

# Remedies for Tying in Computer Applications<sup>\*</sup>

*by*

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First Draft: 30<sup>th</sup> May, 2005

This Version: 25<sup>th</sup> October, 2007

Recent anti-trust decisions have proposed remedies for tying of different computer software and applications. The remedies have drawn criticism for being ineffectual. This paper develops a model tailored to deal with the specific issue of tying in computer applications. It provides a rationale for such tying and also any associated harm to social welfare. It then examines proposed remedies and finds conditions under which those remedies will be effective in improving social welfare. *Journal of Economic Literature* Classification Number: L41.

Keywords: tying, software, Microsoft, remedies.

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## 1. Introduction

Microsoft has long characterised their own strategy aiming to ‘embrace and extend’ popular software standards and applications.<sup>1</sup> This involves Microsoft publicly supporting a standard or application and then assigning resources to its development (Embrace). Then Microsoft developers add proprietary extensions and add-ons to the standard or application (Extend). Perhaps the most high profile of these strategies has been Microsoft’s embrace of web browsing and media players and its extension embedding a browser (Internet Explorer) and a player (Windows Media Player or WMP) in latest versions of its operating system. This also occurred in Microsoft’s adoption of Java and its extension of Sun’s standard. But each of these instances has been the subject of anti-trust action: both public and private. The allegation being that Microsoft’s embrace and extend strategy had a more sinister third stage, extinguish. In this latter stage, Microsoft gains control over a standard and prevents rivals from competing based on it.

The allegation is based on a notion that when Microsoft integrates a standard into its Windows operating system it is tying its own product with one in which is a monopoly provider as a means of leveraging that monopoly power. The recent EU verdict that Microsoft had illegally tied its media player with Windows is instructive. There Microsoft was found to have a dominant position on the PC Operating System (OS) market and to have abused that market power in two respects. First, it refused to supply information that would make programs interoperable with its OS. Second, it tied WMP to its OS product. The company was fined almost half a billion dollars, ordered to provide interoperability information and to provide an unbundled version of Windows (without WMP) within 90 days for a price no more than the bundled version.<sup>2</sup>

Carlton, Gans and Waldman (2007) consider the potential anti-competitive effects of tying in the form of pre-installation. Tying represents a difficult issue for competition economists. As the seminal work of Whinston (1990) illustrates, tying by a monopoly provider of an essential complementary good – such as Microsoft’s Windows – is

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<sup>1</sup> See Wikipedia reference ‘embrace and extend.’

<sup>2</sup> See Yoffie (2005) for a discussion.

generally not profitable for the monopolist; let alone generating anti-competitive effects. In the end, both a motivation and anti-competitive effects are usually found by appealing to dynamic arguments (Whinston, 2001); namely that embracing and extending is a prelude to an extinguish motive and effect. And such arguments have recently been formalized (Choi and Stefanadis, 2001; Carlton and Waldman, 2002).<sup>3</sup>

The model of Carlton, Gans and Waldman (2007) provides a simple theory as to why ‘embrace and extend’ in of itself may cause consumer and social harm without the need for the additional stage of extinguish.<sup>4</sup> Their theory *implicitly* identifies two potential drivers of both motivations for pre-installation in software<sup>5</sup> and their potential anti-competitive effect. The first of these is an inability for a monopoly firm to commit to a low price for a related product when it must first supply the essential complement. Pre-installation provides that commitment and intensifies price competition in the related market; the returns to which can be captured by the monopolist.

The second driver is the fact that consumers in the related market face their own costs associated with installing the complementary products. Media players must be downloaded, installed and any incompatibility issues sorted out. This imposes costs on consumers that do not arise if those products are pre-installed; as they are in the Windows bundled product. In the absence of pre-installation, those costs are borne by consumers and this reduces their value for the essential product. With pre-installation, those costs are borne by other providers. Hence, pre-installation changes the incidence of installation costs in favour of the monopolist and to the harm of rival providers. Thus, pre-installation can produce rent shifting.

Utilising this basic insight, I provide a model with a different timing to Carlton, Gans and Waldman (2007) and ultimately a more general setting with the purpose of analysing the different remedies that might be imposed on a firm, such as Microsoft, found to have engaged in an illegal tie. This is a subtle issue as the substance of the inefficiency is a potential set of consumer benefits that arise from having the tied product available (e.g., saving on pre-installation).

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<sup>3</sup> See Choi (2004) and Tirole (2005) for recent surveys.

<sup>4</sup> This is not to say that latter stage may not be important but that one need not appeal to it to find an anti-competitive rationale for Microsoft’s pre-installation of standards and applications in its OS.

<sup>5</sup> Or as Sidak (2001) terms it ‘software integration.’

Of particular interest is an EU like policy of mandatory untying. Economists have criticised this remedy as being at best innocuous as consumers would be indifferent between purchasing the unbundled and bundled products if they were priced the same. However, I demonstrate that this indifference may, in some circumstances, reduce the effectiveness of pre-installation as consumers may purchase the unbundled product. If this occurs, then competition in the related product market is altered and, indeed, the monopolist – to the extent that bundling is costly – may choose not to bundle. Thus, mandatory untying may be effective.

The paper proceeds as follows. In section 2, I present a simple model based on Carlton, Gans and Waldman (2007) but with an alternative timing that gives rise to a unique equilibrium.<sup>6</sup> This will serve to motivate the type of tying of relevance to the Microsoft case. Section 3 then considers a general model where competition in the related market involves both horizontal and vertical product differentiation. This allows us to more carefully characterize the welfare consequences of pre-installation. Section 4 considers remedies including mandatory untying, investments and rival pre-installation. A final section concludes.

## 2. Simple Model

As is well known, tying represents a puzzle from an economics perspective. As the Chicago School pointed out long ago, tying is unlikely to improve the profits of a monopoly firm. The same is not true of pre-installation.

To see this, first consider the standard Chicago School analysis of tying. Suppose there are two firms 1 and 2 and two products,  $A$  and  $B$ . Firm 1 has both a monopoly over  $A$  but both firms 1 and 2 can produce  $B$ . I denote these latter products by  $B1$  and  $B2$ . In addition,  $A$  is essential for the operability of  $B1$  and  $B2$ . In this case, tying is not profitable for firm 1. If consumers value the products  $A$ ,  $B1$  and  $B2$  at  $V_A$ ,  $V_B$  and  $V_B + \lambda$  respectively (with  $\lambda > 0$ ) and it costs nothing to produce any of these products, then by tying  $A$  and  $B1$ , firm 1 can at most make  $V_A + V_B$ . In contrast, by not tying, firm 1 can set

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<sup>6</sup> Carlton, Gans and Waldman (2007) examine a situation when pricing is simultaneous and hence, have to deal with multiple equilibria. This limits the potential for generalisation of that model in a tractable manner.

the price of  $A$ ,  $P$ , at  $V_A + V_B$  and the price of its  $B$ ,  $p_1$ , at  $\$0$  leaving the maximum price for  $B2$  as  $\lambda$ . In this case, the monopolist earns as at least much by not tying as tying but firm 2 is better off if no tying occurs.<sup>7</sup>

While this example captures the ‘essentiality’ of product  $A$  to allow the operation of  $B1$  and  $B2$  that is a feature of the Microsoft cases, it falls short on two dimensions. First, the costs associated with utilising  $B1$  and  $B2$  can fall on the consumer; i.e., the consumer has to expend time and effort installing the product unless, of course, it was ‘pre-installed’ when they purchased  $A$ . Let’s denote such costs as  $c_1$  and  $c_2$  for  $B1$  and  $B2$  respectively. These costs include the time spend downloading and loading as well as any difficulties that might arise because of incompatibility with existing programs. Second, even if firm 1 pre-installs  $B1$  with  $A$ , the consumer may still find it worthwhile to install  $B2$ , if  $\lambda > c_2 + p_2$  (the price of  $B2$ ). Thus, pre-installation does not preclude further installation of a competitor’s product.

