Why Tie a Product Consumers do not Use?

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by

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ABSTRACT

This paper provides a new explanation for tying that is not based on any of the standard explanations – efficiency, price discrimination, or exclusion. Our analysis shows how a monopolist sometimes has an incentive to tie a complementary good to its monopolized good in order to transfer profits from a rival producer of the complementary product to the monopolist. This occurs even when consumers – who have the option to use the monopolist’s complementary good – do not use it. The tie is profitable because it alters the subsequent pricing game between the monopolist and the rival in a manner favorable to the monopolist. We show that this form of tying is socially inefficient, but interestingly can arise only when the tie is socially efficient in the absence of the rival producer. We relate this inefficient form of tying to several actual examples and explore its antitrust implications.

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I. INTRODUCTION

Because of the attention paid to Microsoft’s behavior in the marketing of Windows and its various applications programs, significant theoretical attention has recently been directed at why a primary-good monopolist would tie a complementary good. Most of this recent literature as well as earlier literature on the subject is based on either efficiency, price discrimination, or exclusionary motivations for tying.¹ This paper provides a new explanation for the monopoly tying of complementary products that we believe matches a number of real-world cases better than existing alternatives. In our explanation, tying alters the equilibrium to the subsequent pricing game and in this way enables the monopolist to capture some of the profits of a rival producer of the complementary good.

The intuition for our result is that a monopolist who ties its complementary product to its monopolized product is providing the consumer with a valuable option. The presence of that option affects consumer willingness to pay for the rival’s complementary good and potentially affects pricing, even when the consumer does in fact buy the rival’s good. More precisely, in a situation in which, in the absence of a rival, tying would be efficient, a monopolist may tie because, in the presence of the rival, the tie transfers profits from the sale of the rival’s complementary good to the monopolist. Because the monopolist’s tied product is never used, this behavior is inefficient, though profitable, and the behavior does not exclude the rival, as in, for example, Whinston (1990) and Carlton and Waldman (2002).

To fix ideas with a simple example, consider Microsoft’s tying of Windows Media Player (WMP) to Windows. First, suppose Microsoft is the monopolist of Windows but that there is a better media player available (as might be arguably the case with Quicktime or Real Player). To put numbers to this, suppose that all consumers are identical and if they purchase Windows and WMP separately and use them together they derive a gross benefit of $15 whereas if they use Windows and a rival media player their gross benefit is $10 higher at $25. Second, suppose that an individual who consumes Windows and WMP derives a higher gross benefit if the two goods are purchased as a tied product rather than purchased separately (either because tying improves functionality or because of savings on installation costs); with a tied Windows and WMP giving
consumers a gross benefit of $20 instead of $15. Finally, suppose that the marginal cost for
supplying either type of media player is $2 (for simplicity assume the cost of producing
Windows is zero).

To examine the incentives for tying, consider what happens when there is no tying and
the pricing game is such that the rival captures the full surplus it generates. In this situation,
consumers pay $12 for the rival’s media player, $13 for Windows, and do not install WMP. In
this outcome the rival’s per consumer profit equals $12 – $2 = $10, while Microsoft’s per
consumer profit equals $13 – $0 = $13.2

Now suppose that, at the time of Windows production, Microsoft can costlessly
incorporate WMP (increase consumers’ gross benefits to $20 if they use WMP). This tying,
however, does not prevent a consumer who purchases this tied product from adding the rival’s
media player and receiving, as before, a gross benefit of $25 because the individual would
employ the superior of the two available players.3 With the tie, as there is a ‘free option’ to use
the bundled WMP, a consumer is only willing to pay $5 for the rival’s media player. Assuming
the surplus associated with the rival’s media player is still fully captured by the rival, the price
for the rival’s media player is $5 and the rival’s per consumer profit falls from $10 to $5 – $2 =
$3, while Microsoft’s price for the tied good is $20 and its per consumer profit rises from $13 to
$20 – $2 = $18. Note that the tying is socially inefficient since consumers do not use WMP, but
it is profitable for Microsoft since it changes the pricing game in a way that shifts profits from
the sale of the rival’s media player to Microsoft.4 5

1 See Carlton and Waldman (2005) for a recent survey.
2 The surplus generated by the rival is $25-$15=$10 which is the rival’s profit in this outcome. Note that, consistent
with the formal analysis in Section III, this pricing outcome where the price of the rival’s complementary good
equals marginal cost plus the incremental surplus associated with the rival’s product is consistent with a Nash
equilibrium in prices where the rival chooses prices first.
3 The example is simplified for tractability reasons in a number of ways. Obviously, if the complementary product
comes in a base version for free but upgrades are costly, then it is the revenue from the upgrades that is relevant. The
fact that the base product is free does not mean that there are no profits from tying because of the associated
revenues from the upgrades and other features. In fact the base versions of Quicktime and Real Player are free but
there are associated revenues from advanced features.
4 Note that should there be costs associated with the initial tie, this would (a) not necessarily remove Microsoft’s
incentive to tie; and (b) increase the inefficiency associated with tying.
5 There are other strategies that one can conceive that eliminate the inefficiency but are not (at least currently)
feasible for transaction cost reasons. For example, one could imagine a strategy in which Microsoft sells Windows
with the condition that if the consumer wishes to also use a rival’s media player, the consumer must pay Microsoft
an additional $8. If it is difficult to monitor such consumer behavior, then this strategy is not feasible. We suspect
that such strategies are likely to become possible in the future as monitoring technologies improve. However, even if
In this paper, we consider a model that captures and extends the logic of the above example. In our model, there is a monopolist of a primary product and a complementary product that can be produced both by the monopolist and an alternative producer. Also, consumers have a valuation only for systems, where a system consists of one primary unit and one or more complementary units (although from the standpoint of consumption an individual uses only one complementary unit even if he owns more than one). At the beginning of the period the monopolist chooses whether or not to tie, sell individual products, or sell both tied and individual products, where we assume ties are reversible. A reversible tie means that a consumer who purchases a tied product from the monopolist can add the alternative producer’s complementary product to his system although he cannot return (say for a refund) the tied product. In effect, the consumer has both but utilizes one. Although most of the literature focuses on irreversible ties, clearly, as in the case of Microsoft, assuming ties are reversible is quite realistic.

What is interesting about this model is that its starting point is on a claim that Microsoft relied upon in its various antitrust cases: that is, that there are efficiencies associated with consuming its products as ties rather than acquired separately.

On the other side of the equation, are there plausible procompetitive explanations for these practices? Regarding its tying, Microsoft argued that its physical integration of Internet Explorer was no different in nature than its past integration of many other functionalities into Windows (and similar behavior by other software producers) which were done to make a better product. (Whinston, 2001, p.74)

Our model embeds the increased functionality that might accompany a tied product and shows how this is linked to a tying strategy that would have been both profitable for Microsoft but also inefficient from a social perspective.

We analyze a number of different cases. First, we analyze how the equilibrium depends on whether consumers prefer the monopolist’s tied product to purchasing primary and complementary units separately. Second, we analyze equilibrium behavior when the increased functionality of the tie is endogenous. Third, we analyze how the equilibrium depends on the heterogeneity of consumer tastes. For each of these cases we show how a tie can sometimes benefit the monopolist even when the tied product is not ultimately used.

Our analysis does not fall into any of the existing theoretical categories for why a monopolist of a primary good would tie a complementary product. Most previous explanations
for such tying are based on either efficiency, price discrimination, or exclusionary motivations. As captured by the example above, in our argument the monopolist sometimes ties a product that winds up not being used by consumers in equilibrium, in order to extract surplus from, but not exclude, a rival producer. Specifically, the tying improves the monopolist’s position in the pricing game that follows and, in this way, serves to shift profits from the rival to the monopolist. Indeed, in contrast to standard results that rely on the exclusion or exit of a rival, here it is the very profitability of the rival that drives strategic tying. Hence, a rival’s presence is required for our results. In addition, in contrast to many models of tying based on price discrimination or exclusion where the tie hurts consumers, in our analysis inefficient tying neither hurts nor helps consumers. Rather, when the tie transfers profits from the rival to the monopolist, the tie is inefficient because the profit increase of the monopolist due to the tie is less than the rival’s profit loss.

As discussed in more detail in the next section, one of the main points of our analysis is that one of the main results in Whinston (1990) is not robust to the introduction of potential efficiencies associated with tying. Whinston showed that, in the presence of a rival producer of a complementary good, there is no return for a monopolist in tying as long as its primary good is essential, i.e., required for all uses of the complementary good. But Whinston considered a setting in which, in the absence of a rival, the monopolist has no incentive to tie. We instead allow for tying to be efficient in the absence of the rival and show that, in combination with our assumption that ties are reversible, this overturns Whinston’s result. That is, given a tie that is efficient in the absence of a rival, in the presence of a rival, a reversible tie can be used to increase profits even though the monopolist’s primary good is essential, where this type of tying is frequently inefficient because, for example, consumers do not use the tied good in equilibrium.

