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Taking Competition to the System Level: Entry Incentives, Market Convergence, and Sticky Prices

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Abstract
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Keywords: De novo entry, product integration, attacker’s advantage, product bundling, sticky prices
1 Introduction

Many individual products that are sold on individual markets require complementary products in order to be useful for customers. Examples include industrial goods and services like maintenance; computers and software applications; cameras and film; or different experts like architects and engineering consultants to plan a new building. While firms that sell individual components may sometimes engage in cooperative activities with their complementors (Brandenburger and Nalebuff 1996, Casadesus-Masanell and Yoffie 2007, Mantovani and Ruiz-Aliseda 2015), in many cases such firms also expand into providing several of the complementary products (Cabral and Villas-Boas 2005, Schmidt et al. 2016). Such an expansion into a complementary market changes the locus of competition, which will then either occur simultaneously at the individual product and the integrated product or system level (Farrell et al. 1998)—leading to partial market convergence—or even completely shift to the system level (Matutes and Regibeau 1988)—which implies full market convergence (Schmidt, et al. 2016, Stieglitz 2003).

We can observe competition (either partly or fully) shifting to the system level in a number of industries. Examples include the move from individual productivity software tools to integrated office suites in the 1980s, which was initiated by Lotus (Cottrell and Nault 2004), the integration of digital cameras into cell phones initiated by Nokia (Doz and Kosonen 2010), the convergence between sellers of crop seeds and those of herbicides in the agrochemicals industry, which exploited advances in genomics (Hinterhuber 2002), the move by specialized consulting firms to integrate and provide “one-stop-shopping solutions” in the British construction industry (Cacciatori and Jacobides 2005), the move by IBM in the 1990s to become an integrated solution provider by adding software and service product categories to its offering (Davies et al. 2007), or the convergence of telephony, internet and entertainment services (Thanassoulis 2011). Manufacturing industries provide a particular instructive example, as many manufacturing firms are increasingly expanding their operations into the provision of complementary services (often through acquisitions), which are bundled with the primary good (Cusumano et al. 2014, Oliva and Kallenberg 2003). Often these firms become systems integrators and offer tailored “solutions” as combinations of goods and services that match specific customer requirements (Davies, et al. 2007). The bundle is sold as a service that substitutes for the combination of the individual complements (Cusumano, et al. 2014). After expansion into the complementary, services firms usually continue selling

1A prominent example is Rolls Royce’s “power-by-the-hour” model, where airline customers do not purchase a jet engine and maintenance but engine availability (“power-by-the-hour”; Smith (2013)).
the original product as a standalone but also continue to be specialized complementary service providers. As a consequence, in these industries often both individual components and the bundle are competing on the market at the same time.

Prior studies have found that such partial or full market convergence, which integrates previously separate markets and thus changes the locus of competition (Greenstein and Khanna 1997, Schmidt, et al. 2016, Stieglitz 2003), is driven by a number of factors including systemic innovation (Fixson and Park 2008), incompatible or proprietary interfaces between complements (Matutes and Regibeau 1988), superior interoperability between complements (Schmidt, et al. 2016), or heterogeneity in the quality of individual components (Farrell, et al. 1998). From a business strategy perspective, prior literature has focused on the decision whether to make complementary product compatible as well as the decision to invest into improving interoperability (thereby typically taking a mix and match setting as the starting point; e.g., Hermalin and Katz (2013), Mantovani and Ruiz-Aliseda (2015), Matutes and Regibeau (1988), Schmidt, et al. (2016)). However, the literature has neglected the more fundamental strategic decision of product market scope (Rumelt 1974, Rumelt 1982), i.e., the conditions under which it would be beneficial for sellers of an individual complement to enter with an integrated offering in the first place and thereby take competition to the system level. Examining this entry decision is the focus of our paper.

We take a market-based (as opposed to a capability-based) approach (Christensen 1997, Shapiro 1989) and use a stylized game-theoretic model (a differentiated Bertrand setting) to examine firms’ incentives to enter a set of two individual complementary markets with an integrated offering (which we assume to be based on a newly available technology or a “systemic innovation”; Teece (1996)). We examine entry incentives for the individual incumbents in each of the complementary markets (which we call “specialists”) as well as for a potential entrant who has no prior presence in either of the complementary markets (which we call a “de novo entrant”). Our model is built on minimal assumptions and, in particular, starts with symmetry among firms: Neither of the specialists has an advantage over the other in providing the integrated offering and, likewise, the de novo entrant does not have an advantage or disadvantage over an integrating specialist in providing the integrated offering. Nevertheless, even with these assumptions our model yields substantial heterogeneity in outcomes, which is due to an integrating specialist facing a trade-off between capturing additional sales from the integrated offering and cannibalizing his sales of the individual complement. A de novo entrant does not face this trade-off.

We start our analysis by examining the incumbents’ incentives to enter with an integrated
offering without the possibility of de novo entry. Here we find that entry decisions are strategic substitutes: Once one specialist starts providing the integrated offering, it will be optimal for the other specialist to refrain from integrating, thus inducing heterogeneity in entry timing. This is because the intensity of competition if only one specialist integrates is lower than under full integration (Thanassoulis 2011). When adding the possibility of de novo entry we find that both horizontal and vertical differentiation affect the entry decision.

Examining the role of horizontal differentiation between the integrated offering and the bundle of individual complements, our model yields the result that as long as the integrated offering and the bundle of individual complements are sufficiently horizontally differentiated (i.e., they address separate customer segments), the de novo entrant will have larger incentives to enter than either of the specialists. This is intuitive as the de novo entrant does not sell another product and therefore does not fear self-cannibalization. Interestingly, this result is reversed when the two types of bundles are close substitutes (i.e., the integrated offering addresses the same customers as the individual complements). In this case, incumbent specialists have stronger incentives to enter. The intuition is also rooted in the self-cannibalization effect but now has the opposite effect. When entering the system market, the incumbent raises its price for its specialist good to reduce competition and diminish the self-cannibalization effect. By contrast, after entry of the de novo entrant, the incumbents lower their prices for the specialized product due to fiercer competition. This effect makes entry of the de novo entrant unattractive. We therefore demonstrate that incumbents have stronger entry incentives particularly in the case when cannibalization effects tend to be an important issue (“direct entry”). By contrast, de novo entrants have higher incentives in the case of “indirect entry” (Bresnahan and Greenstein 1999). This also means that when the integrated offering has disruptive potential in the sense of Christensen and Bower (1996), i.e., it is not seen as a viable substitute by the incumbents’ customers, indirect entry by a de novo entrant is more likely.

Examining vertical differentiation, i.e., superiority of the integrated offering compared to the bundle of individual complements (Schilling 2000, Schmidt, et al. 2016), we obtain that the higher the relative quality of the integrated offering, the higher the de novo entrant’s incentives to enter, even though the specialists can offer an integrated product of exactly the same quality. The reason is that the profit from the integrated offering rises with its quality, which benefits more the firm which was previously not active in any market.

Additionally, we examine the effect of “sticky” prices, which yields novel insights on advantages of timing. In particular, the complementary specialists may have committed
to a certain price level, which cannot be immediately changed once the integrated offering is possible. We model this as a sequential (Stackelberg) setup where prices for individual complements are set before prices for the integrated offering are set. To the best of our knowledge, we are the first to model sticky prices at the product level and not at the firm level. Prior studies of sequential pricing have not made that distinction because in those models each firm sets only one price. In our model, in contrast, an integrating specialist will set prices for different products at different points in time. As a consequence, the typical result that firms prefer sequential pricing as this leads to reduced price competition does not hold in our setting. We demonstrate that an integrating specialist would prefer that prices are set simultaneously rather than sequentially.