In this case, if firm 1 has not pre-installed  $B1$ , in subsequent competition in the  $B$  market,  $p_1 = 0$  and  $p_2 = \lambda - c_2 + c_1$  meaning that the price of  $A$ ,  $P$ , can be set to capture consumer surplus from the  $A$  and  $B$  markets; i.e.,  $P = V_A + V_B - c_1$ . In contrast, if  $B1$  is pre-installed, say at a cost of  $C$ , then to convince consumers to install its product,  $p_2 = \lambda - c_2$ , as installation costs for  $B2$  still need to be incurred and firm 2 must compensate consumers for this. In this case, if  $B1$  is pre-installed, then the price for the combined  $A$  and  $B1$ ,  $P = V_A + V_B$ . Thus, pre-installation will be strictly profitable for firm 1 if  $C < c_1$ .<sup>8</sup>

Put simply, pre-installation means that firm 2 must compensate consumers for installation costs,  $c_2$ ; something that ‘level playing field’ competition between firms 1

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<sup>7</sup> The monopolist may be strictly better off from not tying if firm 2 cannot capture the full marginal consumer surplus from consumers for its product or if providing a tied product is more costly for the monopolist than providing separate ones.

<sup>8</sup> This example explicitly has  $P$  determined before (but in expectation of)  $p_1$  and  $p_2$  as the case may be. If pricing was simultaneous (as it is in Carlton, Gans and Waldman, 2007), then, if there is no tie, it will be optimal for 1 to set  $p_1 = 0$ . Given this, there is a continuum of equilibrium outcomes with  $(P, p_1, p_2)$  such that  $P + p_2 = V_A + V_B + \lambda - c_2 + c_1$  and  $p_2 \in [0, \lambda - c_2 + c_1]$ . If there is pre-installation, then:

$$(P, p_2) \text{ such that } P + p_2 = V_A + V_B + \lambda - c_2 \text{ and } p_2 \in [0, \lambda - c_2].$$

So the sequential pricing version – which happens to reflect reality – allows us to pin down the prices more easily.

and 2 does not require. This reduces  $p_2$  but the additional consumer surplus is captured by 1 through a higher  $P$ .

Given this, it is easy to see that if  $\lambda > c_2 - C$ , the welfare consequences of pre-installation are unambiguously negative. While consumers are always indifferent as to whether  $B1$  is pre-installed or not, when  $\lambda \geq c_2$ , pre-installation is activity without benefit but with a cost of  $C$ . So social welfare is reduced by  $C$ . It also has a distributional consequence as 2's profits are reduced by  $c_1$ . If  $\lambda < c_2$ , pre-installation entails a further social cost as the value  $\lambda$  is lost. Thus, social welfare with pre-installation is lowered by  $\lambda - c_2 + C$ . Again, the costs of this fall upon firm 2. Of course, if  $\lambda < c_2 - C$ , then pre-installation is welfare enhancing as the savings in installation costs exceed the additional benefits from using  $B2$ .

The important thing to notice about this behaviour is that, in this example, it does not necessarily result in foreclosure. Recall that in Whinston (1990), the potential for tying to lead to foreclosure and then an unconstrained monopoly in the  $B$  market provided both the motivation and the adverse welfare consequences from tying. Here, when  $\lambda \geq c_2$ , there is no foreclosure. Indeed, in this example, firm 2's sales are not diminished.<sup>9</sup> What does occur is that pre-installation intensifies effective price competition in the  $B$  market shifting rents from firm 2 to consumers which are, in turn, captured by firm 1 in its pricing of  $A$ . As Whinston (1990) notes, a monopolist over an essential complement will be interested in intensifying competition for related goods. Here pre-installation achieves rather than precludes such competition as all or some consumers may still purchase  $B2$  in any case.

More critically, however, pre-installation changes 1's attitude towards generic post-installation costs. When it pre-installs  $B1$ , firm 1 has an incentive to reduce any costs associated with pre-installing products but no incentive to reduce or contain general post-installation costs (i.e., cost components common to  $c_1$  and  $c_2$ ). In contrast, in the absence of pre-installation, these incentives are reversed. If installing  $B2$  is otherwise valuable for consumers, then this represents an additional social cost from pre-installation. This

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<sup>9</sup> The general model below provides instances where foreclosure does occur in the sense that firm 2 has no sales. However, even in that case, potential competition from firm 2 does constrain firm 1.

provides a link between the EU concerns regarding tying and their concerns regarding interoperability. Effectively removing tying options creates better incentives for firm 1 to improve interoperability.

### 3. General Model

The simple model can leave the impression that the private motives and negative welfare consequences from pre-installation arise solely as a result of the existence of installation and pre-installation costs. In fact, the impact of pre-installation has a subtler impact than this. To explore this, here I introduce a general model with consumer heterogeneity in that some have a greater preference for  $B2$  over  $B1$  than others. This allows us to explore more fully how robust the incentive for pre-installation and its welfare effects are. I find that, in general, the incentive for pre-installation in this environment is strong while the welfare effects – both social and consumer – are more ambiguous.

Suppose that while firm 1 is a monopolist in the market for  $A$ , 1 and 2 are Hotelling duopolists in the  $B$  market. Consumers are located over a  $[0,1]$  continuum and 1 is located at 0 and 2 is located at 1. A consumer located at  $x$  faces total ‘transportation’ costs of  $tx$  when buying from 1 and  $t(1-x)$  when buying from 2. For each consumer, there is still an intrinsic value of  $V_B$  to  $B1$  and  $V_B + \lambda$  to  $B2$ .

For the moment, I assume that  $\lambda \geq c_2$  giving rise to the possibility that consumers may purchase  $B2$  even if  $B1$  is pre-installed with  $A$ .

The timing of the game is as follows:

STAGE 1: 1 sets a price of  $P$  to all consumers for product  $A$  or, if it is pre-installed, products  $A$  and  $B1$ . Consumers then choose whether to purchase  $A$  or not.

STAGE 2: 1 and 2 simultaneously set  $p_1$  and  $p_2$  to all consumers but if there is a tie in Stage 1, only 2 sets  $p_2$ .

STAGE 3: Consumers choose which  $B$  to purchase, payments are made and consumption takes place.