The outline for the paper is as follows. Section II discusses how our analysis is related to the previous literature on tying. Section III presents the main model and then analyzes an illustrative example that demonstrates our argument in a setting characterized by identical consumers who prefer the rival’s complementary good to the monopolist’s. Section IV analyzes the model and then extends the analysis by incorporating an R&D expenditure that endogenously determines the size of the potential efficiency associated with tying. Section V extends the analysis by considering what happens when there are two consumer groups, only one of which finds the alternative producer’s complementary good to be superior. Section VI discusses the
possibility of inefficient tying in the presence of competition and the somewhat unusual antitrust implications of our analysis. Section VII presents concluding remarks.

II. RELATIONSHIP TO PREVIOUS LITERATURE

In most of the previous papers in which tying is used to disadvantage rival producers, such as Whinston (1990), Choi and Stefanadis (2001), Carlton and Waldman (2002), and Nalebuff (2004), the tying results either in the exit of existing rivals or blocks the entry of potential rivals. For example, in Whinston’s model there is one market in which complementary units are used in combination with primary units, while in a second market there is a demand for complementary units by themselves. Whinston shows that, if there are economies of scale in the production of the complementary good, then tying can be profitable because it causes rival complementary-good producers to exit and thus allows the primary-good monopolist to monopolize the market in which there is a demand for complementary units by themselves.

Carlton and Waldman (2002) consider a two-period setting in which there is an incumbent monopoly producer of primary and complementary goods, where a rival producer can enter the primary market only in the second period but the complementary market in either period. In their model the alternative producer’s return to entering the primary market in the second period is that this allows the firm to capture more of the surplus associated with its own superior complementary product. Carlton and Waldman show that, given either entry costs or complementary-good network externalities, the monopolist may tie in order to preserve its monopoly position in the primary market in the second period. The logic is that tying can stop entry into the complementary market by reducing its return and, in their model, the alternative producer does not enter the primary market if it does not plan to enter the complementary market.

The idea captured by the above cited papers that tying is used to exclude competition is certainly a plausible explanation for various important real-world cases. For example, Microsoft’s tying of Internet Explorer with the Windows operating system does seem to have eliminated Netscape’s Navigator as a serious competitor in the browser market and, to the extent

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6 Two exceptions are Carbajo, de Meza, and Seidman (1990) and Chen (1997). These papers are discussed in detail at the end of this section.
that Navigator posed a threat to the Windows monopoly as argued by the Justice Department, also helped to preserve Microsoft’s monopoly in the operating systems market. However, there are other important cases in which tying did not eliminate competition in the complementary-good market. For example, the more recent tying of WMP with Windows does not seem to have eliminated all of the serious competition in media player applications programs. In fact, in relation to Windows there are many similar ties. Instant messaging, movie and photo editing programs, and more recently, computer search and security programs are all provided with Windows despite the existence of seemingly superior independent alternatives that continue to capture large market shares. This leads us to the question, can tying be used to disadvantage a rival and improve monopoly profits even if there is no effect on the entry and exit decisions of rival producers?

The analysis of our model yields that there are a number of cases in which the monopolist improves its own profitability and disadvantages a rival by tying even though there is no effect on entry and exit decisions, although this happens only when in the absence of an alternative producer consumers prefer the monopolist’s tied product to purchasing the monopolist’s primary and complementary products separately. When consumers are indifferent between these two options, tying does not increase profitability. The basic logic for this result was first put forth in Whinston (1990). Whinston showed that tying cannot increase profits when the monopolist’s primary good is essential, i.e., as is the case in our analysis the primary good is required for all uses of the complementary good. The monopolist can ensure itself profits at least as high as the profits associated with tying by selling the products separately, pricing the complementary good at marginal cost, and pricing the primary good at the optimal bundle price minus the complementary good’s marginal cost. Hence, tying in that case will typically not increase profitability.

7 Indeed, the on-going tie of Internet Explorer has been met with competition from Mozilla’s Firefox and Google’s Chrome, both of which some claim are superior to Internet Explorer...
8 This applies to other Microsoft products too. For instance, this paper was written in Microsoft Word. It has a bundled equation editor but the equations here were written in Mathtype; a better, independently sold program.
9 If the model was restated in terms of the monopolist’s cost of producing the tied product relative to its cost of producing primary and complementary goods separately, the corresponding result is that the tie in our model can be profitable only when the monopolist’s cost of producing the tied product is strictly below its cost for producing the two goods separately.
10 This argument in some sense formalizes the earlier Chicago School argument that a monopolist would never tie a complementary good to its monopolized primary good because it can extract all of the potential profits through the
But when, in the absence of an alternative producer, consumers prefer the monopolist’s tied good to purchasing the products individually, then there are a number of cases in which the monopolist ties with no effect on entry and exit decisions but the result is increased monopoly profitability and lower alternative producer profitability and social welfare. The simplest of these cases, as in our example in the Introduction, is when consumers are identical, product qualities are given exogenously, and all consumers prefer the alternative producer’s complementary good. In this setting, there exists a range of parameterizations in which the monopolist ties, consumers purchase the monopolist’s tied good and the alternative producer’s complementary good, and the tie decreases social welfare because of the cost the monopolist incurs in producing complementary units when the product is not used by consumers in equilibrium. We find a similar result when we introduce consumer heterogeneity.

To understand why tying can be profitable, it is helpful to understand why Whinston’s (1990) argument that shows no return to tying when the monopolist’s primary good is essential does not apply.\footnote{Carlton and Waldman (2009) investigate a different setting in which a monopolist’s primary good is essential but Whinston’s argument does not apply. That argument focuses on durable goods and issues that arise in the presence of upgrades and switching costs.} In Whinston’s argument the monopolist can sell its products individually and price the goods in such a way that it ensures itself profits equal to tying profits. Hence, the monopolist cannot increase its profits by tying. But here, because of the extra utility consumers derive from the tied product when the alternative producer’s product is not purchased (when the alternative producer’s product is purchased and used there is no extra utility associated with the tie), the monopolist cannot ensure itself tying profits without in fact tying. The result is cases in which the monopolist ties even though, in equilibrium, consumers purchase and use the alternative producer’s complementary good so consumers receive no benefit from owning the monopolist’s complementary good. Clearly, in such a case the tie lowers social welfare because of the direct production costs associated with the monopolist’s complementary good (and in the case where the functionality of the tie is endogenous any R&D costs the monopolist incurs in improving this functionality).\footnote{This result depends on our assumption that ties are reversible, i.e., a consumer can add the alternative producer’s complementary product to a tied system consisting of the monopolist’s primary and complementary goods. Whinston assumes that ties are irreversible and it is the case that with irreversible ties the type of setting we investigate would never lead to inefficient tying. That is, the monopolist might tie even though the primary good is essential, but this would occur only when tying is efficient.}

\footnote{pricing of the monopolized good. See, for example, Director and Levi (1956), Bowman (1957), Posner (1976), and Bork (1978). Also, see Ordover, Sykes, and Willig (1985) for a formal theoretical analysis related to Whinston’s.}
Two other related papers on tying are Carbajo, De Meza, and Seidman (1990) and Chen (1997). Both papers are similar to our paper in the sense that tying is used to increase profits by altering the outcome of the subsequent pricing game between the firms. For example, Carbajo, De Meza, and Seidman consider a model with two independent products called A and B, where product A is monopolized while B can be produced by the monopolist and a single alternative producer. In the absence of tying, because the two firms produce identical products in the B market and there is Bertrand competition between the firms, profits in the B market equal zero. The main result is that, if the monopolist’s marginal cost for producing A is sufficiently high, then tying allows the monopolist to increase its overall profitability. The basic logic is that tying implicitly creates product differentiation in the B market and it is the introduction of this product differentiation that serves to improve the monopolist’s profitability.

In Chen’s (1997) closely related analysis two firms with homogeneous products and identical marginal costs compete in a Bertrand fashion in one market, market A, while the firms also compete in a second market, market B, which is perfectly competitive. In the absence of tying both firms earns zero profits overall – in A there are zero profits because of Bertrand competition with identical products while in B there are zero profits because of perfect competition. Chen shows that any pure strategy Nash equilibrium is such that one firm ties while the other does not, where the return to tying is the creation of product differentiation which results in positive profits for each firm. The reason both firms do not tie is that, if one firm anticipates the other will tie, it chooses not to tie because tying would eliminate the product differentiation.