With sequential price setting, the non-integrating specialist sets a higher price for its component to reduce competition. To counter this effect, which leads to reduced sales of the specialist product, the integrating specialist lowers the price for its component. This effect is to the detriment of the integrating specialist, and dominates the standard effects of Stackelberg competition. Sticky prices also weaken the degree to which entry decisions by the complementary specialists are substitutes. On the other hand, a de novo entrant does not face the trade-off of an integrating specialist. Therefore, it benefits from sticky prices. Thus, additionally to larger degrees of horizontal and vertical differentiation, stickiness of prices will lead to stronger entry incentives for the de novo entrant compared to either of the specialists.

Our results speak to two literatures. First, we add to the literature in the industrial economics tradition that examines multi-product strategies and the associated strategic decisions. This literature typically takes firm scope as given and examines issues of bundling and compatibility (Armstrong and Vickers 2010, Matutes and Regibeau 1988, Schmidt, et al. 2016). Our contribution to that literature is to show that the decision to offer an integrated product is governed by differences between firms in how that decision affects market structure. We find that among incumbents entry decisions are strategic substitutes, as rivalry is less intense when one incumbent offers the integrated product than when both do, which echoes a result obtained by Thanassoulis (2011) in a mix-and-match setting. Furthermore incumbents and de novo entrants face different entry incentives (Gilbert and Newbery 1982, Reinganum 1983), which depend on the degree of (both horizontal and vertical) differentiation. Specifically, the intuition that the de novo entrant has higher incentives because it does not face a threat of self-cannibalization is only correct for high levels of differentiation. At low levels of differentiation, when the integrated product directly competes against the
incumbents’ specialist products, incumbents have higher incentives to adopt because they can temper rivalry through pricing. If a de novo entrant would directly compete against incumbents, they would instead react aggressively, rendering such a direct entry attempt unprofitable.

Second, our results also contribute to the business strategy literature. We identify an “attacker’s advantage” (Christensen and Rosenbloom 1995), whose existence depends on the degree of horizontal and vertical differentiation and the stickiness of component prices. Specifically, when a systemic innovation arises in an industry, a de novo entrant has larger incentives for taking competition to the system level than incumbent specialists when the systemic innovation is “disruptive” in the sense of Christensen and Bower (1996), i.e., when it addresses the needs of an underserved or newly emerging segment in an industry. Consequently we should see systemic innovations with disruptive potential to be introduced by de novo entrants rather than incumbents (the “indirect entry” by minicomputers and PCs in the computer industry observed by Bresnahan and Greenstein (1999)). Our model thus provides a market-based explanation for why incumbents may not introduce disruptive systemic innovations as opposed to an explanation that relies on internal resource allocation dynamics or bounded managerial rationality (Christensen and Bower 1996, Henderson 2006).

The rest of the paper is organized as follows. Section 2 sets out the model. Section 3 analyzes the entry decisions by incumbents only. Section 4 considers the model with incumbents and a de novo entrant. Section 5 considers sticky prices for the specialist products. Section 6 discusses our result and provides a conclusion.

2 The Model

We use the simplest possible model to capture firms’ incentives to take competition to the system level. Customers demand a set of two perfectly complementary products or components (e.g., hardware and software, or a camera and a mobile phone). At the outset there are two specialist firms that each offer one of the components. A newly available technology (a systemic innovation; Teece, 1996) that allows offering an integrated product that contains the two components is then available. The two specialist firms will have to decide whether to invest in this technology and subsequently launch an integrated offering that competes against the specialists’ bundle. Additionally, the integrated offering can also be launched by a de novo entrant who is not active in either of the markets for separate products.
Firms compete in prices. We denote by $P_{Si}$ the price of specialist $Si$, with $i = 1, 2$, for the component in the offering of the two specialists. If a specialist offers the integrated product, the price for its integrated product is $P_{Ii}$. If the de novo entrant offers the integrated product, its price is $P_{IE}$. A consumer who buys the specialists’ offer needs to pay $P_{S1} + P_{S2}$. On the other hand, when buying the integrated offer the consumer pays a single price, which is either $P_{Ii}$ or $P_{IE}$.

The independent specialists’ offering and the integrated offering are vertically and horizontally differentiated. We model vertical differentiation as a difference in benefits between the two types of offering. Specifically, consumers obtain a benefit of $U_S$ for the bundle of specialist products and a benefit of $U_I$ for the integrated product, where the difference between $U_I$ and $U_S$ represents the degree of vertical differentiation. $U_I$ may be either larger or smaller than $U_S$. In the former case consumers may enjoy benefits from, for example, superior interoperability or increased convenience and therefore put higher value to the bundle (e.g., Schilling, 2000; Schmidt et al., 2016). By contrast, the latter case may reflect that a specialist is more experienced in the production of its component, implying that the two-component offering is of higher quality than the bundle.

We model horizontal differentiation as the degree to which the two types of offerings are substitutes. Specifically, the demand for each offering is decreasing in own price and increasing in prices of the rival offers. However, the increase in demand caused by a raise in the rival’s price is smaller in absolute value than the decrease caused by a raise in the own price. To express this in a simple form, we consider a linear demand system. In particular, suppose that the specialists’ offer and one integrated offer (by specialist $i$, say) are available in the market. The system of inverse demands is then given by

\[ P_{S1} + P_{S2} = U_S - Q_S - \gamma Q_{Ii} \quad \text{and} \quad P_{Ii} = U_I - Q_{Ii} - \gamma Q_S, \]

where $Q_S$ and $Q_{Ii}$ are the demands of the specialists’ offer and the integrated offer, respectively. Product differentiation is captured by the parameter $\gamma$, which is between 0 and 1. If $\gamma = 0$, the two offers are independent, whereas $\gamma \to 1$ means that offers become perfect substitutes. So, a higher $\gamma$ expresses a smaller degree of differentiation. We can invert this

\[ U(Q_S, Q_{Ii}) = U_S Q_S + U_I Q_{Ii} - \frac{Q_S^2 + Q_{Ii}^2 + 2\gamma Q_S Q_{Ii}}{2} + M, \]

where $M$ is the utility from income. Maximizing this utility subject to the budget constraints leads to the demand system.
system to derive the direct demand for each offer, which yields

\[ Q_S = \frac{U_S - P_{S1} - P_{S2} - \gamma(U_I - P_{Ii})}{1 - \gamma^2} \quad \text{and} \quad Q_{Ii} = \frac{U_I - P_{Ii} - \gamma(U_S - P_{S1} - P_{S2})}{1 - \gamma^2} \].

(1)

It is evident that, for example, \( Q_S \) falls in \( P_{S1} + P_{S2} \) and rises in \( P_{Ii} \), with the latter effect being smaller than the former in absolute value for all \( \gamma < 1 \). If only the specialists’ offer is available, then \( Q_{Ii} = 0 \), and the demand for the specialists’ offer is \( Q_S = U_S - (P_{S1} + P_{S2}) \). Similarly, if a second firm (the de novo entrant, say) enters the market with its integrated product, this offer is horizontally differentiated to the other two offers and the demand system for the three bundles becomes

\[ P_{S1} + P_{S2} = U_S - Q_S - \gamma(Q_{Ii} + Q_{IE}), \quad P_{Ii} = U_I - Q_{Ii} - \gamma(Q_S + Q_{IE}), \quad \text{and} \quad P_{IE} = U_I - Q_{IE} - \gamma(Q_S + Q_{Ii}). \]

Therefore, if a new offer becomes available, our demand system allows for demand expansion and business stealing, thereby capturing the main changes in the market following entry.\(^3\)

To offer an integrated offering a firm has to invest in and adopt a new technology which enables it to incorporate the two components in a single integrated system. The cost of adopting this technology and therefore being able to enter the market for the system is the same to all firms and equal to \( C \). Following Adner and Zemsky (2005), one can think of these costs as falling over time, that is, \( C'(t) < 0 \). This is due to technology improvements and experience that allows firms to enter at lower costs. Although our model is not a dynamic one to keep matters simple, we can interpret different levels of the adoption costs as different points in time, with lower costs representing later points in time.\(^4\)

To focus on the market-side effects we assume that firms are homogeneous in terms of their costs, which we thus for simplicity assume to be zero. The profit function of a specialist firm \( i \) is therefore \( \Pi_i = P_{Si}Q_S \) in case it has not entered the market with the integrated product and \( \Pi_i = P_{Si}Q_S + P_{Ii}Q_{Ii} \) in case it offers the integrated product. The profit of the de novo entrant is 0 without entry and \( \Pi_E = P_{IE}Q_{IE} \) with entry. Overall, since firms are symmetric with respect to technology-related factors, such as adoption or production costs, we purely focus how strategic incentives drive market convergence.

