MFN Clauses and the Agency and Wholesale Models in Electronic Content Markets

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Abstract. I investigate strategic interactions and market outcomes in the "agency model" and "wholesale model" of sales, and also most-favored-nation (MFN) clauses. MFN clauses have pro-competitive effects under the agency model, encouraging retail entry and investment, which may be especially important in new markets. Adopting the agency model can also have pro-competitive effects. Indeed, consumers always prefer this model despite the fact that it leads to initial price increases. I relate my results to events in the market for electronic books.

1. Introduction

I investigate the "agency model" and "wholesale model" of sales, which are two distinct ways of structuring relations between suppliers and retailers and of determining final retail prices. I analyze how these sales models effect strategic interactions in general, and in particular how they effect the profits of retailers and suppliers, and the welfare of consumers.

I show the following. First, most-favored-nation (MFN) clauses can have pro-competitive effects under the agency model, rather than the negative effects that are commonly assumed to arise. Second, adopting the agency model can raise retailer profits and encourage entry and investment. Even when entry and investment are fixed, consumers benefit from the agency model | even though retail prices increase immediately following its adoption.

It is useful to clarify what the agency and wholesale models are and why one might care about them before continuing. The wholesale is very traditional, and in it suppliers set per-unit wholesale prices to retailers, who are then free to impose whichever markups they choose as they set retail prices. The agency model is very different, and in it suppliers set retail prices and then split revenue with retailers according to pre-determined shares.

The agency model was recently adopted by electronic book ("e-book") retailers Amazon and Apple and publishers supplying them, and is also commonly used by companies that support marketplaces for applications ("apps") usable on various mobile devices such as smartphones and tablet computers. As such it is of more than purely theoretical interest to understand the differences between these two sales models.

The e-book market and the agency model are currently objects of antitrust scrutiny both in the US and the EU. The reason is that retail prices for many e-books significantly increased

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consequent to the adoption of the agency model. This is despite the fact that Apple entered the e-book market (thus challenging the primary incumbent Amazon) at the same time that the agency model was adopted.

Also of interest and concern to regulators are the most-favored-nation clauses that have been adopted in the e-book market. These clauses guarantee that suppliers do not discriminate between retailers by o ering them di erent prices, and are widely considered to be tools to raise prices or otherwise extract more surplus from the market at the expense of consumers.

To my knowledge, I am the rst to assess the di erences between the agency and wholesale models and to investigate the role of MFNs under the agency model. My analysis allows for both di erentiated retailers and di erentiated suppliers, multiple periods, and consumer lock-in to retailers. In the e-book market, consumer lock-in may exist because a consumer becomes accustomed to using, for example, Amazon's e-book store or e-book reading app, leading them to use Amazon as their primary channel for future purchases.

I now provide a bit more detail regarding my main results. Under the agency model, most-favored-nation clauses serve to transfer surplus away from suppliers and towards retailers. Consumers are not harmed | in equilibrium MFNs do not increase retail prices.

By raising retailer pro ts, MFNs also encourage retailers to enter or otherwise invest in the market. Because consumers are bene ciaries of retail entry and investment, the overall e ect of such clauses is to raise social surplus and consumer surplus in particular. Encouraging retail investment is important in many markets, but perhaps most especially in new markets such as the e-book market in which retailers play a central role in building the market.

My next set of results concern the e ect of moving to the agency model from the wholesale model. Doing so raises the pro ts of retailers whenever the di erentiation of suppliers is higher than that of retailers. An implication is that the agency model itself can spur investment and entry by retailers, similar to how MFNs within the agency model can.

The reason that retailers may prefer the agency model is that it reduces the intense incentives to compete on price within the wholesale model; such incentives exist because retailers desire to lock in consumers so that they may be harvested in later periods. Although abandoning the wholesale model quenches initial price competition between retailers, I show that it actually limits the ability of retailers to harvest consumers later on.