Figure 1(a) and 1(b) illustrate two critical cases for the outcomes of Stage 3. For each, without pre-installation, note that the values of a consumer located at  $x$  for choosing  $B1$  and  $B2$  respectively are given by:

$$V_B - c_1 - p_1 - xt \quad (\text{B1})$$

$$V_B + \lambda - c_2 - p_2 - (1-x)t \quad (\text{B2})$$

Figure 1(a) depicts an interior equilibrium, without pre-installation, where both  $p_1, p_2 > 0$ . Figure 1(b) depicts the case where (B2) > (B1) in equilibrium; with  $p_1 = 0$ . The area below these curves represents each consumers' surplus in the  $B$  market. However, part of that surplus will be extracted through  $P$  (which is priced so that all consumers still purchase  $A$ ). The remaining surplus is the shaded area. The diagrams also depict the profits of firms 1 and 2 in the  $B$  market.

Figures 2(a) and 2(b) then demonstrate what happens with pre-installation. With pre-installation, the consumer values become:

$$V_B - xt \quad (\text{B1})'$$

$$V_B + \lambda - c_2 - p_2' - (1-x)t \quad (\text{B2})'$$

In each case, the effect of bundling is to shift the (B1) line upwards. This change also strengthens price competition in Stage 2 so (B2) is shifted upwards. In 2(a), by pre-installing, consumer surplus in the  $B$  market rises but this gain is partially appropriated by firm 1 through  $P'$ ; although firm 1 also loses its profits from  $B1$ .  $B1$ 's share rises while  $B2$ 's falls. It can also be seen here that those who consumers pre-disposed to  $B1$  are better off while those pre-disposed to  $B2$  are worse off following pre-installation.

Figure 2(b) presents a clearer choice for firm 1. It does not sacrifice  $B$  market profits from pre-installing but strengthens price competition. The gain to consumers from this is  $p_2 - p_2'$  or  $c_1$  which firm 1 fully appropriates through a higher  $P'$ . Of course, it is also possible that (B1)' could rise so much that there is an interior equilibrium (similar to that depicted in Figure 2(a)) following pre-installation. In this case, as in 2(a), those consumers pre-disposed to  $B2$  will be worse off following pre-installation.

Given this, I can demonstrate the following:

**Proposition 1.** *Assume that  $\lambda \geq c_2$  and  $V_B \geq t + c_1$ . If  $\lambda \geq 3t - c_1 + c_2$ , then so long as  $C < c_1$ , firm 1 has a strict incentive to pre-install in any subgame perfect equilibrium. If*

$\lambda < 3t - c_1 + c_2$ , then for  $c_2 \approx c_1$  and  $C < \frac{3}{4}c_1$ , firm 1 has a strict incentive to pre-install in any subgame perfect equilibrium.

All proofs are in the appendix. The first condition of the proposition is that installing  $B2$  is potentially valuable for consumers even if they already have  $B1$ . The second condition ensures that all consumers will choose to consume some  $B$ . Following from that, so long as pre-installation costs,  $C$ , are not too high relative to  $B1$ 's installation costs,  $c_1$ , pre-installation will be strictly profitable for firm 1. This condition is sufficient and in many situations far stronger than is necessary for this conclusion.

Intuitively, by pre-installing, 1 convinces at least some consumers to forego  $B2$  and convert  $c_1$  into  $C$ . However,  $C$  is incurred for all sales with pre-installation but with the benefit of reducing 2's profits in favour of greater consumer surplus in the  $B$ -market. 1 captures this additional surplus in its pricing of  $A$ .

When  $\lambda \geq 3t - c_1 + c_2$ , firm 2 captures the entire market both with and without pre-installation (as in Figure 1(a)). In this case, the general case becomes the same as the simple model considered in the previous section and pre-installation is profitable so long as  $C < c_1$ . Notice that in this case,  $C$ , is pure social waste as no consumption decisions change on the part of consumers but  $C$  is incurred as a pre-installation cost regardless.

Given this, it is useful to state precisely what happens to overall and consumer welfare from pre-installation.

**Proposition 2.** *Pre-installation (weakly) harms consumers located close to 1 and (weakly) benefits consumers located close to 0. If (i)  $\lambda \geq 3t - c_1 + c_2$ ; and/or (ii)  $t \rightarrow \frac{1}{3}(\lambda + c_1 - c_2)$ , then pre-installation reduces social welfare.*

This proposition shows that pre-installation has differing impacts on different types of consumers. Not surprisingly, those that are most harmed are those pre-disposed towards buying  $B2$  while those pre-disposed towards  $B1$  benefit. The impact on social welfare is more ambiguous. Nonetheless, if firm 2's product has sufficient intrinsic value then pre-installation reduces social welfare. The reduction in social welfare comes because pre-installation reduces efficient consumption (fewer consumers utilizing  $B2$  and transportation costs increasing) which is not offset by the cost savings from a substitution of  $c_1$  (for  $B1$  consumers) for  $C$  for all consumers.

When  $B2$  has less intrinsic superiority to  $B1$ , social welfare may be increased by pre-installation so long as  $C$  is not too high nor  $c_1$  not too low; that is, if pre-installation can really reduce overall costs. Interestingly, in this situation, pre-installation is more likely to raise consumer welfare across a wider customer base.

The results here demonstrate that there can be a strong motivation to pre-install even when product  $A$  is sold by a monopolist and is essential for the consumption of product  $B$ . Moreover, this is achieved in an environment without repeated transactions. This represents a departure from the results of Whinston (1990) in two respects. First, as emphasized in our simple example, there are costs to consumers of utilizing  $B$ . When there is ‘level playing field’ competition between 1 and 2 in the  $B$ -market consumers bear a greater proportion of these costs than when  $B1$  is pre-installed in which case they are borne by firm 2. This shifting of cost incidence does not occur when consumers do not face installation costs.

But the second reason, borne out in our more general model is that firm 1 cannot simultaneously commit to  $P$  and  $p_1$ . This precludes it from utilizing a virtual tie by committing to a low  $p_1$ . Pre-installation provides that commitment and hence, has value even for a monopoly seller of an essential good. This can be most clearly seen when all installation costs are 0. In this case, I have the following result:

**Corollary 1.** *Suppose  $C = c_1 = c_2 = 0$ . If (i)  $\lambda \geq 3t$ , firm 1 is indifferent between pre-installing or not; (ii)  $3t > \lambda > t$ , then firm 1 always prefers to install; or (iii)  $\lambda < t$ , firm 1 never pre-installs. When  $\lambda \geq 3t$ , pre-installation has no impact on social or consumer welfare. If  $3t > \lambda > t$ , then pre-installation increases social welfare while if  $\lambda < t$  then pre-installation reduces social welfare.*

Thus, even when there are no installation costs, pre-installation may be profitable for firm 1 when the benefits to  $B2$  are moderately large. In this case, such pre-installation enhances social welfare but may or may not increase consumer welfare. Interestingly, when pre-installation is not profitable it reduces social welfare but would, if done, improve consumer welfare. Thus, in contrast to the case where pre-installation is purely motivated by cost considerations (i.e., when  $\lambda \geq 3t$ ), the commitment issues lead to a mixed divergence between private and social incentives for pre-installation; sometimes favoring pre-installation for consumers even if it is not privately profitable.