We consider a two-stage game. In the first stage, each firm decides whether to adopt the new technology and enter the market for the integrated offer. In the second stage, firms

\(^3\)In our demand system, each integrated offer has the same value \( U_I \). Vertical differentiation therefore occurs on the level of the offer. However, the offers are still horizontally differentiated, as they are sold by different firms.

\(^4\)See also our discussion in Section 6.
simultaneously set their prices, given the entry choices in the first stage.\footnote{In Section 5, we analyze the game in which prices for the specialists’ offer are set first, and prices for the integrated offers are set second.} That is, if no firm offers an integrated product, only the two specialists set their respective prices for the two-component offer. Instead, if all firms offer an integrated product, there are five prices to be set, the two prices for the specialists’ offer and the prices for the three integrated offers. If only a subset of firms entered the market for the integrated product, the prices are chosen accordingly. The solution concept is subgame perfect Nash-equilibrium.

Finally, we assume that the difference between $U_S$ and $U_I$ is sufficiently small, such that in equilibrium all products have positive demand. This implies that $\gamma$ is small relative to this difference. In particular, if $U_S = U_I$, then demand for all products is positive for all $\gamma \leq 1$. If instead $U_S$ is larger or smaller than $U_I$, $\gamma$ must be smaller than 1 to ensure positive market shares of each offer.\footnote{For example, in case only the two specialists can adopt, the boundaries on $\gamma$ are $\gamma \leq U_S/(2U_I - U_S)$ for $U_I \geq U_S$, and $\gamma \leq (\sqrt{U_S^2 + 3U_I^2 - U_S})/U_I$ for $U_I < U_S$. It is evident that if $U_I = U_S$, the threshold value for $\gamma$ equals 1.}

We start with an analysis in which only the two specialist firms can enter the market for the integrated product (e.g., because adoption costs are too high for a firm not in the industry). In Section 4, we turn to the full analysis in which all three firms can enter the integrated product market.

3 Only Specialists Enter

We start by presenting the analysis of the different scenarios that can occur in Stage 2 sequentially.

No firm enters

If no firms enters the market for the integrated offer, the profit of each specialist is given $\Pi_{Si} = P_{Si}Q_S = P_{Si}(U_S - P_{S1} - P_{S2})$. Maximizing with respect to $P_{Si}$ yields $P_{Si} = U_S/3$ and each firm obtains a profit of $U_S^2/9$. As is well-known, prices are set at too high a level to maximize joint profits of firms. If firms sell complementary products, each firm does not consider the positive effect that an own price reduction has on the profit of the other specialist, resulting in higher than optimal prices.

Only firm $Si$ enters

If only firm $Si$ enters the market for the integrated offer, then it offers two products (the integrated product and a component of the specialists’ product) whereas firm $S-i$ offers
only one product. The profits are then given by $\Pi_{Si} = P_{Si}Q_S + P_{Ii}Q_{Ii}$ and $\Pi_{S-i} = P_{S-i}Q_S$, where $Q_S$ and $Q_{Ii}$ are given in (1). The equilibrium prices are $P_{Si} = U_S/3 + \gamma U_I/6$, $P_{S-i} = U_S/3 - \gamma U_I/3$, and $P_{Ii} = U_I/2$. The resulting profits are

$$
\Pi_{Si} = \frac{U_S^2(9 - 5\gamma^2) + 4U_S^2 - 8\gamma U_S U_I}{36(1 + \gamma)(1 - \gamma)} \quad \text{and} \quad \Pi_{S-i} = \frac{(U_S - \gamma U_I)^2(1 - \gamma)}{9(1 + \gamma)(1 - \gamma)}. \quad (2)
$$

Since firm $Si$ sells two substitute products, the firm faces the problem of self-cannibalization (i.e., lowering the price for one product to increase its demand reduces the demand for the other product). This induces the firm to compete less aggressively. Specifically, its price for the specialist component is higher than without entry. Conversely, firm $S-i$ faces competition from the integrated offer of firm $i$. It therefore reacts by lowering its price relative to the case without entry.

**Both firms enter**

If both firms enter, three products are available in the market, the specialized product and the two integrated products. The demand for each product is given by

$$
Q_S = \frac{(U_S - P_S)(1 + \gamma) - \gamma(2U_I - P_{Ii} - P_{S-i})}{(1 + 2\gamma)(1 - \gamma)} \quad \text{and} \quad Q_{Ii} = \frac{U_I - P_{Ii}(1 + \gamma) + \gamma P_{I-i} - \gamma(U_S - P_S)}{(1 + 2\gamma)(1 - \gamma)},
$$

where $P_S = P_{Si} + P_{S-i}$. The profit function of firm $Si$ is $\Pi_{Si} = P_{Si}Q_S + P_{Ii}Q_{Ii}$. The equilibrium prices are symmetric and given by $P_{Si} = U_S/3 - \gamma U_I/(3(2 - \gamma))$ and $P_{Ii} = U_I(1 - \gamma)/(2 - \gamma)$. Comparing these prices with the ones in the case where only firm $Si$ enters, it is evident that both prices of firm $Si$ are lower if the rival entered as well. Since the firm now faces competition for two products and not only for one, both of its prices will fall. Moreover, the price for the specialist good is also lower than in the situation where no firm offered an integrated product. As a consequence, taking competition to the system level, intensifies competition not only within the system but also at the specialized goods. Intuitively, as system prices fall due to competition, demand for the specialized good falls, and this induces firms to lower the prices there as well (component prices and prices of the integrated offer are strategic complements). The competition effect then dominates the effect of self-cannibalization, leading to a fall of all prices. Inserting the equilibrium prices into the profit function, we obtain that profits are given by

$$
\Pi_{Si} = \Pi_{S-i} = \frac{U_S(2 - \gamma) - \gamma U_I(U_S(1 + \gamma) - 2\gamma U_I)}{9(1 + 2\gamma)(2 - \gamma)(1 - \gamma)} + \frac{U_I(U_I(3 - 2\gamma^2) - \gamma U_S(2 - \gamma))}{3(1 + 2\gamma)(2 - \gamma)^2}.
$$

The second-order conditions are fulfilled as both profit functions are strictly concave.
Equilibrium entry decisions

We can now determine the incentives for firms to enter the market with an integrated offer. In particular, we analyze if firms have an incentive to enter the system market at the same time (that is, for the same value of $C$) or at different times (i.e., for different values of $C$). In the former case, entry decisions are strategic complements. If the adoption cost $C$ are low enough, so that one firm optimally enters, this increases the value of entry for the rival. As a consequence, the rival will enter as well, which implies that firms enter at the same time. By contrast, in the second case, the incentives for a firm to enter are lower if the rival has decided to enter. This implies that the firm will enter later, and entry decisions are strategic substitutes. Our first result shows that in equilibrium always the latter case occurs.

**Proposition 1**

Entry decisions are strategic substitutes.

Specifically, in equilibrium, there are two thresholds of the adoption costs, denoted by $\overline{C}$ and $\underline{C}$, with $\overline{C} > \underline{C}$, where the following holds:

- If $C > \overline{C}$, no firm enters.
- If $\overline{C} \geq C > \underline{C}$, only one firm enters.
- If $C \leq \underline{C}$, both firms enter.