An implication is that moving to the agency model has somewhat subtle price e ects; although initial prices do increase, future prices decline relative to the wholesale model. It follows that the observation of price increases following the adoption of the agency model is not su cient to conclude that there has been harm to consumers. Rather, a complete assessment of consumer welfare must take a longer term perspective.

Indeed, I show that consumers unambiguously prefer the agency model. That is, future price decreases are signi cant enough to make up for the initial price increases that occur when the market moves to the agency model.

Suppliers may bene t from the agency model. One reason is that the agency model may spur retail entry, as explained above, potentially allowing suppliers to avoid facing a monopoly retailer. Hence, even if suppliers were to prefer the wholesale model conditional on retail entry, they may be willing to accept the agency model if it ensures retail competition.

I emphasize that the overall goal of my analysis is not to provide a complete description of each event and fact surrounding any particular market, such as that for e-books. Rather, I seek to provide a general and abstract assessment of the agency and wholesale models, and of MFNs. That said, my results are consistent with several key facts surrounding the e-book market, and generate additional insight.

For example, my analysis explains why prices would go up following the adoption of the agency model, as has been observed in the e-book market. But I caution that prices may end up being lower in the future under the agency model. My results also indicate why an incumbent monopoly retailer would not wish to use the agency model, but why an entrant might, and also why an incumbent might prefer it once entry has occurred. This is consistent with the facts of the e-book market, in which the incumbent (Amazon) did not push for the agency model, which only arose due to Apple's insistence on it as a condition of its entry.

There are two important limitations of my analysis. First, I do not consider the presence of alternative, higher-cost distribution channels and formats. In the e-book market, this would correspond to physical books sold through \brick-and-mortar" stores. Second, I do not consider platform pricing issues. In the e-book market, this would involve pricing of devices that host applications for reading e-books.

I discuss these limitations in detail in the Conclusion. A brief summary of that discussion is as follows. First, it is not hard to argue that the emergence of a new low-cost channel may pose a major threat to suppliers if that channel is monopolized, even if the alternative channel continues to exist. Moreover, the cost advantage of new channels may render the existing channels obsolete, suggesting that it is useful to think about how competition works in new channels, abstracting away from the old. Second, on most physical devices, including most Android and all Apple devices, consumers have a choice of e-book applications. Thus, while platform pricing issues may be interesting, competition also exists within platforms.

Before proceeding with the formal analysis, I brie y discuss the related literature. There are many papers on MFN clauses, but most of them focus on ways in which such clauses can be used to raise prices or otherwise harm consumers, as in Cooper (1986), Butz (1990), and Baker (1996). DeGraba and Postlewaite (1992) and McAfee and Schwartz (1994) investigate

the extent to which such clauses can raise the pro ts of a monopolist selling through two franchised retailers by allowing the franchisor to avoid a time-inconsistency problem that.

In contrast to these analyses, MFN clauses in my analysis di er in two main ways. First, they do not involve any sort of time inconsistency or dynamic issues whatsoever. Second, they can have pro-competitive e ects as opposed to working to raise prices.

The only other paper (to my knowledge) that deals directly with the issue of MFNs in an agency model is Gans (2012). Gans considers both lock-in and MFN clauses in a model with a single platform and a single application. In his model, consumers consider joining

that $v \geq (t; 2t)$, which will ensure that the market is covered in equilibrium but rules out corner solutions in certain out-of-equilibrium circumstances.

There are two stages to this game. First, A and B simultaneously o er revenue shares $r_i \in [0; 1]$, $i \in \{A; B\}$, to the supplier. Second, the supplier U sets retail prices

The only caveat (which applies to the both the case with and without MFNs) is that if $r_A = r_B = 0$, U earns zero pro ts regardless of its choices and so is indi erent to what prices it charges. I assume that U selects $x = 1=$

My analysis is not subject to this possibility; in the agency model, retailers truly do bene t from MFNs. In fact, it is easy to show that the equilibrium outcome is identical whether one rm or both rms possess an MFN.