### *Investments in interoperability*

Issues of interoperability have usually been analyzed as a distinct form of strategic behaviour by a monopolist (e.g., Matutes and Regibeau, 1992). Here I consider how pre-installation behaviour might interact with a firm's incentive to provide for interoperability.

To see this, let's return to our simple model (of Section 2). In that model, firm 1 never bears any proportion of  $c_2$  and thus, pre-installation will not change its incentives towards it. In contrast, if it does not pre-install, firm 1 has an incentive to reduce  $c_1$ . However, as  $c_1$  is not actually incurred, any expenditure in reducing it is socially costly. But, if  $c_1$  and  $c_2$  have common elements that might be reduced together, then expenditures to reduce  $c_1$  may be socially desirable if they also reduce  $c_2$ .

If it pre-installs, firm 1 has an incentive to reduce  $C$ . As  $C$  is a social cost in this instance, such expenditures are desirable but only to the extent that socially costly pre-installation is occurring in any case.

This basic result carries over to our more general model.

***Proposition 3.*** *If it pre-installs, firm 1 completely internalizes  $C$  and has no incentive to reduce  $c_1$ . If it does not pre-install, firm 1 does not internalize  $C$  but completely internalizes  $c_1$ . Pre-installing means that firm 1 only cares about  $c_2$  (bearing  $\frac{1}{4}$  of these) if  $\lambda < 3t + c_2$ . Pre-installing reduces the common drivers of  $c_1$  and  $c_2$  that firm 1 internalizes.*

The proof relies on an examination of firm 1's profits for various cases.

This proposition highlights the basic incentives of firm 1 to reduce common elements of  $c_1$  and  $c_2$  and  $C$ . Pre-installation shifts those incentives markedly. It diminishes incentives to incur any costs associated with reducing common elements of  $c_1$  and  $c_2$  (i.e., making  $A$  more interoperable with  $B$  products) but raises incentives to reduce  $C$  (e.g., by integrating  $B1$  into the design of  $A$ ). To the extent that pre-installation is otherwise socially undesirable, the former incentive raises its social costs while the latter reduces it. Overall, the impact is ambiguous. Nonetheless, strategies of pre-installation and not making  $B$  products interoperable are complementary from the perspective of firm 1.

### *Future Market Effects*

Several recent papers have examined motivations for pre-installation based on defensive incentives for monopolists. The basic idea is that pre-installation can raise costs or reduce incentives for firms in complementary product markets to enter into the monopoly segment in the future. Carlton and Waldman (2002) premise that entry on the achievement of economies of scale; something denied if sales are reduced by pre-installation. Choi and Stefanadis (2001) provide a similar mechanism through R&D incentives where reduced sales also reduce R&D incentives making entry less likely in the future. In each case, the current effect of pre-installation in reducing sales or profits of rivals in the *B* market provides the mechanism by which strategic future market effects occur.

With this in mind, the following proposition summarizes the impact of pre-installation on 2's price, profits and market share.

***Proposition 4:*** *Firm 2's price and profits always fall as a result of pre-installation. Firm 2's market share always falls if  $\lambda < 3t + c_2$  and stays the same if  $\lambda \geq 3t + c_2$ .*

In this model, the effect of pre-installation is always to make firm 2 worse off. Pre-installation intensifies price competition – thereby reducing price – and in most cases leaves 2 with fewer sales in the *B* market. As such, it can be seen as an explanation for pre-installation that is only reinforced by a consideration of future market effects. However, the presence of those effects can make the social costs associated with pre-installation stronger.

## **4. Remedies**

I now turn to consider various remedies that were proposed in the Microsoft cases in the context of the model here.<sup>10</sup> The purpose is to assess whether they will have the desired effect of improving social and consumer welfare in situations where pre-installation as already been assessed to be undesirable.

One obvious remedy is of course to prohibit pre-installation altogether. In this case, the outcome would be the same as if there were no pre-installation above. Similarly,

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<sup>10</sup> Ayres and Nalebuff (2005) provide a non-technical discussion of many of these.

if firm 1 were forced to compensate 2 for lost profits, then it would not have an incentive to tie as the returns to this are often shared between it and consumers. For this reason, here I focus upon alternatives that are subtler in terms of their overall effect on behavior and welfare.

### *Mandatory Untying*

The EU's remedy with regard to Microsoft and Windows Media Player was to require – in our notation – that 1 provide a standalone product  $A$  with a price  $P + p_1$  that is less than the price of the bundled product. Of course, if  $p_1 = 0$ , then the standalone and bundled product will likely have the same price. Note, however, that firm 1 is prevented from discounting its bundled product even slightly to ensure that indifferent consumers purchase that product.

But will consumers buy the standalone product? If they do, they are most likely to be the consumers who expect to receive the most consumer surplus from purchasing  $B2$ . Let  $P$  be the bundled price of  $A$  and  $\underline{P}$  be the standalone price of  $A$ .

**Proposition 5.** *Suppose that  $\lambda \geq 3t + c_2 - c_1$ , then there always exists an equilibrium where  $P = \underline{P}$  and the prices and outcomes are the same as pre-installation in Proposition 1. When  $C > 0$ , there also exists an equilibrium where  $P > \underline{P}$  or a tied product is not offered at all with the same prices and outcomes as in the absence of pre-installation.*

Let's examine the case where  $\lambda \geq 3t + c_2$  here. Recall that with this case, firm 2 sold  $B2$  to all consumers both before and after pre-installation. When there is mandatory untying, suppose that  $P = \underline{P}$ . In this case, all consumers are indifferent between buying the bundled and unbundled  $A$  product as they expect to purchase and install  $B2$ . There are three broad cases to consider (where I initially assume that  $C = 0$ ):

1. Suppose all consumers buy bundle if they are indifferent. Then 1 sets  $P = \underline{P} = V_A + V_B$  and  $p_1 = 0$  while 2 sets  $p_2 = \lambda - c_2$ . A consumer considering purchasing the standalone  $A$  is no better off so this is an equilibrium outcome.
2. Suppose that some fraction,  $x$ , of consumers buy bundle if indifferent.
  - Then suppose that 1 sets  $P = \underline{P}$  and  $p_1 = 0$ .

- If  $c_1/(\lambda - t - c_2 + c_1) > x$ , firm 2 chooses  $p_2 = \lambda - c_2 + c_1$  as  $(\lambda - t - c_2 + c_1)(1 - x) > \lambda - t - c_2 \Rightarrow c_1/(\lambda - t - c_2 + c_1) > x$ . Given this, firm 1 sets  $P = \underline{P} = V_A + V_B - c_1$ .
  - If  $c_1/(\lambda - t - c_2 + c_1) \leq x$ , then  $p_2 = \lambda - c_2$  and firm 1 sets  $P = \underline{P} = V_A + V_B$ .
  - If  $c_1/(\lambda - t - c_2 + c_1) > x$ , can firm 1 do better by setting  $P > \underline{P}$ ? No, as now all consumers will just buy the unbundled product and 2's price behavior will be unchanged. However, by the same reasoning there exists an equilibrium where  $P > \underline{P} = V_A + V_B - c_1$ .
3. Suppose no consumer buys the bundled A when  $P = \underline{P}$ . Then 1 sets  $p_1 = 0$  but  $p_2 = \lambda - t - c_2 + c_1$ . In this case, consumers will only purchase A if  $P = \underline{P} = V_A + V_B - c_1$  and this is what 1 sets. 1 would like to convince consumers to purchase the bundled product but is prevented from setting  $P < \underline{P}$  to do this as  $p_1 \geq 0$ .