Although these two papers are similar to ours in the sense that tying is used to affect the subsequent pricing game between the sellers, there are also important differences. Most importantly, both papers focus on the case of independent products while we focus on the monopoly tying of a complementary good where the monopolist’s primary good is essential. As a result, the findings in these earlier papers are perfectly consistent with Whinston’s result concerning essential primary products since, given independent products, any monopolized product cannot be essential for the use of the other product. In contrast, as just discussed, one of the main results of our paper is to show that Whinston’s result concerning essential primary goods is not robust to the introduction of efficiencies such as increased functionality or reduced installation costs associated with tying.
Finally, Farrell and Katz (2000) examine a market structure similar to ours with a single monopoly provider of an essential primary good and one or more independent suppliers of a complementary good. They consider various strategies the monopolist might engage in, most notably, vertical integration, R&D and exclusionary deals, in order to squeeze rival producers of the complementary good and appropriate greater profits. They do not consider the possibility of tying in their analysis likely because in their setting tying is inferior to vertical integration under the standard but not necessarily realistic assumptions that tying is irreversible and that there are no efficiencies associated with tying. Under our assumptions of reversible tying and tying efficiencies, tying can turn out to be more profitable than vertical integration and this leads to our result that a firm might tie a product that in equilibrium is not used (see footnote 20 for further discussion).13

III. MODEL AND EXAMPLE

Here we develop our model and assumptions and illustrate it using a specific example. A general analysis follows in Section IV.

A. The Model

We consider a one-period setting characterized by a monopolist (M) and a single alternative producer (A). The monopolist is the sole producer of what is referred to as the primary good (P), while there is also a complementary good (C) that can be produced either by the monopolist or the alternative producer. M has a constant marginal cost denoted \( c_P > 0 \), for producing the primary good, while both M and A have a constant marginal cost \( c_C > 0 \), for producing the complementary good. Further, there are no fixed costs of production for either good and a unit of either type of good has a zero scrap value.

Primary and complementary goods are consumed together in what is referred to as systems, where a system consists of either M’s primary and complementary products, M’s primary good and A’s complementary good, or M’s primary good and both complementary

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13 Miao (2007) considers the role tying might have in achieving the type of price squeeze discussed by Farrell and Katz. However, the set-up of that analysis is much different than ours and, in particular, Miao does not capture why a firm would tie a product that is not consumed in equilibrium.
products. In the last case, although the consumers own both complementary goods, they use and, thus, derive direct benefit from only one of the complementary products. Think of, for example, the primary good as a computer operating system and the complementary good as a media player applications program. The assumption that primary and complementary products are consumed only together means that the monopolist’s primary good is essential in this model, i.e., it is required for all uses of each of the complementary products.

At the beginning of the period the monopolist decides whether to offer the products individually, sell a tied product consisting of its primary and complementary goods, or sell both tied and individual products, where we assume there is an extra cost $Z (> 0)$, associated with selling both tied and individual products. As discussed in Evans and Salinger (2005, 2008), such costs can be due to additional production and packaging costs associated with increasing the variety of products produced or retail costs associated with stocking additional products in a store.

In contrast to most of the previous theoretical literature on tying used to disadvantage rival producers such as Whinston (1990), Choi and Stefanadis (2001), Carlton and Waldman (2002), and Nalebuff (2004), we assume that ties are reversible. That is, a consumer that purchases $M$’s tied product can add $A$’s complementary good to create a system consisting of $M$’s primary good and both complementary goods. Especially in terms of Microsoft whose behavior is the motivation for much of the recent attention to tying behavior, the assumption of reversible ties is quite realistic.

There are $N$ identical consumers. We make several assumptions on the gross benefits derived by a consumer from various combinations of purchases. First, $M$’s primary good is essential for all uses of the complementary good and vice versa. Hence, each consumer’s gross benefit equals zero if they only consume one or the other of the primary and complementary goods. Second, if a consumer uses the primary and complementary goods each bought separately from $M$, their gross benefit is $V^M$ where we assume that $V^M > c_P + c_C$. Third, if $P$ and $C$ are purchased and consumed as a tied product from $M$, the consumer’s gross benefit equals $V^M + \Delta$, $\Delta \geq 0$. Note, $\Delta = 0$ means that consumers derive no direct added benefit from consuming a tied product, while $\Delta > 0$ means that a consumer with a system consisting of $M$’s primary and

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14 See Adams and Yellen (1976) for an earlier analysis that allows the sale of both tied and individual products, although that analysis is in the setting of a pure monopoly seller.
complementary goods derives a strictly positive added benefit from having purchased and consumed a tied product. For example, $\Delta$ could represent increased functionality made possible through the tie. Notice that this means that, given there are no additional costs beyond $c_p + c_c$ to producing a tied product, when $\Delta > 0$, tying would, in fact, be privately and socially desirable if no alternative complementary product existed.\footnote{See Carlton and Perloff (2005) and Evans and Salinger (2005, 2008) for more extensive discussions of efficiency-based arguments for tying.}

What happens if the consumer purchases $A$’s complementary product? First, by consuming a system consisting of $M$’s primary good and $A$’s complementary good, then the consumer’s gross benefit equals $V^d$. We also assume that $V^A > V^M$, i.e., in the absence of tying $A$’s product is superior. Second, if the individual consumes a system consisting of $M$’s primary good and both complementary goods (as may occur if $M$ sells only a tied product), then the complementary good that yields the highest gross benefit is used. For example, if a consumer adds $A$’s complementary good to $M$’s tied product, then the consumer’s gross benefit is given by $\max\{V^M + \Delta V^A\}$.\footnote{If the consumer adds $A$’s complementary good to a system consisting of primary and complementary units purchased separately from $M$, then the individual’s gross benefit is given by $\max\{V^M, V^A\} = V^*$.} Note, in this specification, even when $\Delta > 0$, the tie is only valuable in terms of gross benefits when the consumer uses the monopolist’s complementary good.

The timing of events in the model is as follows. First, $M$ decides whether to offer a tied product, individual products, or both tied and individual products. Second, $A$ chooses a price for its complementary product. Third, $M$ chooses prices for its products. Fourth, consumers make their purchase decisions. Note that throughout the paper we focus on Subgame Perfect Nash Equilibria.

Alternative assumptions concerning the timing of the pricing game would yield qualitatively similar results. For example, we could assume that there is a strictly positive probability $A$ chooses prices first and a strictly positive probability $M$ chooses prices first.\footnote{The results are not found if $M$ chooses prices first with probability one. In that case $M$ is able to capture all the potential surplus without tying.} We discuss this case at the end of Subsection IV.A. Similarly, we would find similar results by assuming that $A$ and $M$ choose prices simultaneously and the resulting multiple equilibria problem is resolved using the surplus sharing assumption found in Choi and Stefanadis (2001).
and Carlton and Waldman (2002). In fact, any specification where at the pricing stage $A$ receives some share of the surplus associated with its superior complementary product would yield similar results. We have chosen to present the case where $A$ chooses prices first with probability one because that case is a bit simpler, so the logic behind the main results is easier to follow.

**B. An Illustrative Example**

In this subsection, we present a specific parameterization of the model to illustrate our main argument. When tying is efficient in the absence of an alternative producer, i.e., $\Delta > 0$, but $A$’s complementary good is strongly preferred by consumers, then $M$ ties, not because this is efficient, but because this allows $M$ to capture more of the surplus associated with $A$’s complementary product. The reason that tying is not efficient is that consumers purchase and use $A$’s complementary product so, from the standpoint of consumption, the fact that consumers own $M$’s complementary good provides no benefit. Note that the parameterization that follows is similar to the example discussed in the Introduction.

Let $V^M = 100$, $V^A = 200$, $\Delta = 50$, $c_r = c_c = 10$, and $Z = \infty$. (Recall that $Z$ is the extra cost of selling both tied and individual products.) To maximize social welfare, the optimal production and allocation of products is clear. Consumers receive 50 more in gross benefit by purchasing and using $A$’s complementary product rather than purchasing and using $M$’s complementary product even when it ties (without the tie, consumers prefer $A$’s complementary product by 100 rather than 50). Hence, the socially efficient outcome is that, for each consumer, $M$ produces a primary unit, $A$ a complementary unit, and each consumer purchases and consumes a system consisting of $M$’s primary good and $A$’s complementary good. That is, even though, in the absence of $A$, faced with a choice of $M$’s products through a tie or separately, there is a large incremental consumer benefit to the tie, in $A$’s presence, not tying is socially optimal because consumers would not use $M$’s complementary units even if they owned them due to tying.