Another view of MFNs in vertical relationships is that of DeGraba and Postlewaite (1992) and McAfee and Schwartz (1994). These authors identify a time-inconsistency problem that may limit the pro ts of a franchisor who contracts sequentially with franchisees, and explore the e ectiveness of MFNs in resolving the problem. In contrast, I show that MFNs work to raise the pro ts of retailers at the expense of suppliers, and that this e ect exists independently of the sort of time-inconsistency issue that they focus on. Additionally, a crucial element in their analyses is that franchisors utilize two-part tari s, which means that under sequential contracting the franchisor has an incentive to conspire with later franchisees. Such e ects are absent from my model, and indeed MFNs serve no role under the wholesale model, as I show in more detail in Section 3.

Gans (2012) also considers MFNs in the agency model. His focus is very di erent from mine. He looks at a platform pricing environment with a single platform and a single app, and shows that MFNs can mitigate a hold up problem faced by the end consumer. The reason is that MFNs impose an exogenous pricing constraint on the fee for the app, which encourages consumers to join the platform.

I now argue that there are three circumstances in which MFNs are not merely competitively neutral, but in fact pro-competitive. The rst case is where, for some reason, there are asymmetric revenue shares r_i, as might be the case if the shares are determined sequentially or via some sort of asymmetric bargaining process. To investigate, suppose that (exogenously) $r_A > r_B$.

In this situation, MFNs raise social surplus by ensuring e cient consumption decisions by consumers. To see why, recall that without an MFN U has an incentive to manipulate prices so as to distort demand away from whichever retailer is o ering it less advantageous terms. While this bene ts U and one retailer, it hurts the other retailer. Moreover, by so skewing consumer demand, overall transportation costs of consumers increase; such costs are minimized when $x = 1/2$.

In other words, MFNs ensure that consumers base their nal purchasing decisions on the underlying di erentiation between the retail channels, leading all consumers to purchase from their most-preferred retailer. This raises overall surplus. Nonetheless, imposing MFNs in this case is not a pareto improvement for consumers; MFNs lead to a decline in one price but an increase in the other.

Proposition 2. Suppose that (exogenously) $r_A > r_B$. Then imposing MFNs increases social surplus, lowers the pro ts of U, increases the pro ts of the retailer o ering the smaller r_i

but lowers the profits of the other retailer, and makes some consumers better off but other consumers worse off.

I now turn to two other reasons why MFNs can be pro-competitive.

2.3. MFNs as devices to encourage entry. Here I consider the effect of MFNs on entry. Because MFNs raise retailer profits, the presence of MFNs encourages retail entry which in turn raises social surplus.

To see this formally, augment the model above with an initial stage in which both A and B must choose whether to enter the market, where entering requires a non-recoverable investment $F > 0$. I consider pure-strategy equilibria.

Proposition 3. MFNs increase the level of entry and raise consumer surplus. In particular, there exists values F_1, F_2, and F_3, with $0 < F_1 < F_2 < F_3$, such that the following statements are true.

(1) For $F < F_1$ both retailers enter whether there are MFNs or not.
(2) For $F \in [F_1, F_2]$ only a single retailer enters if there are not MFNs, but both enter if there are MFNs.
(3) For $F \in (F_2, F_3]$, only a single retailer enters.
(4) For $F > F_3$, no retailer enters.
(5) MFNs strictly raise consumer surplus if $F \in [F_1, F_2]$ but otherwise have no effect on consumer surplus.

This differs from the typical perspective on the effect of MFNs on entry, which is that MFNs restrict entry, especially by potential discount players. For example, as Baker (1996) discusses, if an entrant requires a lower-cost access to an input in order to successfully compete against an incumbent, then entry may be unprofitable if incumbents have MFNs.

In other words, in the standard story an incumbent demands an MFN because that reduces the incentive of the supplier to offer discounts to an entrant, which may lower the entrant's profits and impede entry. However, in the agency model the main role of an MFN is to reduce the incentives of downstream firms to compete against one another for preferential treatment from the supplier, and hence MFNs raise entry incentives.