Now, if  $C > 0$ , 1 will still provide a bundled product if at least  $x \geq c_1/(\lambda - t - c_2 + c_1)$  purchase the bundle when  $P = \underline{P}$ . However,  $x < c_1/(\lambda - t - c_2 + c_1)$  then firm 1 will not offer a bundled product.

The basic intuition is that, if sufficient consumers purchase the unbundled product, this will alter 2's pricing behaviour; causing it to raise price. Seeing this, firm 1 will be forced to discount the price of the unbundled product in order to maintain sales. Obviously, if providing a bundled product is costly to 1, then it will cease to do so in this case. However, it is entirely possible that  $C < 0$  and, at present, providing a bundled product is cheaper than providing a stand-alone one. In this case, even if consumers purchase large volumes of the unbundled product, both products will still be offered and it may be that their prices diverge.<sup>11</sup>

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<sup>11</sup> This could also arise if tying is motivated by future market effects (as in Carlton and Waldman, 2002; Choi and Stefanadis, 2001).

For other cases in Proposition 5, what is interesting about mandatory unbundling is that it offers a commitment device to 1 to set  $p_1 = 0$ . Recall that one of the reasons why pre-installation was profitable in this model is that 1 could not offer such a commitment ex ante. Now, by setting  $P = \underline{P}$  that commitment is made and this reduces  $p_2$ . Note, however, in order to make that commitment a bundled product must still be offered. In this case, firm 1 need not encourage sales of the bundled product and could, therefore, economize on pre-installation costs. As this is one of the welfare costs of pre-installation, this provides a further benefit from this remedy; a benefit whose returns flow to firm 1.

What is significant here is that *mandatory untying could have a positive effect in changing behaviour and improving welfare*. A common argument was that this remedy was innocuous because Microsoft could simply set  $P = \underline{P}$  and continue to charge a high price. While I cannot rule out this as an equilibrium, I have demonstrated here that alternative equilibria with lower prices and higher welfare always exists under this remedy. Thus, one need not rely upon how mandatory untying might impact on Microsoft's negotiations with OEMs nor future market effects (see Ayres and Nalebuff, 2005) to provide a positive rationale for this remedy.<sup>12</sup>

### *Mandatory Investment*

Another possible remedy is for firm 1 to be required to invest to reduce  $c_2$ . This would be the equivalent of an order on Microsoft to improve interoperability. If a reduction in  $c_2$  to  $\alpha c_2$  cost firm 1,  $f$ , the following can be shown.

**Proposition 6.** *Suppose that  $f < (1-\alpha)c_2$  and  $\lambda \geq 3t + c_2 - c_1$ . Then requiring 1 to make this investment will increase its incentives towards pre-installation.*

The proof relies on a simple comparison of firm 1's profits from pre-installation and not pre-installation (see the proof of Proposition 3) and is omitted. The first condition states

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<sup>12</sup> If the goal of competition authorities is to encourage platform competition, untying may not be desirable in a two-sided market (i.e., where applications are developed for either). Notice that if  $B2$  is currently more desirable for consumers, then pre-installation may give it a monopoly over the platform. On the one hand, it may seem that there is no incentive for 1 to install their own product ex post as the inability to tie in the future limits its ability to earn rents then. However, if 1 expects  $B1$  to improve at a faster rate than  $B2$ , then it will have an incentive to subsidize installation costs today. Untying would also allow this to happen if  $B2$  was inferior today in which case that provider might subsidize installation costs.

that the investment itself is socially desirable while the second is a sufficient condition for no pre-installation to be socially optimal. Basically, by investing in this way, 1's profits from not pre-installing do not change as in those cases it does not bear any proportion of  $c_2$ . However, reductions in installation costs of  $B2$  actually increase its profits when it ties. As the investment is mandated, this increases its incentives to pre-install. Of course, it will continue not to pre-install if  $C$  is sufficiently high and in this case the costs borne by others are reduced. If, however, pre-installation reduces social welfare, this change in incentives may be undesirable if firm 1 might otherwise choose not to pre-install.

Thus, mandatory investment may not deter pre-installation for strategic reasons although any welfare detriments arising from this will be mitigated by the improvement in interoperability.

#### *Mandatory Pre-Installation of B2*

A final remedy that was proposed in the Microsoft case was a 'must carry' requirement. This would be an order to Microsoft to 'pre-install' other browsers or media players. Of course, there are some issues associated with this remedy: what software to install and how to arrange technical support (Ayres and Nalebuff, 2005). Here, however, it is useful to consider what the impact of this would be in the absence of those issues.

Suppose that pre-installing  $B1$  and  $B2$  costs  $2C$ . If consumers use only one or the other this is clearly not an efficient situation. However, it is potentially more efficient than pre-installation that could involve similar duplication of costs.

The issue with pre-installation is how to consider  $p_2$ . Suppose I considered it as an upgrade option. For instance, both Real Player and Quicktime have basic versions that are given away and deluxe versions that consumers pay for. Thus, I assume here pre-installation gives a consumer access to  $B2$  but not to the additional benefit,  $\lambda$ . But I will also assume that in this case,  $c_2 = 0$ . This is in comparison with the rest of the paper where only the deluxe version is sold.

With this assumptions I can prove the following:

**Proposition 7.** *Suppose that  $\lambda \geq 3t + c_2 - c_1$ , then mandatory pre-installation leads to a socially optimal outcome.*

In this case, when  $B1$  is not pre-installed with  $A$ , there is no interior equilibrium in the  $B$  market. Firm 2 sells to all consumers and  $p_1 = 0$ . In this case,  $p_2 = \lambda - t$ . This allows 1 to set a price of  $P = V_A + V_B$  for product  $A$ .

In contrast, by bundling  $B1$  with  $A$ , then firm 2 still gets the entire market at the same  $p_2 = \lambda - t$ . This is the same outcome as if there is no pre-installation. Thus, in this case, firm 1 will choose not to pre-install its own  $B$  product if  $C > 0$  and so long as  $C < c_2$ , the outcome is socially optimal.

When  $\lambda < 3t + c_2 - c_1$ , pre-installation dramatically reduces the incentives of firm 1 to pre-install (effectively by eliminating installation costs,  $c_1$ , as a motivation for this). However, in this case, the welfare effects are more ambiguous as pre-installation may improve consumer welfare in some instances.

Thus, pre-installation is another potentially effective remedy. Not only may in appropriately substitute pre-installation for installation costs, it also levels the playing field in ex post competition. What is interesting about pre-installation is that this is always really an option for firm 1. That is, firm 1 could offer 2 a pre-installation alternative. Firm 2 would be willing to pay for this if it effectively amounted to a pre-commitment from firm 1 not to bundle its own product. However, in the absence of the mandate, rents are shifted away from firm 2 and towards firm 1. This may have an impact on future market effects.

