nash bargaining solution, seller i and D choose w_i to maximize this joint payoff and use f_i to split the surplus according to the respective bargaining weights. Disagreement payoffs depend on the rival's contract, not on w_i. Since the seller's best response is strictly increasing in w_i, choosing w_i is equivalent to choosing p_i through (26). Hence, the optimal p_i satisfies

$$q_i + (p_i + \sigma)\frac{\partial q_i}{\partial p_i} + (w_j + \sigma)\frac{\partial q_j}{\partial p_i} = 0,$$

where the first two terms represents how seller i's and D's joint profit from sales of i change with p_i, whereas the third terms represents how D's per-unit profit from sales of seller j change with p_i. Subtracting (26) from the last equation gives $(w_i + \sigma)\, \partial q_i/\partial p_i + (w_j + \sigma)\, \partial q_j/\partial p_i = 0$. Using symmetry, that is, $w_i = w_j = w$, yields

$$(w + \sigma)\left(\frac{\partial q_i}{\partial p_i} + \frac{\partial q_j}{\partial p_i}\right) = 0. \tag{27}$$

The pair i–D internalizes that D earns $w_j + \sigma$ on each unit sold by the rival and $w_i + \sigma$ on each unit sold by i. Because the product market is covered, $\partial q_i/\partial p_i + \partial q_j/\partial p_i = 0$, and so (27) holds for every w. As a result, the per-unit fee is indeterminate.

Given this indeterminacy, we can nevertheless solve for the equilibrium contracts. Let

$$\overline{w} \equiv \underline{v} + \Delta - \frac{3t}{2}$$

denote the per-unit fee for which the symmetric price $t + w$ reaches the highest level consistent with full market coverage. Thus, $w \leq \overline{w}$, where the coverage constraint binds at $w = \overline{w}$. We assume that in case of disagreement, the market remains remains covered. Let $q(w) \equiv (3t - \Delta + w)/(6t)$ denote the market share of a non-adopting seller whose rival adopted and pays per-unit fee w. Define

$$A(w) \equiv \frac{t}{2} - 2t\, q(w)^2 = \frac{(\Delta - w)(6t - \Delta + w)}{18t} \quad \text{and} \quad B(w) \equiv (\sigma + w)\, q(w),$$

where $A(w)$ is the product-market gain from agreement for a seller (the analog of $t/2 - R^{NA}$ in the

main text) and $B(w)$ is the per-unit revenue, net of the fee, that D obtains from seller i's customers who would buy from the rival if i did not adopt. We can then state the following result, which determines value migration, dependent on w:

Proposition A2. *Let $\mathcal{W} \equiv \{w : -\sigma \leq w \leq \overline{w},\ A(w) + B(w) \geq K\}$. For every $w \in \mathcal{W}$, there is a symmetric equilibrium in which both sellers adopt with contract $(f(w), w)$, where*

$$f(w) = \omega A(w) - (1-\omega)B(w) - \omega K.$$

Prices are $t + w$, each seller earns $t/2 - K - f(w)$, and individual value migration is

$$M_i(w) = \omega A(w) - (1-\omega)\big[B(w) - K\big]. \tag{28}$$

At $w = 0$, all payoffs coincide with those of the fixed-fee model in the main text.

Proof. Given a rival fee of w, the rival charges $t + w$. A seller with fee w_i charges $t + (w + w_i)/2$ and sells $q_i = 1/2 + (w - w_i)/(4t)$. The joint variable payoff of i and D is

$$\frac{t}{2} + \sigma + w - \frac{(w_i - w)^2}{8t},$$

which is maximized at $w_i = w$. Deviations that leave some consumers unserved are not profitable: The joint payoff can be written as $(\sigma + w)(q_i + q_j) + (p_i - w)q_i$. For $\sigma + w \geq 0$, the first term is at most $\sigma + w$. Against the rival price $t + w$, a seller with marginal cost w earns at most $t/2$. Hence the joint payoff is at most $t/2 + \sigma + w$, attained at $w_i = w$.