This result shows that although firms are completely symmetric, their entry decisions will differ, with one firm ultimately being the leader and the other firm being the follower. In fact, there is a region with intermediate adoption costs, in which only one firm enters with an integrated product. The intuition for this asymmetry is as follows: The firm that enters offers both the specialized component and the integrated offering. Being able to set two prices gives it an additional lever that allows it to segment the market (and price the specialist product higher than it otherwise would) and thus squeeze the remaining specialist. Because imitating the leader would increase rivalry the remaining specialist will not immediately integrate but wait until the cost of integration is low enough to make integration worthwhile.

Our prediction is therefore that there is a sizable amount of time that will elapse between entry times of firms. In fact, this is what we observe in many industries. For example, in the market for office suites, Lotus were the first firm combining spreadsheet, database, programming, and graphics categories in a single package (called Lotus 1-2-3) several years before other firms (such as Ashton-Tate) followed. Similarly, in the market for digital cameras and cell phones, Nokia bundled these goods together some years before other cell phone producers followed.

**Prisoner’s Dilemma**

As is evident from the discussion above, a firm’s decision to enter does not only affect its own profit but also the profit of its rival. In particular, entry increases demand due to product
differentiation but also intensifies price competition. Therefore, the profit of firm $S - i$ falls, if firm $Si$ offers the integrated product. We can therefore analyze whether this negative effect of entry can lead to a situation in which both firms decide to enter individually but it would be jointly optimal not to enter.

**Proposition 2**
*If competition is sufficiently intense, firms are trapped in a prisoner’s dilemma.* Specifically, for $C < C_0$ and $\gamma$ sufficiently large, both firms offer the integrated product but would make higher profits if none of them offered the integrated product.

The Proposition demonstrates that firms may enter the market too early. They would be better off by either waiting until adoption costs are smaller or even do not enter at all. The intuition behind this result lies in the effect that each entry decision opens a new front of competition. Whereas the first firm offering an integrated product increases competition because its integrated good competes with the specialized good, the second entrant’s decision leads to competition between the second integrated good with the specialized product and competition between the two integrated goods. As shown above, this leads to a fall in prices because the increased competition effect dominates the self-cannibalization effect. Therefore, if differentiation between products is relatively small, the later entrant lowers the profits of the first entrant by a significant amount. This implies that both firms find it individually rational to enter although they would jointly be better off not to enter.

Interestingly, as we show in the proof of Proposition 2, the result even holds if adaptation costs are equal to 0, which demonstrates the strength of the competition-intensifying effect. Although industries are ultimately transformed to the system level, this can nevertheless be profit destroying. This is consistent with the observation that integrated solutions can lead to deep discounts in many industries. For example, as reported by Thanassoulis (2011), the introduction of triple play (i.e., bundling of broadband internet access, television, and fixed telephony) lowered prices dramatically for these services, both in the US and in Europe.

## 4 De Novo Entry
We now extend our analysis to the case where, additional to the two incumbent specialists, there is a potential de novo entrant who does not offer one of the specialist components and who considers offering the integrated bundle. In case the de novo entrant offers the integrated bundle, four different products can potentially be supplied. These are the integrated product
from each of the three firms plus the bundle consisting of the specialized products. The profits for the different cases can be determined in the same way as in the last section.\textsuperscript{8}

As in the case without the de novo entrant, we obtain that entry decisions are strategic substitutes, as entry of one firm lowers the value of entry for competitors. However, in addition, to the case where only specialists can enter, we can now determine if a de novo entrant has stronger or weaker incentives to offer the integrated product than specialists have. In particular, we will demonstrate under which conditions an attacker’s advantage exists (that is, due to its lack of presence in the specialized good market, the de novo entrant has a greater incentive to attach the market via the bundle). At first glance, it might be natural to presume that such an attacker’s advantage exists as the de novo entrant does not suffer from the self-cannibalization problem. Our next result demonstrates that this intuition is only partially correct.

**Proposition 3**

*The de novo entrant has either the strongest or the weakest incentives to enter. This is, it will either be the first or the last to enter (but never between the two specialists). It will be the first if competition is weak and the last if competition is fierce.*

The result shows that standard intuition is only confirmed if competition between products is weak. In this case, the de novo entrant has in fact the strongest incentives to offer the integrated product. The reason is that the de novo entrant does not need to fear self-cannibalization. The profit of the de novo entrant without offering the bundled product is zero. Therefore, when entering, it will face no loss in the demand on other products. Instead, a specialist partly cannibalizes its own product and therefore prefers to wait until entry costs are low enough. As a consequence, the de novo entrant enters first.\textsuperscript{9}

By contrast, if competition is fierce, a different effect comes into play. Since a specialist firm is always active (either only on the specialized product or on the specialized and the integrated product), it can always influence the competitiveness through its price setting. If the de novo entrant enters, the specialist faces competition from an additional product and will therefore lower its price. This renders entry of the de novo less profitable than if the specialist does not adjust its price. Moreover, if a specialist enters first, it will price less aggressively for the specialist good in order to reduce self-cannibalization. This makes entry more profitable. If competition between products is relatively fierce, these effects are

\textsuperscript{8}We report the respective value in the Appendix in the proof of Proposition 3 in case they are relevant for the entry decision of a firm.

\textsuperscript{9}Formally, for $U_I = U_S$, the threshold for $\gamma$ is around 0.506.
particularly important, and the different reactions in the price of the specialized product to own entry versus de novo entry are large. It follows, that this effect dominates the standard effect if the degree of competition is fierce.

Interestingly, it is precisely the self-cannibalization effect, that gives rise to an attacker’s disadvantage if competition is fierce. Therefore, the strategic implications of self-cannibalization are very different than in previous studies. The possibility of an incumbent to temper rivalry through pricing reverses the standard intuition. Our result shows that a firm can diminish the self-cannibalization effect via its price choice for the existing product but can also reduce the profitability of entry of rivals. This possibility can lead to further entry of incumbents without any preemption or proliferation reasons, and therefore implies an attacker’s disadvantage.

Having determined how horizontal product differentiation affects entry incentives, we now turn to vertical differentiation. Specifically, we can analyze if an increase in the quality of the integrated offers makes entry of the de novo entrant more or less likely. We obtain the following result:

**Proposition 4**

*The higher the quality of the integrated product (relative to the bundle of the two specialized products), the more likely it is that the de novo entrant enters first.*

The intuition behind this result can be related to the one given after Proposition 3. If the integrated product has higher quality, the difference between $U_I$ and $U_S$ increases. Such an increase in vertical differentiation reduces the toughness of competition between products. Although a specialist firm acts more aggressively if the de novo entrant offers the integrated product than when the firm offers the integrated product itself, this effect is now smaller. This renders entry of the de novo entrant relatively more profitable, thereby explaining the result.

It follows that both a larger degree of horizontal differentiation and of vertical differentiation increases entry incentives of the de novo entrant relative to the ones of the incumbent specialists. Therefore, our model provides a clear-cut prediction how a reduction in the competitiveness of the market affects entry incentives.

Finally, we can analyze how the prisoner’s dilemma between the two specialist firms pointed out in the last section is affected by the possibility of de novo entry. We obtain a clear-cut result:

**Proposition 5**

*The prisoner’s dilemma problem becomes more severe for the specialists. Specifically, the*
parameter range for which a prisoner’s dilemma occurs becomes larger with a de novo entrant than without.

As the result indicates, the presence of the de novo entrant increases rather than reduces the possibility that a prisoner’s dilemma occurs. This means, given that the de novo entrant offers the integrated product, specialist firms are better off not to enter the market for the specialist good for a large parameter range but in equilibrium they nevertheless do so, as this is individually (but not jointly) optimal. For example, if $U_I = U_S$, then even if adoption costs are zero, a prisoner’s dilemma occurs for $\gamma$ larger than approximately 0.252. Instead, without the presence of the de novo entrant, a prisoner’s dilemma can only occur if $\gamma$ is larger than approximately 0.705.