## 5. Conclusions

This paper demonstrates how the particular characteristics of computer software and its installation give rise to a rationale for tying in the presence of consumer heterogeneity on the set of applications they value. Tying is profitable for a monopolist in an essential market (such as computer operating systems) because it intensifies ex post competition for applications; allowing them to appropriate more rents in the monopoly segment. However, if pre-installation has costs that would not otherwise be incurred there are welfare losses from this tying behaviour and, moreover, the distortion to competition from tying does not uniformly benefit all consumers. Consequently, there is a potential for welfare losses.

Examining the cases where such welfare losses could arise, this paper investigated various remedies that have been implemented to deal with tying in computer applications. While mandatory unbundling may be innocuous, it is also possible that it could be effective in giving consumers additional choice and mitigating the effects of tying. Mandatory investments in operability will likely encourage more tying while mitigating some of welfare costs associated with it. Finally, by pre-installing more products, not just those owned by the monopolist, then, so long as the costs of so doing are not too large, a socially optimal outcome can be generated.

Future research might be involved in seeing whether the imposed remedies did in fact have the impact as predicted by the theory of this paper. It would also be of interest to see how the remedies proposed might be implemented to deal with tying in a broader set of industries.

## 6. Appendix

### *Proof of Proposition 1*

Case 1 ( $\lambda < 3t - c_1 + c_2$ ): Working backwards, if there was no tie, then  $p_1 = \frac{3t - \lambda - c_1 + c_2}{3}$  and  $p_2 = \frac{3t + \lambda + c_1 - c_2}{3}$  and the marginal consumer,  $\bar{x}$ , is at location  $\frac{1}{2} - \frac{\lambda + c_1 - c_2}{6t}$ . In the  $B$  market, 1's profits are  $\frac{(3t - \lambda - c_1 + c_2)^2}{18t}$  while 2's are  $\frac{(\lambda + 3t + c_1 - c_2)^2}{18t}$ . In stage 1, 1 can set  $P$  to extract all consumer surplus. Observe that 1 will want to sell to all customers. That is, if it sets  $P$  such that some consumers around  $\bar{x}$  do not purchase, then this will increase 2's profits but reduce the sum of 1's profits and consumer surplus in the  $B$  market. Given this,

$$P = V_A + \frac{1}{2} \underbrace{(2V_B - c_1 - c_2 + \lambda - 3t)}_{\text{Consumer Surplus of } \bar{x} \text{ in B}}$$

So that 1's profits from not pre-installation are:  $V_A + V_B + \frac{1}{2}(\lambda - 3t - c_1 - c_2) + \frac{(3t - \lambda - c_1 + c_2)^2}{18t}$ .

Alternatively, pre-installation implies that  $p_1 = 0$  while 2's demand is determined by:

$$tx + 0 = c_2 + p_2 + t(1 - x) - \lambda \Rightarrow 1 - x = \frac{1}{2t}(\lambda + t - p_2 - c_2)$$

Thus, 2 solves:  $\max_{p_2} p_2(1 - x)$  which gives  $p_2 = \frac{1}{2}(\lambda + t - c_2)$  with  $\bar{x} = \frac{3t + c_2 - \lambda}{4t}$  the marginal consumer. That consumer has consumer surplus of  $\frac{1}{4}(4V_B + \lambda - 3t - c_2)$  which is positive by our assumption that  $V_B > t + c$ . Firm 1 does not earn profits in the  $B$  market.

Note that pre-installation yields greater profits if:

$$\begin{aligned} V_A + V_B + \frac{1}{4}(\lambda - 3t - c_2) - C &> V_A + V_B + \frac{1}{2}(\lambda - 3t - c_1 - c_2) + \frac{(3t - \lambda - c_1 + c_2)^2}{18t} \\ \Rightarrow \frac{1}{2}c_1 - C &> \frac{1}{4}(\lambda - 3t - c_2) + \frac{(3t - \lambda - c_1 + c_2)^2}{18t} \\ \Rightarrow C - \frac{3}{4}c_1 &< \frac{(3t - \lambda)(2\lambda + 3t) + (c_2 - c_1)(4\lambda - 3t - 2c_2 + 2c_1)}{36t} \end{aligned}$$

Note that for  $c_1 = c_2$ , it must be the case that  $3t \geq \lambda$  so that the RHS is always positive. While the LHS is always negative if  $C < \frac{3}{4}c_1$ .

Case 2 ( $\lambda \geq 3t - c_1 + c_2$ ): In this case, when there is no pre-installation, there is no interior equilibrium in the  $B$  market. 2 sells to all consumers and  $p_1$  is constrained to 0 so that  $p_2 = \lambda - t - c_2 + c_1$ . In this case, the consumer surplus of the marginal consumer,  $\bar{x} = 0$ , becomes  $V_B - c_1$ . If there is pre-installation, then:

- If  $\lambda < 3t + c_2$ , then as in the interior outcome in Case 1, the marginal consumer is  $\bar{x} = \frac{3t + c_2 - \lambda}{4t}$  and that consumer has surplus of  $\frac{1}{4}(4V_B - 3t - c_2 + \lambda)$ . In this case, pre-

installation is profitable if  $V_B + \frac{1}{4}(\lambda - 3t - c_2) - C > V_B - c_1$ . This will hold if  $C < \frac{5}{4}c_1$ .

- If  $\lambda > 3t + c_2$  then 2 still gets the entire market but at a price of  $p_2 = \lambda - t - c_2$ . In this case, consumer surplus of the marginal consumer,  $\bar{x} = 0$ , becomes  $V_B$ . Thus, pre-installation is profitable so long as  $C < c_1$ .

### *Proof of Proposition 2*

Note first that the socially optimal level of  $B$  market allocations is determined by:

$$xt + c_1 = (1-x)t + c_2 - \lambda \Rightarrow \bar{x}^* = \frac{1}{2} - \frac{\lambda - c_2 + c_1}{2t}.$$

This means that having some consumption of  $B1$  is socially desirable if  $t - c_1 > \lambda - c_2$ .

Case 1 ( $\lambda < 3t - c_1 + c_2$ ): No pre-installation gives welfare of  $V_A + V_B + \frac{7\lambda^2 + 18\lambda t + 9t^2 + 2(c_1 - c_2)(7\lambda - 9t) + 7(c_1 - c_2)^2}{36t}$  and consumer surplus to  $x = 0$  of  $\frac{1}{6}(3t - \lambda - c_1 + c_2)$  and to  $x = 1$  of  $\frac{1}{6}(3t + \lambda + c_1 - c_2)$ . While pre-installation gives welfare of  $V_A + V_B - C - \frac{-3(\lambda - c_2)^2 - 6t(\lambda - c_2) + 5t^2}{16t}$  and surplus to  $x = 0$  of  $\frac{1}{4}(3t - \lambda + c_2)$  and to  $x = 1$  of  $\frac{1}{4}(t + \lambda - c_2)$ .