We now derive what equilibrium behavior looks like in this setting. Since $Z = \infty$, we know the monopolist won’t choose to sell both tied and individual products (as will be seen later, this is in fact the case for any strictly positive value for $Z$ no matter how small). Given this,

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18 This case is analyzed in Carlton, Gans, and Waldman (2008).
suppose $M$ sells individual products. Let $P^M_p$ be $M$’s price for its primary product, $P^M_c$ be its price for its complementary product, $P^A_c$ be $A$’s price for its complementary product, $\pi_M$ be $M$’s per consumer profits, and $\pi_A$ be $A$’s per consumer profits. If $A$ sets $P^A_c > 110$, then $M$ responds by choosing prices such that $P^M_p + P^M_c = 100$ and $P^A_c - P^M_c > 100$. Consumers would then purchase $M$’s primary and complementary goods and $A$ would earn zero. Realizing this, $A$ sets $P^A_c = 110$ and $M$ responds by setting $P^M_p = 90$ and $P^M_p + P^M_c \geq 100$. In this case, $\pi_M = 90 - 10 = 80$ and $\pi_A = 110 - 10 = 100$.

Now suppose $M$ chooses to sell a tied product. Let $P^M_t$ be $M$’s price for its tied product. If $A$ sets $P^A_c > 50$, then $M$ responds by setting $P^M_t = 150$ and consumers respond by purchasing $M$’s tied product but not $A$’s complementary product. Realizing this, $A$ sets $P^A_c = 50$, $M$ responds by setting $P^M_t = 150$, and consumers purchase $M$’s tied product and $A$’s complementary product. In this case, $\pi_M = 150 - 20 = 130$ and $\pi_A = 50 - 10 = 40$. Since $\pi_M$ is higher here, in equilibrium $M$ ties; essentially because this allows it to capture profits that otherwise would have gone to $A$.

This example captures the main argument of the paper. If, in the absence of an alternative producer, there is an efficiency-based reason for tying, then given that alternative producer’s existence, the monopolist may tie even when its complementary product is not used in equilibrium. Thus, tying constitutes a deadweight loss consisting of the production and R&D costs incurred by the monopolist in producing the complementary units that are purchased but not used in equilibrium. The logic for the result is that tying decreases the surplus associated with the alternative producer’s complementary good by making the monopolist’s offering more attractive. Tying, though socially inefficient, can, thus, be profitable for the monopolist because the monopolist captures all of the profits associated with the value consumers place on the monopolist’s products in the absence of an alternative producer, but none of the incremental value consumers have for the alternative producer’s product. In other words, by tying a

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19 Throughout the paper we assume consumers purchase $A$’s complementary product when prices are such that they are indifferent between purchasing and not purchasing the product. We also assume $A$ chooses to sell its complementary product whenever it is indifferent between selling it and not selling it. These assumptions are not essential but serve to simplify the exposition and proofs.
complementary good to its monopolized good, the monopolist creates a valuable option to consumers for the complementary good. Even when consumers do not use the tied good and instead buy the alternative producer’s complementary good, this option allows the monopolist to transfer profits from the alternative producer to itself. This inefficient investment in tying raises the monopolist’s profits by altering the outcome of the subsequent pricing game involving the rival’s complementary product.\(^{20}\)

IV. ANALYSIS WITH IDENTICAL CONSUMERS

In this section we analyze in detail the model presented in the previous section. We do this in two parts. First, we demonstrate under what conditions tying occurs and whether the outcome is socially optimal or not. Second, we extend the model by allowing the increased benefit due to tying to be a function of an R&D expenditure.

A. Analysis

To begin, we characterize the socially optimal outcome. First, if \( V^M + \Delta > V^A \), then it is efficient for consumers to purchase and use \( M \)'s tied product. Second, if \( V^M + \Delta < V^A \), then it is efficient for consumers to purchase \( M \)'s primary good and purchase and use \( A \)'s complementary good (if \( V^M + \Delta = V^A \), then the two outcomes are equally efficient). In other words, from an efficiency standpoint, consumers purchase and use a tied product if the benefit of tying is sufficiently large, but when it is small, tying is not efficient and consumers purchase and use \( M \)'s primary good and \( A \)'s complementary good. Note that a key point here is that, from an efficiency standpoint, \( M \) should tie only when consumers actually use \( M \)'s complementary good.

We now turn to equilibrium behavior. We begin with a preliminary result concerning when tying is not profitable in this setting. Proposition 1 considers what happens in the case of

\(^{20}\) As mentioned briefly above, Farrell and Katz (2000) also consider behavior that a monopolist of a primary good can employ in order to shift profits from rival producers of a complementary good to itself. They consider the value of vertical integration, though not tying. In their analysis of integration, they show that integration can be beneficial for the monopolist because it allows the monopolist to increase the price of \( A \) by pricing \( B \) low, and this, in turn, squeezes the other producers of \( B \). This logic implies that tying cannot be better than integration because tying eliminates the ability to price \( A \) high and \( B \) low. This result is correct, however, only in a world in which tying is irreversible and/or there are no efficiencies associated with tying. As we show above, when one adopts the more
identical consumers when \( \Delta = 0 \), i.e., tying does not increase the gross benefit a consumer receives from purchasing and using both of \( M \)'s products. Below \( \pi^*_M \) denotes per consumer monopoly profitability in the absence of a rival.

**Proposition 1.** Suppose that \( \Delta = 0 \). Then there are multiple equilibria, where in any equilibrium the monopolist either sells a tied product only and \( \pi_M = \pi^*_M \) or sells individual products only and \( \pi_M = \pi^*_M \).

All proofs are in the appendix.\(^{21}\) Proposition 1 tells us that, if \( \Delta = 0 \), tying does not increase monopoly profits. That is, although there is a tying equilibrium, this is not because tying increases monopoly profitability. Rather, in the tying equilibrium the monopolist is indifferent between tying and not tying because it anticipates that, if it were to sell individual products, then its profitability would be the same as with tying. Note that this result is similar to Whinston's (1990) finding that a monopolist of an essential primary good has no incentive to tie. Whinston implicitly assumes \( \Delta = 0 \), but his analysis is different than ours because he assumes irreversible ties while we assume ties are reversible. However, Proposition 1 shows that even given this difference, consistent with Whinston's finding, when \( \Delta = 0 \) there is no incentive in our model for the monopolist to tie.

To get a sense of the logic here consider parameterizations in which \( V^A - V^M > c_c \), i.e., the incremental value consumers place on \( A \)'s complementary good is larger than the marginal cost of producing that product. Suppose \( M \) chooses to sell a tied product only. In that case the equilibrium to the resulting subgame is \( P^T = V^A - V^M \), \( P^M = V^M \), consumers purchase \( M \)'s tied product and \( A \)'s complementary product, and profits are \( \pi_A = V^A - V^M - c_c \) and \( \pi_M = V^M - c_p - c_c = \pi^*_M \). Now suppose instead \( M \) chooses to sell only individual products. Then any pricing equilibrium satisfies \( P^A = c_c + V^A - V^M \), \( P^M = V^M - c_c \), \( P^M \geq c_c \), consumers purchase \( M \)'s primary product and \( A \)'s complementary product, and profits are \( \pi_A = V^A - V^M \) and \( \pi_M = V^M - c_p - c_c = \pi^*_M \). In other words, because \( A \) is the Stackelberg leader and can push

\(^{21}\) If \( \Delta = 0 \) and \( Z = 0 \), then there are also equilibria in which \( M \) offers both individual and tied products but it is still the case that \( \pi_M = \pi^*_M \).
down $M$’s profits to the level achievable by $M$ in the absence of the rival, $M$ earns the same profitability whether or not it ties. Table 1 describes the equilibrium outcomes.

**Table 1: Equilibrium Outcomes ($\Delta = 0, \ V^A - V^M > c_c$)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>No Tying</th>
<th>Tying</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P^M, P_T^M$</td>
<td>$V^M - c_c$</td>
<td>$V^M$</td>
</tr>
<tr>
<td>$P^M_c$</td>
<td>$c_c$</td>
<td>n.a.</td>
</tr>
<tr>
<td>$\pi_M$</td>
<td>$V^M - c_p - c_c$</td>
<td>$V^M - c_p - c_c$</td>
</tr>
<tr>
<td>$\pi_A$</td>
<td>$V^A - V^M$</td>
<td>$V^A - V^M - c_c$</td>
</tr>
</tbody>
</table>

We now consider what happens when $\Delta > 0$. Here we begin by taking as fixed $M$’s choice concerning whether to sell only a tied product, only individual products, or tied and individual products, and describe the equilibrium to the subgame that follows. When $M$ sells individual products only the subgame equilibrium is the same as described above for the case $\Delta = 0$ since the positive $\Delta$ is immaterial if $M$ sells individual products only. That is, consumers purchase $M$’s primary good and $A$’s complementary good, while prices and profits are given in Table 1.