The reason for this difference is that the offer of the de novo entrant increases competition on multiple fronts. If all firms enter the market for integrated products, there are overall four different products available. Since all products are substitutes to each other, there are six different competition margins. (Specifically, the specialized product competes against the three bundles, which gives three margins, and the thee bundles compete against each other, which are another three margins.) By contrast, if the de novo entrant is not present, there are only three margins, in case both specialists enter. This implies that the presence of an additional product increases competition not just linearly but convexly, thereby making the prisoner’s dilemma problem more severe.

5 Sticky Prices

In the baseline model, we assumed that prices of the integrated product and prices of specialist product are set at the same time. This is a realistic assumption in situations in which prices can be adjusted relatively flexibly. This is the case for the integrated offer which comes newly on the market, implying that each firm sets the price for the integrated product for the first time. However, the specialist products exist already for some time. Therefore, long-term contracts with retailers may exist, which make it difficult for incumbents to change the prices of the specialist products. In addition, consumers are perhaps familiar with the prices of these products and would be repelled by large changes in the prices. This implies that prices of the specialist products are likely to be more sticky than those of the integrated products.

A natural way to capture such stickiness in prices is by sequential price setting. In particular, in this section we consider a Stackelberg game in which incumbents first set the
prices of the specialized products whereas prices for the integrated offers of the different firms are set thereafter. As an example, if, say, firm $S1$ and the de novo entrant have entered with an integrated offer, then in the first stage firms $S1$ and $S2$ set the prices for the specialist product ($P_{S1}$ and $P_{S2}$), and in the second stage firm $S1$ and the de novo entrant set the prices for their integrated products ($P_{I1}$ and $P_{IE}$), respectively. This structure represents that incumbents can commit to the prices set for the specialist products but do not have flexibility to adjust them easily once the prices for the integrated products are set.

It is important to note that the sequentiality of price setting in this structure occurs on the product level rather than on the firm level. In the classic literature on Stackelberg competition, one firm (the Stackelberg leader) sets its strategy variable before the second firm (the Stackelberg follower) where the role of the firms is either exogenously given (e.g., due to size) or firms can invest to be the leader. This implies that the role of being leader or follower is not due to different products or technology-driven but assigned to firms. Instead, in our case in which multiple heterogeneous products are offered on the market, the sequentiality of pricing decisions follows more naturally from the heterogeneity of products. It is therefore a new way of analyzing Stackelberg competition, which cannot be done in the previous literature, as each firm produces only one product there. Note that our setting also implies that a specialist firm which offers the integrated product sets prices at different stages. (i.e., $Si$ sets the price for its specialized product $P_{Si}$ in stage 1 and the price for its integrated product $P_{I1}$ in stage 2).

We follow the same structure as in the case with simultaneous pricing and analyze first the situation without the de novo entrant. We consider the case with de novo entry thereafter. To simplify the exposition and bring out the novel results in the simplest way, in what follows we focus on the case without quality differentiation ($U_I = U_S = U$).

### 5.1 Specialists only

As on the case of simultaneous pricing, we consider the different entry scenarios in turn. If both specialists do not offer the integrated product, prices are set simultaneously and the profits are $U_S^2/9$, as before.

Now suppose that only $Si$ offers an integrated product. In the second stage, $Si$ maximizes its profit $P_{Si}Q_S + P_{Ii}Q_{Ii}$ with respect to $P_{Ii}$, for given $P_{Si}$ and $P_{S_{-i}}$. Doing so yields $P_{Ii}(P_{Si}, P_{S_{-i}}) = (U(1 - \gamma) + \gamma(P_{Si} + P_{S_{-i}}))/2$. In the first stage, the two specialists set

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the prices for the specialist good, taking into account that $P_{Ii}$ will be set as in the formula above. Solving the first stage, we obtain $P_{Si} = U(1 + \gamma)(2 - \gamma)/(2(3 - \gamma^2))$ and $P_{S-i} = U(1 - \gamma)/(3 - \gamma^2)$. Plugging this into $P_{Ii}$ yields $P_{Ii} = U/2$ The resulting profits are

$$\Pi_{Si} = \frac{U^2(13 + 5\gamma - 10\gamma^2 - 2\gamma^3 + 2\gamma^4)}{4(1 + \gamma)(3 - \gamma^2)^2}$$ and $$\Pi_{S-i} = \frac{U^2(1 - \gamma)(2 - \gamma^2)}{2(1 + \gamma)(3 - \gamma^2)^2}.$$ (3)

In the same, we can solve the case in which both firms offer an integrated product. The resulting the profit of each firm in this case is

$$\Pi_{Si} = P_{S-i} = \frac{U^2(1 - \gamma)(1 + \gamma)(8(26 + \gamma(59 + 80)) - 3\gamma^3(48 + 53\gamma))}{(1 + 2\gamma)(24 + 36\gamma - 10\gamma^2 - 17\gamma^3)^2}.$$ (4)

We can now determine the optimal entry decisions and compare the results with simultaneous pricing. Before doing so, we state an important result for the case in which only firm $Si$ offers an integrated product.\textsuperscript{11}

**Proposition 6**

If only firm $Si$ enters, then this firm is hurt by sequential pricing relative to simultaneous pricing. By contrast, firm $S-i$ benefits from sequential pricing. In this respect, there is a second-mover disadvantage.

To put the result in perspective to previous literature on Stackelberg competition, let us first briefly recap the main insights from Stackelberg games when firms set prices. With sequential price setting, the first mover raises its price relative to the equilibrium with simultaneous price setting to induce the second mover to behave less aggressively in the second stage. (This occurs because prices are strategic complements.) As a consequence, both firms benefit but the second mover benefits more because it reacts optimally to a higher price set of the first mover. Therefore, there is a second-mover advantage.

Our result runs counter to this result, as we identify a disadvantage for the firm that entered the integrated product market—and therefore moves second—relative to simultaneous pricing. The intuition is as follows: The non-entering firm $S-i$ sets a higher price in the first stage, precisely to induce less aggressive behavior in the second stage. However, since the specialists’ products are perfect complements, this leads to lower sales for firm $Si$ on the specialist product. The firm counters this effect partially by lowering its price $P_{Si}$ in the first stage, which implies that it obtains a lower revenue on the specialist product. Since the price of the specialist product rises, and firm $Si$ reacts optimally with its price of the integrated

\textsuperscript{11}The result will also help us in comparing the optimal entry decisions below.
product, it obtains higher profits on the integrated product in the sequential timing than in the simultaneous one. However, this effect is only indirect, whereas the effect on the lower profit of the specialized product is a direct one. The reason is that both effects are triggered by the $S - i$’s price increase of the specialized good, implying that the effect in this market dominates. Therefore, the profit of the firm offering an integrated bundle is lower.

This explanation demonstrates that sequential pricing decisions on the product level can lead to fundamentally different results than on the firm level. We can now draw on this result to analyze optimal entry decisions. We obtain the following result:

**Proposition 7**

*Comparing sequential with simultaneous pricing, the following results occur:*

- First entry with sequential pricing occurs for a lower value of $C$ than first entry with simultaneous pricing.
- Second entry with sequential pricing occurs for a higher value of $C$ than second entry with simultaneous pricing if competition is relatively fierce (that is, products are relatively close substitutes) and for a lower value of $C$ if competition is weak.
- The difference in $C$ between first and second entry decisions is lower with sequential than with simultaneous pricing.

The first result of Proposition 7 follows from Proposition 6. Since the profit of $Si$ from entering is strictly lower with sequential pricing whereas the profit from not entering is unchanged (given that $S - i$ has not entered), a lower adoption cost $C$ is needed to induce the firm to enter. Interpreted in terms of time, this implies that first adoption occurs at a later point in time with sequential pricing.