Notice that in this case,  $\bar{x}^* < \bar{x}_N = \frac{3t - \lambda - c_1 + c_2}{6t} < \bar{x}_T = \frac{3t - \lambda + c_2}{4t}$  so that pre-installation further increases the distortion to consumer choices in the  $B$  market. This is offset by changes in total installation costs which will be higher under pre-installation if:

$$\begin{aligned} C + c_2(1 - \bar{x}_T) &> c_1\bar{x}_N + c_2(1 - \bar{x}_N) \\ \Rightarrow C &> \frac{(2c_1 + c_2)(3t - \lambda - c_1 + c_2) + 3c_1c_2}{12t}. \end{aligned}$$

Consequently, pre-installation reduces welfare if:

$$-\frac{55\lambda^2 + 126\lambda t - 9t^2 + 4c_1(14\lambda - 18t - 7c_1) - 2(55\lambda + 63t + 28c_1)c_2 + 55c_2^2}{144t} < C$$

The former inequality may or may not hold. Taking limits as  $t$  approaches  $\frac{1}{3}(\lambda + c_1 - c_2)$  makes the LHS always negative.

Pre-installation reduces consumer surplus if:

$$\begin{aligned} x = 0: \lambda - 3t &> 2c_1 + c_2 \text{ (which cannot hold)} \\ x = 1: \lambda - 3t &< 2c_1 + c_2 \text{ (which always holds)} \end{aligned}$$

Case 2 ( $\lambda \geq 3t - c_1 + c_2$ ): now  $\bar{x}_N = 0$  so welfare is  $V_A + V_B - c_2 + \lambda - \frac{1}{2}t$ . Consumer surplus to  $x = 0$  is \$0 and to  $x = 1$  of  $t$ .

- If  $\lambda < 3t + c_2$ , then  $\bar{x}_T = \frac{3t + c_2 - \lambda}{4t}$  and welfare is  $V_A + V_B - C - \frac{-3(\lambda - c_2)^2 - 6t(\lambda - c_2) + 5t^2}{16t}$ . This represents a welfare reduction if  $\frac{(\lambda - c_2 - 3t)(3\lambda - 3c_2 - t)}{16t} < C$  which is true as the upper

bound on the RHS is 0. Consumer surplus to  $x = 0$  rises to  $\frac{1}{4}(3t - \lambda + c_2)$  and to  $x = 1$  becomes  $\frac{1}{4}(t + \lambda - c_2) < t$  if  $\lambda - c_2 < 3t$  (which always holds).

- If  $\lambda \geq 3t + c_2$  then  $\bar{x}_N = 0$ . Thus, welfare falls by  $C$ . Consumer surplus remains the same for all consumers.

### *Proof of Proposition 3*

The proof relies on an examination of firm 1's profits for the cases considering in the proof of Proposition 1. These are summarized in the following table:

	No pre-installation	Pre-installation
$\lambda < 3t - c_1 + c_2$	$V_A + V_B - c_1 - c_2 + \frac{(3t - \lambda - c_1 + c_2)^2}{18t}$	$V_A + V_B + \frac{1}{4}(\lambda - 3t - c_2) - C$
$3t - c_1 + c_2 \leq \lambda < 3t + c_2$	$V_A + V_B - c_1$	$V_A + V_B + \frac{1}{4}(\lambda - 3t - c_2) - C$
$\lambda \geq 3t + c_2$	$V_A + V_B - c_1$	$V_A + V_B - C$

### *Proof of Proposition 4*

The proof relies on an examination of firm 2's sales and profits for the cases considering in the proof of Proposition 1. These are summarized in the following table:

Firm 2's Profits and Sales

	No pre-installation	Pre-installation
$\lambda < 3t - c_1 + c_2$	$\frac{3t + \lambda + c_1 - c_2}{3} \left( \frac{1}{2} + \frac{\lambda + c_1 - c_2}{6t} \right)$ and $\frac{1}{2} + \frac{\lambda + c_1 - c_2}{6t}$	$\frac{1}{4t}(\lambda + t - c_2) \frac{t - c_2 + \lambda}{4t}$ with $\frac{t - c_2 + \lambda}{4t}$
$3t - c_1 + c_2 \leq \lambda < 3t + c_2$	$\lambda - t - c_2 + c_1$ and 1	$\frac{1}{4t}(\lambda + t - c_2) \frac{t - c_2 + \lambda}{4t}$ with $\frac{t - c_2 + \lambda}{4t}$
$\lambda \geq 3t + c_2$	$\lambda - t - c_2 + c_1$ and 1	$\lambda - t - c_2$ and 1

### *Proof of Proposition 5*

The case where  $\lambda \geq 3t + c_2$  is dealt with in the text.

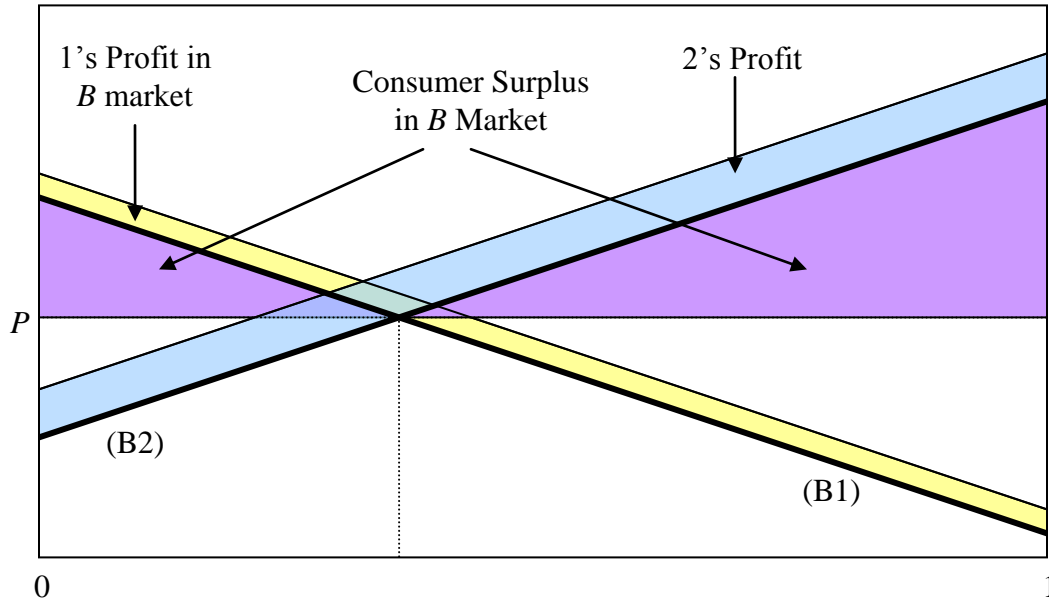
If  $\lambda < 3t + c_2 - c_1$ , suppose that  $P = \underline{P}$ . If some fraction  $1-x$  do not purchase the bundle when the prices are the same and suppose that those consumers are all located close to firm 2, then 2 optimally sets

$$p_2 = \begin{cases} \frac{1}{4t}(\lambda + t - c_2) & \text{if } x > \frac{3t + c_2 - \lambda}{4t} \\ \lambda - t(1 - 2x) - c_2 + c_1 & \text{if } x \leq \frac{3t + c_2 - \lambda}{4t} \end{cases}$$

Thus, for sufficiently high  $x$ ,  $P = \underline{P} = V_A + V_B + \frac{1}{4}(\lambda - 3t - c_2)$  while for low  $x$ ,  $\underline{P} = V_A + V_B - tx - c_1$  and 1 will be better off setting  $P > \underline{P}$  or not offering the tied product at all.