The case in which $M$ offers a tied product only and $\Delta > 0$ is a bit more complicated. It hinges upon whether tying is reversed by consumers or not. The tie will not be reversed if $V^M + \Delta > V^A - c_c$, since the incremental value from $A$’s superior complementary product is less than its production cost. In this case, the monopolist sets $P_T^M = V^M + \Delta$, consumers purchase only the tied product, and $\pi_M = V^M + \Delta - c_p - c_c$. However, if $V^M + \Delta \leq V^A - c_c$, the tie would be reversed since the incremental value associated with $A$’s product exceeds its production cost. In this case, consumers would purchase $A$’s complementary product and $M$’s tied product. Further, $M$ again chooses $P_T^M = V^M + \Delta$, $A$ sets $P^A_c = V^A - (V^M + \Delta)$, while $\pi_M = V^M + \Delta - c_p - c_c$ and $\pi_A = V^A - (V^M + \Delta) - c_c$. The prices and profits for each of these cases are listed in Table 2.

**Table 2: Outcomes under Tying ($\Delta > 0$)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>$V^M + \Delta &gt; V^A - c_c$</th>
<th>$V^M + \Delta \leq V^A - c_c$</th>
</tr>
</thead>
</table>
The last possibility is that $M$ offers both tied and individual products and $\Delta > 0$. There are again two cases. If $V^M + \Delta > V^A$, then it is efficient for $M$ to sell the tied product and this is the outcome. That is, $M$ sets $P_T^M = V^M + \Delta$, consumers purchase the tied product only, and $\pi_M = V^M + \Delta - c_p - c_c - (Z / N)$ and $\pi_A = 0$. The other possibility is $V^M + \Delta \leq V^A$. In this case the threat that $M$ can sell the tied product for $V^M + \Delta$ limits what $A$ can charge for its complementary good. Specifically, $A$ sets $P_C^A = V^A - (V^M + \Delta) + c_c$, $M$ chooses $P_P^M = V^M + \Delta - c_c$, $P_C^M \geq c_c - \Delta$, $P_T^M \geq V^M + \Delta$, consumers purchase $M$’s primary good and $A$’s complementary good, $\pi_M = V^M + \Delta - c_p - c_c - (Z / N)$, and $\pi_A = V^A - (V^M + \Delta)$. The prices and profits for each of these cases are listed in Table 3.

**Table 3: Outcomes under Mixed Bundling ($\Delta > 0$)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>$V^M + \Delta &gt; V^A$</th>
<th>$V^M + \Delta \leq V^A$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_T^M$</td>
<td>$V^M + \Delta$</td>
<td>$\geq V^M + \Delta$</td>
</tr>
<tr>
<td>$P_C^A$</td>
<td>$&gt; V^A - (V^M + \Delta)$</td>
<td>$V^A - (V^M + \Delta) + c_c$</td>
</tr>
<tr>
<td>$P_P^M$</td>
<td>n.a.</td>
<td>$V^M + \Delta - c_c$</td>
</tr>
<tr>
<td>$P_C^M \geq$</td>
<td>n.a.</td>
<td>$c_c - \Delta$</td>
</tr>
<tr>
<td>$\pi_M$</td>
<td>$V^M + \Delta - c_p - c_c - (Z / N)$</td>
<td>$V^M + \Delta - c_p - c_c - (Z / N)$</td>
</tr>
<tr>
<td>$\pi_A$</td>
<td>0</td>
<td>$V^A - (V^M + \Delta)$</td>
</tr>
</tbody>
</table>

We can now use the analysis concerning what happens when $M$’s product choices are taken as fixed to derive equilibrium product choices and consumer purchase decisions when $\Delta > 0$. This is done in Proposition 2. The prices and profitabilities that relate to these are those in Tables 1, 2, and 3.

**Proposition 2.** Suppose that $\Delta > 0$. Then, in equilibrium,
(i) if $V^M + \Delta \geq V^A$, $M$ offers a tied product only and consumers purchase the tied product only;

(ii) if $V^M + \Delta + c_c > V^A > V^M + \Delta$, $M$ offers a tied product only and consumers purchase the tied product only;

(iii) if $V^A \geq V^M + \Delta + c_c$, $M$ offers a tied product only and consumers purchase $M$’s tied product and $A$’s complementary product.

For (i), consumers receive a higher gross benefit from $M$’s tied product than from consuming $M$’s primary product and $A$’s complementary product. It is straightforward to see that, in this case, tying is profitable for the monopolist. For (ii) and (iii) the proof (omitted) involves employing Tables 1, 2, and 3 to conduct a simple comparison of $M$’s profits under tying only versus its other options.22

Proposition 2 tells us that for many parameterizations the equilibrium is efficient, but there are others characterized by inefficiency. Beginning with the efficient outcomes, in (i) $\Delta$ is sufficiently large that consumers derive the highest gross benefit from purchasing and using $M$’s complementary product when it is part of a tied product. So, in this case, when $M$ offers a tied product only the tying is efficient.

We now consider parameterizations with inefficient outcomes, or more precisely, inefficient tying. Let us start the discussion with (iii) of the proposition. These are the parameterizations consistent with the example of the previous section. Here, $\Delta$ is sufficiently small that the first-best outcome is that $M$ sells individual products and consumers purchase its primary product and purchase and use $A$’s complementary product. But, instead, what happens in equilibrium is that $M$ offers only a tied product and consumers purchase its tied product and $A$’s complementary product. Since consumers use $A$’s complementary good the tie causes a deadweight loss to society equal to $M$’s cost of producing the complementary units for its tied systems. The reason that $M$ ties is that tying raises the value consumers place on its goods in the absence of an alternative producer and lowers the surplus associated with $A$’s complementary product. Since $M$ captures all of the former and none of the latter, when $V^A \geq V^M + \Delta + c_c$ it increases its own profits but lowers social welfare by tying, though consumers are unaffected.

22 If $Z = 0$, then (i) of Proposition 2 would be unchanged. But in (ii) and (iii), there would also be equilibria where $M$ offers both tied and individual products and consumers purchase $M$’s primary product and $A$’s complementary product
The other parameterizations characterized by inefficient tying is the set considered in (ii) of Proposition 2. Here, it is again the case that $\Delta$ is sufficiently small that the first-best outcome is that $M$ sells individual products and consumers purchase its primary product and $A$’s complementary product. But what happens, in equilibrium, here is that $M$ offers a tied product only and consumers purchase its tied product only. Since production costs are the same across the first-best and the equilibrium outcomes, the deadweight loss here is the reduced gross benefit received by consumers because they consume the tied product rather than $M$’s primary good and $A$’s complementary good. The logic is that, as before, $M$ ties because it captures all of the value consumers place on its products in the absence of an alternative producer and none of the surplus associated with $A$’s complementary product. The difference here is that after $M$ ties, this surplus is negative so $A$ does not sell complementary units.

As a final point, it is interesting to consider the impact of our timing assumption concerning pricing. We assume that $A$ is the Stackelberg leader at the pricing stage and so $A$ is able to capture all of the surplus associated with its superior complementary product. As just shown, the result is that the monopolist always ties and this tying is frequently socially inefficient.

An alternative assumption is that at the pricing stage there is a probability $\rho$ that $A$ is the Stackelberg leader and a probability, $1 - \rho$, that $M$ is the Stackelberg leader, and when $M$ makes its tying decision the firm knows $\rho$ and $1 - \rho$ but not the eventual realization of who will be the Stackelberg leader. When $A$ is the Stackelberg leader, then as before $A$ is able to capture all of the surplus associated with its superior complementary product. But when $M$ is the Stackelberg leader it captures all of the surplus associated with $A$’s superior complementary product.

Analysis of this setting yields parameter ranges similar to those found above. First, there is efficient tying when $V^M + \Delta \geq V^A$. Second, there is a range of parameterizations characterized by inefficient tying where consumers purchase $M$’s tied good and purchase and use $A$’s complementary good. Third, there is a range of parameterizations characterized by inefficient tying where consumers purchase $M$’s tied good only but receive a higher gross benefit from purchasing $M$’s primary good and $A$’s complementary good.

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product. In these equilibria there is no deadweight loss, although adding an R&D decision as in the following subsection would result in inefficiency even in these equilibria.
But there are also two other parameter ranges in this setting. In one $M$ offers individual products only. This occurs when it is efficient for consumers to purchase $M$’s primary good and $A$’s complementary good, but $\rho$ is low and both $c_C$ and $Z$ are high. $\rho$ is low means there is a small return to tying since at the pricing stage $M$ will likely be able to capture all of the surplus even without tying, while $c_C$ is high means the cost of tying is high (the role of high $Z$ is explained next). In the other parameter range $M$ offers tied and individual products. This can occur when $Z$ is low. The logic is that, when $Z$ is low, it is sometimes optimal for $M$ to offer and sell its primary product when it is the Stackelberg leader and offer and sell its tied product when $A$ is the Stackelberg leader which it achieves by offering both tied and individual products.