If both firms offer the integrated bundle, the profit of each firm is higher in the sequential game than in the simultaneous one if competition is relatively fierce. In this case, the well-known price-dampening effect of sequential competition dominates. By contrast, if competition is weak, the effect described above for the case in which only firm $Si$ entered dominates. Each firm sets the specialist good price higher leading to lower sales of this product, which cannot be compensated by the higher sales of the integrated products.

Finally, the difference between the threshold values of $C$ between first and second entry is always lower with sequential pricing. This occurs because the effect that first entry occurs at a lower level of $C$ is larger in size than the effect that the second entry might also occur at a lower $C$. In addition, for fierce levels of competition, the firm entering second will do
so even at a higher value of $C$, implying that both thresholds move closer together. Finally, we note that entry decisions are nevertheless strategic substitutes, that is, incumbents will never enter at the same time.

### 5.2 De Novo Entry

We finally consider the case of de novo entry with sequential pricing. If the de novo entrant decides to offer the integrated product, its pricing decision will always occur in the second stage, as it does not offer a specialized product. Therefore, independent of the entry decision of the specialists, the entrant will be a second mover.

Analyzing the case with sequential competition, we obtain that the main results of the case with simultaneous pricing carry over: First, the de novo entrant will enter either first or last but never in between the two specialists. Second, whether the de novo entrant is first or last to enter still depends on the degree of competition. It enters first if the degree of competition is weak but last of the degree of competition is fierce. This shows that our main results are robust to sequential pricing.

However, Stackelberg competition changes the ranges in which one or the other result occurs.

**Proposition 8**

*Compared to simultaneous price competition, the de novo entrant is more likely to enter first than last with sequential price competition.*

The intuition is along the lines of the insights following previous literature on Stackelberg competition: Since the de novo entrant offers only an integrated product, and therefore sets its price in Stage 2, it benefits from the second-mover advantage. This induces the de novo entrant to offer the integrated product already at higher costs than in case of simultaneous competition. Because the de novo entrant is not active at different stages, the results are in line with the classical insights derived from sequential price competition.

Taking the result from Proposition 7 and 8 together we obtain if the de novo entrant enters first, its entry decision will occur earlier with sequential competition than with simultaneous competition. By contrast, if a specialist firm enters first, its entry decision will occur later with sequential competition. The result gives a clear picture on how sequentiality changes the incentives of the different firms.
6 Discussion and Conclusion

In this article we have taken a market-based perspective on firms’ incentives to take competition to the system level. While firm-specific capabilities may often provide certain firms (and probably often incumbent specialists) with advantages for launching an integrated product our assumption of firm homogeneity allows us to isolate important market-based effects. A key insight that can be gained from our model is that an incumbent specialist’s incentives to take competition to the system level are conditioned by his ability to use the price of the specialized component as a competitive weapon to reduce self-cannibalization and affect rivalry to its advantage after integration. Thus, the mere fact that a firm is an incumbent can provide it with an advantage over potential new system-level entrants. The same lever can also be effective in competing with the remaining specialist. Our analysis yields important boundary conditions to this advantage. Specifically, the integrating specialist’s competitive weapon will be ineffective when the integrated offering is a weak substitute to the incumbent specialists’ bundle (i.e., when it addresses a more distant customer segment), when it has a large quality advantage or disadvantage over the incumbent specialists’ bundle, and when the separate component prices are ‘sticky’. In all these cases a de novo entrant will have an ‘attacker’s advantage’.

These results provide novel insights into the antecedents and drivers of systems competition, the existence of incumbent and attacker advantages, and industry evolution and market convergence. First, the literature on systems competition takes firm scope as given and analyzes issues of bundling and compatibility (Armstrong and Vickers 2010, Matutes and Regibeau 1988, Schmidt, et al. 2016). Our contribution to that literature is to show how the decision to offer an integrated product is governed by differences between firms in how that decision affects market structure. We find that among incumbents entry decisions are strategic substitutes, as rivalry is less intense when one incumbent offers the integrated product than when both do, which echoes a result obtained by Thanassoulis (2011) in a mix-and-match setting. Furthermore incumbents and newcomers face different entry incentives (Gilbert and Newbery 1982, Reinganum 1983), which depend on the degree of (both horizontal and vertical) product differentiation. Specifically, the intuition that the de novo entrant has higher incentives because it does not face a threat of self-cannibalization is only correct for high levels of product differentiation, i.e., when competition among incumbents is relatively weak. At low levels of product differentiation, when the integrated product directly competes against the incumbents’ specialist products, incumbents have higher incentives to offer systems solutions because they can temper rivalry through pricing. If a de novo entrant
would directly compete against incumbents, they would instead react aggressively, rendering such a direct entry attempt unprofitable.

Second, the business strategy literature is interested under which conditions incumbents are able to retain their positions and when they are at danger of being replaced by new entrants. Here we identify the conditions under which there is an “attacker’s advantage” (Christensen and Rosenbloom 1995): the existence depends on the degree of horizontal and vertical differentiation and the stickiness of component prices. Under these conditions incumbents are constrained in their ability to react because they are unable to manage self-cannibalization through segmenting their offering. Specifically, they are unable to fend off de novo entry when a systemic innovation is relatively highly differentiated compared to the incumbent specialists’ bundle and thus is “disruptive” in the sense of Christensen and Bower (1996), i.e., it addresses the needs of an underserved or newly emerging segment in the industry. Likewise sticky prices will facilitate de novo entry, which points to a potential disadvantage of locked-in customers (Klemperer, 1987). Our model thus provides a market-based explanation for why incumbents may not introduce disruptive systemic innovations as opposed to an explanation that relies on internal resource allocation dynamics (Christensen and Bower 1996), bounded managerial rationality (Henderson 2006), or firm-specific capabilities.

Third, the literature on industry evolution has started to examine how separate industries co-evolve over time and under what conditions different industries converge either in part or as a whole (Greenstein and Khanna, 1997; Stieglitz, 2003). The fact that firms start offering integrated products shifts the locus of competition away from the component level to the system level and thus contributes to market convergence. At the extreme, component industries might be completely dissolved in an industry structure in which competition unfolds purely on the system level. Our analysis shows that market convergence will be initiated by incumbents when the integrated system directly competes against the specialist bundle whereas it will be driven by de novo entrants when the integrated system is differentiated or when prices are sticky. The fact that entry decisions for incumbent specialists are strategic substitutes will slow down the speed of market convergence because some component producers will find it optimal to continue to focus on the component segment. Finally, we also find that market convergence often traps incumbents in a prisoner’s dilemma, so that converged markets with system competition may exhibit lower overall profitability (Cabral and Villas-Boas, 2005).

There are also a number of managerial implications that flow from our findings. First,
the fact that taking competition to the system level may lead to firms being trapped in a prisoner’s dilemma should caution managers of specialists to rush to imitate competitors that provide integrated offerings. Second, managers must be mindful about the degree of differentiation of the integrated offering compared to the specialist bundle to assess the threat of entry and whether there is an attacker’s advantage, because their competitive weapons may not be useful and even harm performance when self-cannibalization outweighs the benefits of market segmentation.
7 Appendix

Proof of Proposition 1:

Suppose that firm $S - i$ has not entered the system market. Then, when entering, firm $Si$’s profit is
\[
\frac{U_I^2(9 - 5\gamma^2) + 4U_S^2 - 8\gamma U_S U_I}{36(1 + \gamma)(1 - \gamma)} - C,
\]
whereas the profit from not entering is $U_S^2/9$. Taking the difference yields the benefit of entering, which is
\[
\frac{U_I^2(9 - 5\gamma^2) + 4\gamma^2 U_S^2 - 8\gamma U_S U_I}{36(1 + \gamma)(1 - \gamma)} - C. \quad (5)
\]