At $w_i = w$, the seller's gain from agreement is $A(w) - f - K$ and D's gain is $B(w) + f$. The bilateral surplus is $A(w) + B(w) - K \geq 0$. Nash bargaining gives the seller a share $1 - \omega$ of it, which yields $f(w)$. Seller profit is $t/2 - K - f(w)$, and $M_i = t/2 - \pi_i = K + f(w)$ gives (28). At $w = 0$, $A(0) = t/2 - R^{NA}$ and $B(0) = \sigma(3t - \Delta)/(6t)$, so (28) coincides with the expression for M_i in the proof of Proposition 1. ■

The proposition shows that, subject to the adoption condition $A(w) + B(w) \geq K$, any $w \in [-\sigma, \overline{w}]$ can constitute an equilibrium. Even negative values of w can arise. The equilibrium in our main model, which occurs if $w = 0$, is thus also a member of the equilibrium set whenever it satisfies the adoption condition. The other equilibria in the model with two-part tariffs differ in how the per-unit fee shifts the outside options. A higher w raises the non-adopter's market share $q(w)$ in the disagreement outcome, which lowers $A(w)$, and raises D's revenue at stake, $B(w)$. Both effects reduce the fixed fee and hence value migration—i.e., value migration falls in w. In the covered market, bilateral bargaining does not determine which member of the set is played.

More generally, the per-unit fee determines where the value created per each sale is captured and, consequently, how much of it is exposed to downstream competition. A positive per-unit fee transfers value from the seller layer to D. Because sellers treat the per-unit fee as a marginal cost, it is reflected in higher product prices, protecting part of the per-unit value from being competed away. A negative per-unit fee operates in the opposite direction: D transfers some of its complementary revenue to sellers as a per-unit subsidy, which lowers their marginal cost and is passed on to consumers through competition. Relative to the fixed-fee benchmark $w = 0$, a per-unit subsidy increases value migration, whereas a positive per-unit fee reduces it.

Multiple ways are possible to select among the equilibria. One is to select the equilibrium that maximizes the joint profits of D and the sellers. A higher per-unit fee raises product prices, $t + w$, without affecting total demand. Joint profits, $t + \sigma + w - 2K$, therefore increase with w, and this criterion selects $w = \overline{w}$, the upper endpoint of $\mathcal{W}$. The resulting price,

$$t + \overline{w} = \underline{v} + \Delta - \frac{t}{2},$$

is the monopoly price.[40] Because value migration decreases with w, this is also the equilibrium in which sellers obtain the largest profits. It does not necessarily maximize D's profit, however: D's profit, $\sigma + w + 2f(w)$, can decrease with w, for instance if ω is small and σ is large, because a higher per-unit fee also lowers the fixed fee $f(w)$.

Another way to select among the equilibria is to note that the indeterminacy results from the perfectly inelastic total demand. Suppose that, in addition to the Hotelling consumers, each seller faces a small segment of consumers with demand $\varepsilon(a - p_i)$, with $\varepsilon > 0$ and a large. On this segment, D also earns σ per user. Then, $\partial q_i/\partial p_i + \partial q_j/\partial p_i = -\varepsilon < 0$ and (27) implies $w = -\sigma$ in any symmetric equilibrium in which both sellers adopt, for every $\varepsilon > 0$. The same holds for any perturbation under which a lower price expands total demand. As $\varepsilon \to 0$, the selected equilibrium is therefore the one with $w = -\sigma$. As explained above, given that value migration decreases with the per-unit fee w, this fee is the one that maximizes value migration.

Finally, if per-unit fees are constrained to be non-negative, the demand-perturbation refinement selects the boundary solution $w = 0$, reproducing the equilibrium of our main model. Such a restriction may be natural when sales are reported by sellers and are costly to verify: a negative per-unit fee would turn the seller into the recipient of an output-contingent payment, creating incentives to overstate eligible sales.

[40] Given our assumption that $\underline{v}$ is large enough for the market to be covered, a firm controlling both products would optimally serve all consumers and set the highest price consistent with full coverage, which extracts the entire surplus of the marginal consumer. This outcome is the same the one that would obtain with observable contracts or with symmetric beliefs, that is, seller j expects that seller i negotiates the same contract as seller j. Such symmetry may arise from the use of most-favored-nation clauses by D.

In summary, the baseline model without two-part tariffs has shown that value migration is determined by the technological characteristics of the developer's system. The analysis of two-part-tariffs adds to this by showing that value migration may be additionally affected by contracting. A per-consumer subsidy from the developer to sellers relocates complementary revenue to the downstream layer, where competition passes it through to consumers. Therefore, it increases value migration. A positive per-consumer payment from sellers to the developer has the opposite effect: it shields part of the value from competition and reduces value migration.