In summary, when $\Delta > 0$, there is a broad range of parameterizations characterized by inefficient tying. In some of these parameterizations, like in the example in the Introduction and the previous section, the monopolist ties a product that consumers purchase but do not use. Consequently, the cost the monopolist incurs in producing the good represents a pure deadweight loss. In the other parameterizations characterized by inefficient tying $M$’s complementary good is used in equilibrium. But because $V^A > V^M + \Delta$, societal surplus would be higher if the monopolist had instead sold individual products and consumers had purchased the monopolist’s primary product and the alternative producer’s complementary product. Note that, as indicated in the Introduction, the inefficient tying in this model is not driven by any of the standard rationales in the literature for why a firm would tie – efficiency, price discrimination, or exclusion. Rather, the tying is used to change the pricing game so that some of the surplus associated with the alternative producer’s superior complementary product is shifted from the alternative producer to the monopolist with no effect on consumers.

B. Analysis Where the Functionality of the Tie is Endogenous

In this subsection we extend the previous analysis to show that, in addition to causing distortions or inefficiencies concerning the monopolist’s product choice decisions, the tying rationale identified here can also result in distortions concerning the monopolist’s R&D

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23 In our model here, if the marginal cost associated with adding $M$’s complementary good in a tied product was zero, there would be no inefficiency. However, this is an artifact of some of our simplifying assumptions. For instance, below we show that $M$ has an incentive to engage in inefficient R&D that would create inefficiencies even when the marginal cost of the complementary good equals zero. Moreover, in an analysis related specifically to
decisions. The basic idea is that, even if the monopolist’s complementary product is not used in equilibrium so the tie provides no social welfare return, increasing the investment in R&D that affects the functionality of the tie can be privately optimal because of the manner in which it alters the outcome in the subsequent pricing game between the monopolist and the alternative producer.

Relative to the model considered in Subsection IV.A, we make the following change; the added functionality associated with consuming M’s tied product rather than it’s primary and complementary goods purchased individually can now be either high or low. Let $\Delta^L$ be the increased gross benefit when the added functionality is low while $\Delta^H, \Delta^H > \Delta^L$, is the increased gross benefit when the added functionality is high. Further, whether the increased gross benefit associated with consuming M’s tied product is high or low is a function of an R&D choice M makes at the beginning of the game. To be exact, at the beginning of the game M chooses an R&D expenditure denoted $R$, where $p(R)$ is the probability the increased gross benefit associated with the tie equals $\Delta^H$ while $(1 – p(R))$ is the probability it equals $\Delta^L$. We further assume $p(0) = 0$, $p'(0) = \infty$, and $p'(R) > 0$ and $p''(R) < 0$ for all $R \geq 0$. Following the realization of whether the added functionality is high or low, M decides whether to offer a tied product only, individual products only, or tied and individual products.

As suggested above, our focus in this subsection is on parameterizations in which M ties but consumers proceed to purchase and use A’s complementary good. Based on the analysis of the previous section, this translates into focusing on parameterizations for which $V^A \geq V^M + \Delta^H + c_c$; we consider other parameterizations briefly below. Let us start by describing the first best in this case. Since consumers, even after purchasing the tied product, do not use M’s complementary good in equilibrium, there is no social welfare return to either tying or increasing the gross benefit associated with consuming the tied product. In other words, for these parameterizations the first best is characterized by no tying since tying causes inefficient production of M’s complementary units. But, in addition, the first best is now also characterized by $R = 0$, i.e., no investment in R&D, so the added gross benefit associated with consuming the tied product is sure to be low. The logic here is that, since M’s complementary units are not used in equilibrium even if the added functionality associated with using the tied product is high, from computer applications, Gans (2007) demonstrates a range of inefficiencies that can be generated by tying of the sort analyzed here.
a social welfare standpoint there is no reason to invest in improving the added functionality associated with tying.

In contrast to the first best, actual equilibrium behavior is characterized both by tying and by a positive investment in R&D. For both actions, the deviation from first-best behavior is driven by a desire by $M$ to alter in its favor the outcome of the subsequent pricing game played between $M$ and $A$.

We formalize this argument in Proposition 3.

**Proposition 3.** If $V^A \geq V^M + \Delta^H + c_c$, then $R > 0$, $M$ offers a tied product only, and consumers purchase $M$’s tied product and $A$’s complementary product.

The reason $M$ ties in Proposition 3 even though consumers do not use $M$’s complementary product is the same as the logic for tying in (iii) of Proposition 2. That is, tying raises the value that consumers place on $M$’s goods in the absence of an alternative producer and lowers the surplus associated with $A$’s product. Since in the subsequent pricing game $M$ captures all of the former but none of the latter, it chooses to tie.

What is new here is the inefficient investment in R&D, i.e., $R > 0$. The logic for this result builds on the logic above. As just discussed, $M$ ties because tying raises the value consumers place on it’s goods in the absence of an alternative producer and because tying allows $M$ to capture all of that value. But note that the return to tying is higher when the R&D investment is successful because then tying is associated with a larger increase in the value consumers place on $M$’s goods in the absence of an alternative producer. Hence, it invests a positive amount in R&D even though it’s complementary good is never used in equilibrium because a positive investment increases the probability the R&D investment is successful and, thus, increases the return to tying.

As a final point, above we focus on R&D distortions when $M$ ties but it’s complementary good is not used by consumers in equilibrium. But building on (ii) of Proposition 2, there is also a range of parameterizations in which there is overinvestment in R&D relative to the first best but, when $M$ ties, consumers purchase it’s tied product only. That is, suppose $V^M + \Delta^L + c_c > V^A > V^M + \Delta^M$. Given $V^A > V^M + \Delta^H$, for these parameterizations the first best is characterized by $R = 0$ and no tying since consuming a system with $A$’s complementary product yields the highest gross benefit. But consistent with (ii) of Proposition 2, in equilibrium $M$ ties whether or not the R&D investment is successful. In turn, since $M$ sells its tied product for
a higher price when the R&D investment is successful, there is a positive return to investing so $R > 0$. In other words, the R&D investment exceeds the first-best level.

V. HETEROGENEOUS CONSUMERS

In this section we investigate the extent to which our results generalize to a setting characterized by heterogeneous rather than homogeneous consumers. Specifically, we consider what happens when we introduce a second group of consumers who are indifferent between $M$'s complementary good and $A$'s complementary good. Our analysis shows that there are still many parameterizations characterized by inefficient tying, where in some of these parameterizations some consumers purchase but do not use $M$'s tied complementary product. Overall, our analysis shows that the main results of Section III fully generalize to this case.

Here we assume everything is the same as before except there are now two groups of consumers only one of which prefers $A$'s complementary product. To be specific, there are $N_1$ consumers in group 1 who, as before, receive gross benefits equal to $V^M$ from a system consisting of $M$'s primary and complementary goods purchased separately, $V^M + \Delta$ from a system consisting of $M$'s primary and complementary goods purchased as a tied product, $V_1^A$, $V_1^A > V^M$, from a system consisting of $M$'s primary good and $A$'s complementary good, and $\max\{V^M + \Delta, V_1^A\}$ from a system consisting of $M$'s tied product and $A$'s complementary good. But now there are also $N_2$ consumers in group 2 who are identical to group 1 consumers except they receive a gross benefit of $V_2^A$, $V_2^A = V^M$, from a system consisting of $M$'s primary good and $A$'s complementary good and $\max\{V^M + \Delta, V_2^A\} = V^M + \Delta$ from a system consisting of $M$'s tied product and $A$'s complementary good.

We start by considering what happens when $\Delta = 0$, i.e., there is no incremental benefit to consuming $M$'s primary and complementary goods purchased as a tied product. Analysis of this case yields basically the same results found in Proposition 2 for the one-group analysis. That is, tying is consistent with equilibrium behavior, but this is not because the monopolist increases its profitability by tying. Whether or not the monopolist ties, in the subsequent pricing game $A$ is able to capture all the surplus associated with its complementary product with the result that
\[ \pi_M = V^M - c_p - c_c = \pi_M^*. \] In other words, consistent with Whinston’s analysis concerning essential primary products, even in the two-group model there is no incentive for the monopolist to tie when \( \Delta = 0 \).