By contrast if firm $S - i$ has already entered the system market, firm $Si$’s profit when doing so as well is
\[
\frac{(U_S(2 - \gamma) - \gamma U_I)(U_S(1 + \gamma) - 2\gamma U_I)}{9(1 + 2\gamma)(2 - \gamma)(1 - \gamma)} + \frac{U_I(U_I(3 - 2\gamma^2) - \gamma U_S(2 - \gamma))}{3(1 + 2\gamma)(2 - \gamma)^2} - C,
\]
whereas it is $[(U_S - \gamma U_I)^2(1 - \gamma)]/ [9(1 + \gamma)(1 - \gamma)]$ when staying out. The difference between these profits, expressing the benefit of entering, is
\[
\frac{U_I^2(9 - 15\gamma^2 - 2\gamma^3 + 11\gamma^4 - 2\gamma^5) + \gamma(2 - \gamma)^2(\gamma U_S^2 - 2U_I U_S)}{9(1 + 2\gamma)(2 - \gamma)^2(1 + \gamma)(1 - \gamma)} - C. \quad (6)
\]

Taking the difference between (5) and (6) yields
\[
\frac{\gamma [U_I^2(36 - 23\gamma + 6\gamma^2 - 9\gamma^3 - 2\gamma^4) + 8\gamma U_S(2 - \gamma)^2(\gamma U_S - 2U_I)]}{36(1 + 2\gamma)(2 - \gamma)^2(1 + \gamma)(1 - \gamma)}. \quad (7)
\]

The denominator is strictly positive. Moreover, the first term in the bracket of the numerator is also positive as $\gamma < 1$. The second term is most negative if $U_I$ is largest. As noted in Footnote 6, the boundary for $\gamma$ if $U_I \geq U_S$ is $\gamma \leq U_S/(2U_I - U_S)$, which implies that the highest possible value for $U_I$ is $U_S(1 + \gamma)/(2\gamma)$. Inserting this into (7), we obtain
\[
\frac{U_S^2(36 + 13\gamma - 73\gamma^2 + 79\gamma^3 - 15\gamma^4)}{144\gamma(1 + \gamma)(2 - \gamma)^2},
\]
which is strictly positive as $\gamma < 1$. It follows that (7) is positive for all $\gamma$ strictly larger than zero, within the admissible range. Therefore, the profit from entering given that the other firm has not entered is larger than in case the rival firm has already entered. It follows that the threshold value for $C$ below which first entry occurs, denoted by $C$, is above the one at
which second entry occurs (denoted by $C$). Therefore, firms enter at different thresholds, implying that entry decisions are strategic substitutes. ■

**Proof of Proposition 2:**
We show the result for the case $U_I = U_S$. In this case the profit if both firms enter is

$$\frac{U_S^2(1 - \gamma)(13 + \gamma)}{9(1 + 2\gamma)(2 - \gamma)^2} - C. \quad (8)$$

Subtracting the profit if no firm enters (i.e., $U_S^2/9$) from (8) yields that the former profit is higher than the latter if and only if

$$\frac{U_S^2(9 - 16\gamma + 6\gamma^2 - 2\gamma^3)}{9(1 + 2\gamma)(2 - \gamma)^2} - C \geq 0. \quad (9)$$

We now consider the two extremal values for $C$. First, setting $C$ equal to 0 and solving the resulting expression for $\gamma$ yields that (9) does not hold if $\gamma$ is larger than approximately 0.705. Second, the threshold value for $C$ such that both firms enter can be determined by setting (6) equal to 0. Solving for $C$, taking into account that $U_I = U_S$ gives $C = \frac{[U_S^2(1 - \gamma)(9 + 10\gamma + 8\gamma^2 - 2\gamma^3)]}{[(1 + \gamma)(1 + 2\gamma)(2 - \gamma)^2]}$. Inserting this into the left-hand side of (9) yields

$$-\frac{2\gamma U_S^2}{9(1 + \gamma)},$$

which is negative for all $\gamma > 0$. The condition in (9) is then violated for all $\gamma > 0$. Since the left-hand side of (9) is strictly decreasing in $C$, it follows that for all values of $C$ there exists a $\gamma$ such that (9) is violated if $\gamma$ is above this value. By continuity of the model, a similar argument can be shown for $U_I \neq U_S$ (but both values still in the admissible range). Therefore, if competition is sufficiently intense, both firms obtain higher profits without entering but it is individually rational for each firm to enter—a prisoner’s dilemma. ■

**Proof of Proposition 3:**
We start the analysis by determining whether the de novo entrant or one of the incumbents has stronger incentives to enter first. From the proof of Proposition 1, we know that if no firm has entered, the benefit of entering for an incumbent is

$$\frac{U_I^2(9 - 5\gamma^2) + 4\gamma^2U_S^2 - 8\gamma U_S U_I}{36(1 + \gamma)(1 - \gamma)} - C. \quad (10)$$

Determining the profits for the case where only the de novo entrant offers the integrated
product, we obtain (following the same steps as described in Section 3)

\[ \Pi_{Si} = \frac{(U_S(2 - \gamma^2) - \gamma U_I)^2}{4(1 + \gamma)(1 - \gamma)(3 - 2\gamma^2)} \quad \text{and} \quad \Pi_E = \frac{(U_I(3 - 2\gamma^2) - \gamma U_S)^2}{4(1 + \gamma)(1 - \gamma)(3 - 2\gamma^2)}. \]

It follows that the de novo entrant’s benefit of entering is

\[ \frac{(U_I(3 - 2\gamma^2) - \gamma U_S)^2}{4(1 + \gamma)(1 - \gamma)(3 - 2\gamma^2)} - C. \] (11)

Comparing the benefits of entry for the de novo entrant and an incumbent, we obtain that the value in (11) is larger than the one in (10) if and only if

\[ 2U_I U_S(9 - 6\gamma^2 + 4\gamma^4) - \gamma U_I(9 + 3\gamma^2 - 5\gamma^4) - \gamma U_S^2(9 - 2\gamma^2)(3 - 2\gamma^2). \] (12)

Looking at the extreme values for \( \gamma \), we obtain that for \( \gamma = 0 \), (12) boils down to \( 18U_I U_S \), which is strictly positive. By contrast, for \( \gamma = 1 \), (12) equals \( -7(U_I - U_S)^2 \), which is strictly negative. In addition, one can show that, given the bounds on \( U_I \) and \( U_S \), for \( 0 < \gamma < 1 \) there is a unique value of \( \gamma \), solving (12). It follows that for all \( \gamma \) below the value, the de novo entrant has the strongest incentives to offer the integrated product, whereas for \( \gamma \) above this value, the incentives for the incumbents are stronger. This implies that in the former case, there exists a range of \( C \) such that only the de novo entrant enters the system market but none of the incumbents. By contrast, in the latter case, there exists a range of \( C \) such that only one of the incumbents enters the system market.

We now turn to the second range and determine whether the second incumbent has a stronger incentive to enter than the de novo entrant or vice versa, given that the first incumbent already offers the integrated product. Proceeding in the same way as above, we obtain that the incumbent has stronger entry incentives than the de novo entrant if and only if

\[ \frac{(U_S(2 - \gamma) - \gamma U_I)(U_S(1 + \gamma) - 2\gamma U_I)}{9(1 + 2\gamma)(2 - \gamma)(1 - \gamma)} + \frac{U_I(U_I(3 - 2\gamma^2) - \gamma U_S(2 - \gamma))}{3(1 + 2\gamma)(2 - \gamma)^2} - \frac{(U_S - \gamma U_I)^2}{9(1 + \gamma)(1 - \gamma)} > 0. \] (13)

We know that we are in a range in which it was optimal for the first incumbent to enter before the de novo entrant, which implies that (12) is negative. Using this in (13), one can show that (13) is fulfilled for all \( \gamma \) at which (12) is negative. It follows that if the de novo entrant has weaker incentives to enter compared to the first incumbent, its incentives are also weaker than the one of the second incumbent. Therefore, there exists a range of \( C \) in
which both incumbents offer the integrated product but not the entrant. By contrast, there does never exist a range of $C$ such that for $C$ above this range, one incumbent offers the integrated product and for $C$ in this range, the de novo entered offers the integrated product. The de novo entrant has either the strongest or the weakest incentive to enter.