**Figure 1 (No Pre-Installation)**

**(a) Interior Equilibrium**



**(b) Firm 2 Superior**

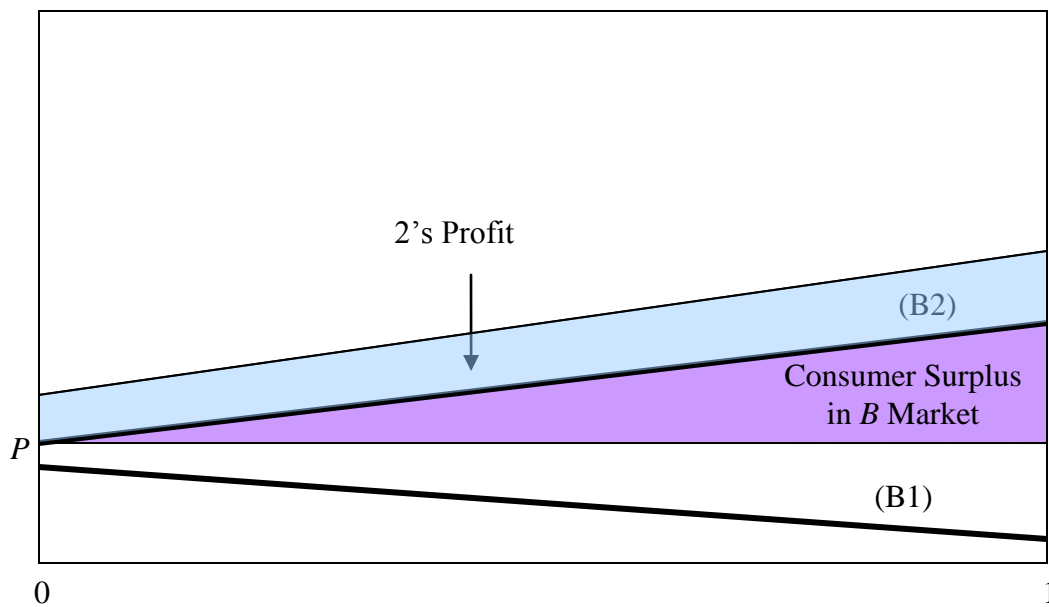
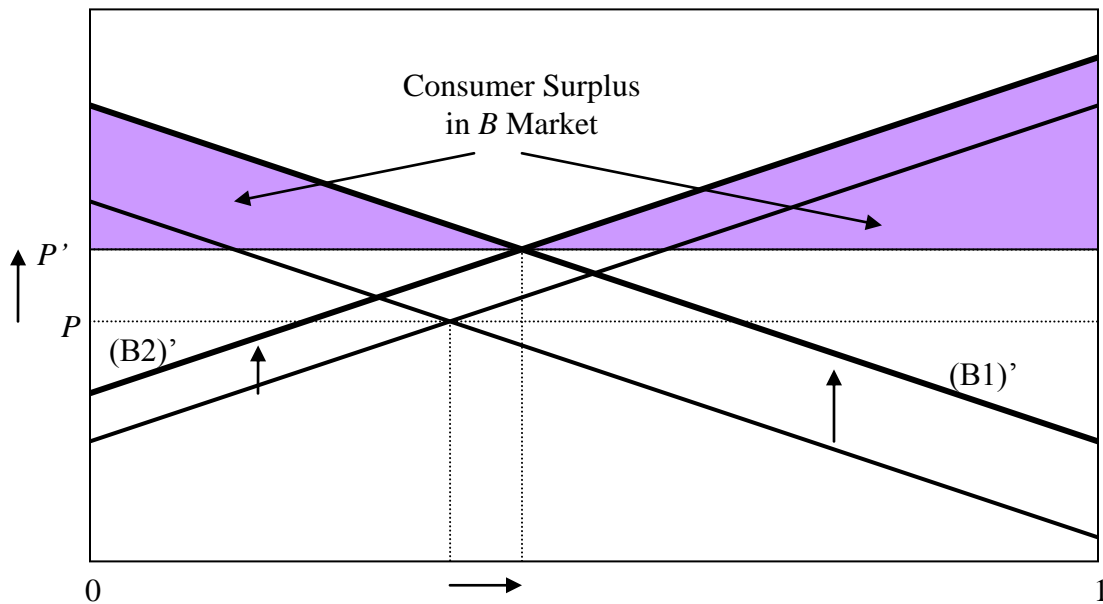
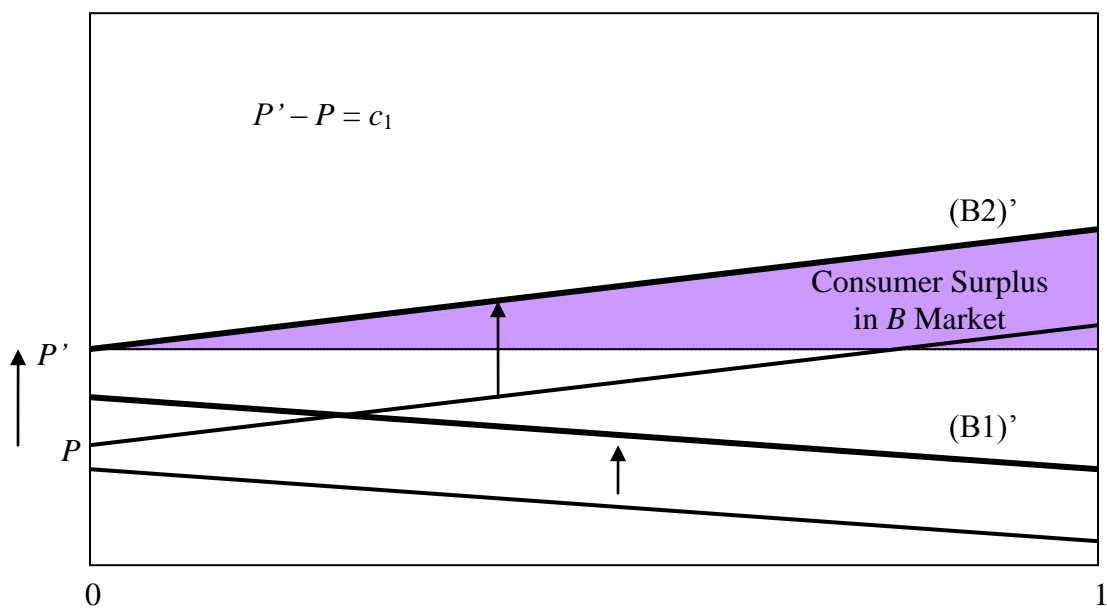


Figure 2 (Pre-Installation)

(a) Interior Equilibrium



(b) Firm 2 Superior



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