We now consider what happens when \( \Delta > 0 \). As before, we begin by taking as fixed \( M \)’s choice concerning whether to sell a tied product only, individual products only, or tied and individual products, and then describe the equilibrium to the resulting subgame. If \( M \) sells individual products only, then \( \Delta \) is irrelevant since \( \Delta \) is the added gross benefit associated with \( M \) tying. So this subgame is the same as the subgame above when \( \Delta = 0 \) and \( M \) sells individual products only. So \( \pi_M = V^M - c_p - c_c \).

Now suppose that \( M \) sells a tied product only and \( \Delta > 0 \). If \( V^M + \Delta > V^A_1 - c_c \), then \( A \) cannot profitably sell complementary units. In this case \( M \) sets \( P^M_T = V^M + \Delta \) and sells tied units to both groups, so \( \pi_M = V^M + \Delta - c_p - c_c \). If \( V^M + \Delta \leq V^A_1 - c_c \), then \( A \) sells complementary units to group 1 consumers because for group 1 the incremental benefit associated with \( A \)’s complementary good is greater than or equal to its production cost. In this case the subgame equilibrium is \( A \) sets \( P^A_C = V^A_1 - (V^M + \Delta) \), \( M \) chooses \( P^M_T = V^M + \Delta \), group 1 consumers purchase \( M \)’s tied product and \( A \)’s complementary product, group 2 consumers purchase \( M \)’s tied product only, and \( \pi_M = V^M + \Delta - c_p - c_c \).

The last case is that \( M \) offers both tied and individual products and \( \Delta > 0 \). If \( V^M + \Delta > V^A_1 \), then it is efficient for both groups to purchase the tied product only and this is the outcome. For these parameterizations \( \pi_M = V^M + \Delta - c_p - c_c - (Z/(N_1 + N_2)) \). The other possibility is that \( V^M + \Delta \leq V^A_1 \). In this case \( A \) sets \( P^A_C = V^A_1 - (V^M + \Delta) + c_c \), \( M \) chooses \( P^M_T = V^M + \Delta \) and \( P^M_P = V^M + \Delta - c_c \), group 1 consumers purchase \( M \)’s primary product and \( A \)’s complementary product, group 2 consumers purchase \( M \)’s tied product only, and \( \pi_M = V^M + \Delta - c_p - c_c - (Z/(N_1 + N_2)) \).

We can now use the above analysis concerning what happens when \( M \)’s product choices are taken as fixed to derive equilibrium behavior. This is done in Proposition 4. The prices and profitabilities for each of the parameter ranges below are found in the above discussion concerning equilibrium behavior when \( M \) chooses to sell a tied product only.
Proposition 4. Suppose that $\Delta > 0$. Then, in equilibrium,

(i) if $V^M + \Delta \geq V_1^A$, $M$ offers a tied product only and both groups of consumers purchase the tied product only;

(ii) if $V^M + \Delta + c_c > V_1^A > V^M + \Delta$, $M$ offers a tied product only and both groups of consumers purchase the tied product only;

(iii) if $V_1^A \geq V^M + \Delta + c_c$, $M$ offers a tied product only, group 1 consumers purchase $M$’s tied product and $A$’s complementary product, and group 2 consumers purchase $M$’s tied product only.

For (i), even group 1 consumers receive a higher gross benefit from consuming $M$’s tied product than from consuming $M$’s primary product and $A$’s complementary product. So in this case it is straightforward to see that $M$ offers a tied product only. For (ii) and (iii) the proof (omitted) involves comparing the values for $\pi_M$ across $M$’s three possible product choices found above.

Proposition 4 tells us that the model with two consumer groups works similarly to the model with a single group. That is, $M$ always offers a tied product only where this is efficient for some parameterizations but inefficient for others. In (i), $M$ offers a tied product only and this is efficient because the added benefit associated with the tie exceeds the extra benefit group 1 consumers receive from $A$’s complementary product.

In (ii), $M$ offers a tied product only, both groups purchase the tied product only, and for some of these parameterizations this outcome is inefficient. For example, if $Z$ is sufficiently small, then the first best is that $M$ offers both tied and individual products, group 1 consumers purchase $M$’s primary good and $A$’s complementary good, and group 2 consumers purchase $M$’s tied good only. But in equilibrium this is not the outcome and instead both groups purchase $M$’s tied good only. The logic is that, because $A$ is the Stackelberg leader and is able to capture all the surplus at the pricing stage, $M$ is not able to capture additional profits from group 1 consumers by offering both tied and individual products. So $M$ maximizes profits by selling only a tied product and avoiding the extra cost, $Z$, associated with selling both tied and individual products.

Another set of parameterizations where (ii) is inefficient is when $Z$ is high and $N_1$ is much greater than $N_2$. A high value for $Z$ means that it is not efficient for $M$ to offer both tied and individual products. But if $N_1$ is much higher than $N_2$, then the first best is $M$ sells individual products only, group 1 consumers purchase $M$’s primary good and $A$’s complementary good, and group 2 consumers purchase $M$’s primary good and either complementary good. But this is never the outcome because the monopolist can increase its profits by selling a tied good only even
though most consumers receive a higher gross benefit from consuming $M$’s primary good and $A$’s complementary good.

In (iii), $M$ offers a tied product only, group 1 consumers purchase $M$’s tied product and $A$’s complementary product, group 2 consumers purchase $M$’s tied good only, and for some of these parameterizations this outcome is inefficient. For example, suppose $Z$ is small. Then, as above, the first-best outcome is $M$ offers both tied and individual products, group 1 consumers purchase $M$’s tied good and $A$’s complementary good, and group 2 consumers purchase $M$’s tied good only. But instead in equilibrium $M$ offers a tied product only and group 1 consumers purchase $M$’s tied product and $A$’s complementary product. This is inefficient because group 1 consumers do not use $M$’s complementary good so the costs associated with producing that good for group 1 (minus $Z$) represent a deadweight loss.

There is also a set of inefficient parameterizations where $Z$ is high but $N_1$ is much greater than $N_2$. As above, the first-best outcome for these parameterizations is $M$ sells individual products only, group 1 consumers purchase $M$’s primary good and $A$’s complementary good, and group 2 consumers purchase $M$’s primary good and either complementary good. For these parameterizations the deadweight loss equals $M$’s cost of producing the complementary units purchased but not used by group 1 consumers in equilibrium minus the extra benefit received by group 2 consumers due to consuming a tied rather than individual products.

In summary, with a second group of consumers who are indifferent between $M$’s and $A$’s complementary products there are still many parameterizations characterized by inefficient tying. In some of these parameterizations the inefficiency is due to some consumers purchasing the monopolist’s tied product when they do not use the monopolist’s complementary product in equilibrium. In other parameterizations the inefficiency is due to some consumers purchasing the monopolist’s tied product only when these consumers would receive a higher gross benefit from purchasing and consuming the monopolist’s primary good and the alternative producer’s complementary good. So overall the main results of Section III extend to our heterogeneous consumer case.
VI. EFFECTS OF COMPETITION AND ANTITRUST IMPLICATIONS

In previous sections, we showed how a monopolist of a primary good may tie an inferior complementary good that consumers do not use, where the goal is increased profits through a more advantageous outcome in the pricing game between the monopolist and the complementary good’s alternative producer. Further, this behavior can lower social welfare in various ways including forcing the production of units that are purchased but not used in equilibrium and also causing distortions in the monopolist’s R&D decisions. In this section, we discuss how competition affects our results concerning tying and decreased social welfare. We then discuss the implications of our results for antitrust policy.

The first question we examine is how our results change if we introduce competition. To analyze this, suppose that there are two symmetric suppliers of the primary product and that each can supply a complementary product that has value in its own system. Similarly, with each primary product there is an associated alternative complementary product provider who provides a complementary good of value to that specific system. That is, complementary goods are associated with one primary good but not the other. Thus, there are four firms in this model. Moreover, the products they supply are homogeneous in the eyes of consumers in the sense that, as before, $V^M$ is the value of a system comprising a primary product and that primary good producer’s complementary good, $V^d$ is the value of a mixed system, $\Delta$ is the incremental value associated with a tie, and $V^M$ and $V^d$ are the same for each system. Costs are as assumed in the monopoly case.

Suppose, first, that similar to our monopoly analysis the timing is that each primary product producer first chooses whether to offer tied, individual, or tied and individual products, then the alternative producers choose prices, then the primary product producers choose prices, and finally consumers make their choices and payoffs are realized. Also, let us focus on the case where $V^d \geq V^M + \Delta + c_c$; the set of parameterizations in our monopoly analysis where there was inefficient tying and consumers did not use the monopolist’s complementary good.