**Proof of Proposition 4:**

The threshold value of $\gamma$ below which the de novo entrant has stronger incentives to enter first is determined by (12). Taking the derivative with respect to $U_I$ yields

$$2U_S(9 - 6\gamma^2 + 4\gamma^4) - 2\gamma U_I(9 + 3\gamma^2 - 5\gamma^4).$$

(14)

Using the fact that the threshold is given by (12), one can show that (14) is strictly positive. Therefore, the range for which the entrant has the strongest incentives to offer the integrated product increases in $U_I$.

**Proof of Proposition 5:**

Proceeding in the same way as in Proposition 2, that is, setting $U_I = U_S$ and then comparing the profit of the incumbents for the cases in which all three firms enter and in which only the de novo entrant enters, yields that the equivalent to (9) is

$$\frac{U_S^2(1 - \gamma)(36(1 + 4\gamma) - 33\gamma^2(7 + 65\gamma) + 2\gamma^7(286 + 125\gamma) - 4625\gamma^4 - \gamma^5(4407 + 1138\gamma))}{4(1 + \gamma)(1 + 3\gamma)(3 - \gamma)^2(6 + 15\gamma + \gamma^2)^2} - C \geq 0.$$

(15)

Inserting $C = 0$ in (15) and solving for $\gamma$ yields that the condition is only fulfilled if $\gamma$ is smaller than approximately 0.252. By contrast, (9) was fulfilled for $\gamma$ is smaller than approximately 0.705. In addition, the first term in the left-hand side of (15) is smaller than the first term on the left-hand side of (9) for all $\gamma < 0.705$. It follows that for any $C$ the inequality in (15) is violated for a larger range of $\gamma$ than the inequality in (9). Therefore, the prisoner’s dilemma of the two incumbents occurs for a larger range with the de novo entrant than without.

**Proof of Proposition 6:**

From Section 3, we know that in case of simultaneous pricing the profits if only firm $Si$ enters are given by (2). Inserting $U_S = U_I = U$, these profits can be written as

$$\Pi_{Si} = \frac{U^2(13 + 5\gamma)}{36(1 + \gamma)} \quad \text{and} \quad \Pi_{S-i} = \frac{U^2(1 - \gamma)}{9(1 + \gamma)}.$$ 

(16)
Subtracting the profits with sequential competition, given by (3), from (16) for firm $S_i$ and $S - i$, respectively, we obtain that the difference is given

$$-\frac{U^2\gamma^2(1 - \gamma)(12 - 5\gamma^2)}{36(1 + \gamma)(3 - \gamma^2)^2} < 0$$

for firm $S_i$ and by

$$\frac{U^2\gamma^2(1 - \gamma)(3 - 2\gamma^2)}{18(1 + \gamma)(3 - \gamma^2)^2} > 0$$

for firm $S - i$. Given the signs of the two expressions, the result follows. ■

**Proof of Proposition 7:**

The first result follows from Proposition 6. This proposition shows that the value of entry of a specialist firm, given that the other specialist has not yet entered, is lower with sequential than with simultaneous pricing. As the profit without entry of any firm is the same with sequential and with simultaneous pricing, first entry occurs or a lower value of $C$ with sequential pricing than with simultaneous pricing.

Turning to the second result, with simultaneous pricing, the benefit from entering of a firm given that the other firm has already entered is given by (6). With $U_I = U_S = U$, (6) can be written as

$$\frac{U^2(1 - \gamma)(9 + 10\gamma + 8\gamma^2 - 2\gamma^3)}{9(1 + \gamma)(1 + 2\gamma)(2 - \gamma)^2} - C. \quad (17)$$

With sequential pricing, using (3) and (4), the benefit from entering, given that the other firm has entered is

$$\frac{U^2(1 - \gamma)(1 + \gamma)(8(26 + \gamma(59 + 80)) - 3\gamma^3(48 + 53\gamma))}{(1 + 2\gamma)(24 + 36\gamma - 10\gamma^2 - 17\gamma^3)^2} - \frac{U^2(1 - \gamma)(2 - \gamma^2)}{2(1 + \gamma)(3 - \gamma^2)^2} - C. \quad (18)$$

Subtracting (17) from (18), we obtain that the sign of this difference is given by the sign of

$$-1728(14 + 13\gamma) + 1872\gamma^2(42 + 43\gamma) - 72\gamma^4(953 + 1015\gamma)$$

$$+16\gamma^6(1662 + 1633\gamma) - 5483\gamma^8 + 2\gamma^9(289\gamma - 1676). \quad (19)$$

Setting the expression in (19) equal to zero and solving numerically for $\gamma$ yields approximately 0.666. It is easy to check that (19) is negative for $\gamma < 0.666$ but positive otherwise. Therefore, given that $S_i$ has already entered, entry is more profitable for $S - i$ in case of sequential pricing than in case of simultaneous pricing if competition is relatively fierce, implying that it occurs
for a larger value of $C$. By contrast, entry is less profitable with sequential pricing than with simultaneous pricing if competition is weak, and therefore occurs for a lower value then.

Finally, we can evaluate the difference between the critical thresholds for first entry and second entry. With simultaneous pricing, this difference is given by (using $U_I = U_S = U$ in (5) and (6)),

$$
\frac{U^2 \gamma (12 - 17 \gamma + 17 \gamma^2 - 2 \gamma^3)}{12(1 + \gamma)(1 + 2 \gamma)(2 - \gamma)^2}.
$$

(20)

With sequential pricing, this difference is given by

$$
\frac{U^2 \gamma (3 + 2 \gamma)(27 - 15 \gamma - 12 \gamma^2 + 10 \gamma^3 - 2 \gamma^4)}{36(1 + \gamma)(3 - \gamma^2)^2}
$$

(21)

$$
- \left[ \frac{U^2 (1 - \gamma)(1 + \gamma)(8(26 + \gamma(59 + 80)) - 3 \gamma^3(48 + 53 \gamma))}{(1 + 2 \gamma)(24 + 36 \gamma - 10 \gamma^2 - 17 \gamma^3)^2} - \frac{U^2 (1 - \gamma)(2 - \gamma^2)}{2(1 + \gamma)(3 - \gamma^2)^2} \right].
$$

Building the difference between (20) and (21), the difference is only a function of $\gamma$ and it can be shown that for all $\gamma \in (0, 1)$, this difference is positive. This implies that the difference between the threshold values for $C$ is larger with simultaneous pricing than with sequential pricing.

Proof of Proposition 8:

Solving the game with sequential competition and determining the profit of the de novo entrant from offering the integrated product, given the two specialists do no offer the product, we obtain

$$
\frac{U^2 (1 - \gamma)(6 + 4 \gamma - \gamma^2)^2}{36(1 + \gamma)(2 - \gamma^2)^2}.
$$

(22)

Since the de novo entrant obtains zero profits without entry, it enters if (22) is equal to $C$. By contrast, a specialist firm enters if

$$
\frac{U^2 (13 + 5 \gamma - 10 \gamma^2 - 2 \gamma^3 + 2 \gamma^4)}{4(1 + \gamma)(3 - \gamma^2)^2} - \frac{U^2}{9} - C = 0.
$$

(23)

Solving (23) for $C$ and comparing the resulting value with (22), we obtain that (22) is larger if and only if $\gamma$ is lower than approximately 0.646. Hence, in this range the de novo entrant will enter first, whereas for $\gamma > 0.646$, a specialist firm enters first. By contrast, with simultaneous pricing, the threshold value was 0.506. It follows that the range of parameters for which the de novo entrant enters first is larger with sequential than with simultaneous pricing.
References