In this case, it is easy to show that all firms would have an incentive to price their products at marginal cost. Deviating from this would cause the ‘system’ and themselves to lose all of their consumers and so would not be worthwhile. In this situation, it would be worthwhile
to tie a product only if consumers would not want to reverse the tie. Hence, there would be no opportunity for rent extraction through tying when $V^A \geq V^M + \Delta + c_c$ and thus no inefficiency.

In order to better understand how competition is constraining behavior, let’s change slightly the timing in the model. Suppose that each primary good producer first sets its prices (for individual products and/or a tied product as the case may be). Then following this, consumers purchase primary products and, having observed this, each firm competes for sales of complementary products.

Each primary good producer would be forced under competition to set its prices so as to just break even. Thus, in the absence of a tie, $P^h_p = c_p$, while $P^h_c = c_c$ and $P^d_c = c_c + (V^A - V^M)$. The prices for the complementary goods mirror those in the monopoly case. Notice that in the subgame perfect equilibrium of this game, each alternative producer of the complementary good has market power and earns rents, while primary good producers do not. Compared to the monopoly case, consumers benefit from the competition between the primary good producers and therefore enjoy additional surplus. The alternative producers of the complementary good exploit the lock-in effect in their pricing. This exploitation would not occur if there was competition among producers of the complementary good initially in up-front payments to consumers before consumers chose which primary product to purchase. Because we do not have that price flexibility in the model, the complementary good producers earn a rent. In the initial formulation of the model where alternative producers chose prices first, that type of competition occurs, in effect, and so consumers benefit and no producer earns rents.

Now suppose that a primary good producer offers a tied product only. The break-even price of the tied good is $P^d_T = c_p + c_c$. Critically, however, given this, the alternative provider is free to price up to the incremental value of the alternative system; that is, $P^d_c = V^A - (V^M + \Delta)$ so that it appropriates all of the surplus given the availability of the tied product. A primary producer will tie if, in so doing, it can make consumers better off. This will happen if the joint surplus between the primary producer and a consumer under tying, $V^M + \Delta - c_p - c_c$, exceeds that surplus when there is no tie, $V^M - c_p - c_c$; as is always the case here with $\Delta > 0$. Thus, tying is possible even when primary producers have no market power. Note that this tying is inefficient.

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24 See Borenstein et al. (1995) and Shapiro (1995) for previous discussions and analyses of pricing in the presence of consumer lock-in.
since consumers purchase the tied product and purchase and use the alternative producer’s complementary product; causing a deadweight loss. But it increases consumer welfare.

What is illuminating about this formulation is that it reveals that there can remain an incentive for an inefficient tie even under competition. The reason is that, by tying, a primary good producer can, as before, alter the pricing of the complementary product and transfer rents away from the complementary good producer. In the model without competition, the transfer went to the monopolist of the primary product. But now with competition between primary good producers, the transfer goes to consumers. Competition between primary good producers will guarantee, therefore, that the tie occurs to the benefit of consumers, even though we know the tie is inefficient since consumers never use the tied complementary product. One way to get rid of the inefficiency in this model is to allow primary and complementary good producers to merge in which case we get back to the equilibrium in the specification in which the primary good producers choose prices first where there is no tie, no inefficiency, firms earn no rents, and consumers benefit.

What, if anything, do our results imply for antitrust policy? The social inefficiency that arises from tying in the model with market power or in the competitive model above (where the market power resides with the complementary good producers) has nothing to do with harming the competitive process in the sense that the tie creates additional market power. Unlike other examples in the literature, rivals are not excluded nor is the firm practicing the tie able to force the consumer to pay a higher total price for the system. The tie is a clever strategic tool to transfer rents from the producer of the complementary good to either the monopolist when there is no competition or to consumers when there is competition among primary good producers. Accordingly, we see little grounds to justify intervention on antitrust grounds even though we are aware that there might be a social inefficiency. Some might advocate intervention on social engineering grounds to eliminate the inefficiency but that course of action is fraught with the usual difficulties of figuring out when to intervene and interfering with the functioning of markets.

Although the results of our model do not provide a basis for aggressive antitrust intervention, there is an important antitrust policy prescription that emerges regarding mergers and contracting between rival producers. Consider, for example, merger policy. In our basic model a firm sometimes ties an inferior complementary product that consumers do not use in
order to improve the outcome in the ex-post pricing game between the monopolist and the alternative producer. This lowers social welfare because of the production costs associated with the tied but unused complementary product (in the analysis of Subsection IV.B welfare also falls because of distortions concerning the monopolist’s R&D choices). Allowing a merger between the firms in this setting may raise welfare by avoiding these unnecessary and inefficient production costs. Similar considerations arise in evaluating contracts between the firms that allow the monopolist, for example, to tie the alternative producer’s superior complementary good to its monopolized good. The same insights hold true when there is competition between primary good producers. In such a case, allowing mergers or contracts between primary good producers and the supplier of the superior complementary good may be welfare enhancing with the consumers reaping the benefit.

**VII. CONCLUSION**

Most previous analyses of tying have focused on efficiency, price discrimination, or exclusionary rationales for the practice in the context of irreversible ties. In this paper, we focus on the empirically important case of reversible ties and develop a new rationale for the practice in which a monopolist ties a complementary good in order to alter the outcome of the subsequent pricing game between itself and the rival producer of the complementary good. Interestingly, we find that this motivation for tying arises only when tying by the monopolist is efficient in the absence of the rival producer. But, in the presence of the rival, this type of tying is frequently inefficient because, for example, consumers do not use the monopolist’s complementary good even after they have purchased the monopolist’s tied product. Clearly, in such a case the monopolist’s expenditures on developing and producing the complementary good represent a deadweight loss to society.

We believe this new explanation for tying has wide applicability. There are many instances in which a firm ties a complementary good when rivals sell superior complementary products with the result that few consumers wind up using the monopolist’s tied good. For example, we believe this a good description of Microsoft’s behavior in its tying of various complementary products such as instant messaging, movie and photo editing, and security

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25 Subject, of course, to potential strategic issues that may arise if A could itself engage in R&D expenditures.
programs. Note that, although our analysis indicates that tying in many of these instances may be socially inefficient, we explain why our results do not provide a basis for antitrust intervention. Indeed, the implication of our results is that antitrust policy should, under some circumstances, look kindly on certain types of vertical contracting and mergers because they may improve total and consumer welfare.

APPENDIX

A. Proof or Proposition 1

Suppose first that $M$ sells a tied product only. Given this, suppose $V^A - V^M \geq c_C$. Then $A$ sets $P^M_C = V^A - V^M$, $M$ responds by choosing $P^M_T = V^M$, and consumers purchase $M$’s tied product and $A$’s complementary product (see footnote 19). The reason is that if $A$ sets $P^A_C$ at a higher value it sells nothing and $\pi_A = 0$. The result is that $\pi_M = V^M - c_p - c_c$. Suppose $V^A - V^M < c_C$. Then $A$ cannot profitably sell complementary units and $M$ responds by choosing $P^M_T = V^M + \Delta$, consumers purchase $M$’s tied product only, and we again have $\pi_M = V^M - c_p - c_c$.

Suppose $M$ sells individual products only. Then $A$ sets $P^M_C = V^A - V^M + c_c$, $M$ responds by choosing $P^M_p = V^M - c_c$, and consumers purchase $M$’s primary product and $A$’s complementary product (see footnote 19). The reason is again that if $A$ sets $P^A_C$ at a higher value it sells nothing and $\pi_A = 0$. The result is that $\pi_M = V^M - c_p - c_c$.

Suppose $M$ sells both tied and individual products. Then $A$ sets $P^M_C = V^A - V^M - c_c$, $M$ responds by choosing $P^M_p = V^M - c_c$, and consumers purchase $M$’s primary product and $A$’s complementary product (see footnote 19). The result is $\pi_M = V^M - c_p - c_c - (Z / N)$.

Comparing the values for $\pi_M$ across $M$’s three possible choices concerning which products to produce yields that $M$ either sells a tied product and $\pi_M = \pi_M^*$ or sells individual products and $\pi_M = \pi_M^*$.
B. **Proof of Proposition 3**

The result that $M$ offers a tied product only and consumers purchase $M$'s tied product and $A$'s complementary product follows from the argument used to prove Proposition 2. So we only need to show $R > 0$. From Table 2, we have that monopoly profitability is given by (A1).

$$p(R)[V^M + \Delta^H - c_p - c_c] + (1 - p(R))[V^M + \Delta^L - c_p - c_c] - R$$  (A1)

Taking the first-order condition with respect to $R$ yields yields (A2).

$$p'(R)(\Delta^H - \Delta^L) - 1 = 0$$  (A2)

Given $p'(0) = \infty$, $p'' < 0$, and $\Delta^H > \Delta^L$, (A2) yields $R > 0$.

**REFERENCES**