It should be noted that in the evolution of the e-book market, the incumbent player was Amazon and the entrant was Apple. Apple demanded MFNs as a condition of its entry, and also the adoption of the agency model in the industry. Thus, Proposition 3 presents the possibility that MFN clauses provided an important inducement for Apple to enter the e-book market. (In Section 3 I investigate whether adoption of the agency model itself might also help retailers.)

2.4. MFNs as devices to encourage post-entry investments. Here I show that MFNs raise investment incentives even conditional on both retailers being in the market.

Augment the basic model above (in which both retailers are in the market) with an initial stage in which both A and B select investment levels $e_i \geq 0$ at convex cost $c(e_i)$, where these costs determine the value v that consumers place on consumption according to the increasing concave function $v(e_1 + e_2)$. I assume that $t = v(0)$ and $v(e) < 2t$ for all values, with $v'(0) = 1$ and $\lim_{e \to 1} v'(e) = 0$.

The investments under consideration increase the overall willingness to pay of consumers. These might include marketing expenditures or improvements in the sales or consumption experience. This formulation provides a simple framework, but the underlying logic of the main result below does not hinge on this exact specification.

An equilibrium of this game is an investment level e_i for each firm and revenue shares r_i such that (i) the r_i comprise an equilibrium given the aggregate investment level $e_1 + e_2$, (ii) investment levels e_i are optimal given how they influence retailer profits. I consider symmetric equilibria, so that $e_1 = e_2 = e$ and $r_A = r_B = r$.

Proposition 4. MFNs raise the profits of both retailers and lead to strictly higher investment levels. MFNs raise consumer surplus.

Proposition 4 follows directly from the basic idea that MFNs raise the share of surplus that retailers claim. Hence, the result is robust to other modeling choices regarding the investments of retailers | so long as investments become more attractive when retailers' share of the profits increases, MFNs will encourage investments.

Retailer investments can be important for the success of products and even of entirely new markets. For example, the e-book market becomes more attractive to consumers when more retailers invest in their online storefronts, allowing consumers to more easily shop for books. Online stores can be very sophisticated, allowing consumers to read reviews, quickly search for specific books or types of books (such as those within a particular genre or by a certain author), and receive customized recommendations based on past purchases or search behavior. Additionally, e-book retailers typically provide software apps that are used to actually read the books, or even design the hardware on which the apps run; investments in these products is also important to the overall success of the market. Finally, advertising and promotion by trusted firms may be crucial for building demand, especially in new markets.

Thus, when retailer investments are crucial to the success of a new market, MFNs may provide needed incentives to provide such investments, benefiting overall welfare and consumers in particular.

2.5.

one only), and given that consumers observe the average price levels.[1] Note that if it were the case that $p_A^2 = p_B^2$ then it would also be that

$$y = \frac{p_B^1 \quad p_A^1 + t_d}{2t_d}; \tag{4}$$

corresponding to a static hotelling demand system with prices p_i^1.

This completes the description of the demand side of the market. Below I separately consider the supply side under the agency model and the wholesale model, and state appropriate results related to equilibrium of the overall market. I restrict attention to equilibria that are symmetric (either within or between retailers or both if possible).

3.2. The supply side and equilibrium in the agency model. Under the agency model, suppliers simultaneously set prices within each channel and in each period. As above, r_A and r_B denote the share of revenues given to the suppliers, where these shares are fixed across periods and taken as given by the suppliers.

I begin by considering prices in period two. Note that, due to consumer lock-in, there is no interaction between the prices charged through one retailer and what happens with consumers locked into the other retailer. Consider a representative supplier, say firm 1, choosing its price for, say, retailer A. For notational simplicity I suppress retailer subscripts and write this price simply as p_1^2, and let the prices of all other firms selling through this retailer this period be equal and given by p^2, with x_1 denoting the demand for supplier 1. Thus, 1 is interested in maximizing

$$r_A p_1^2 x_1(p_1^2; p^2) = r_A p_1^2 \quad \frac{p^2 \quad p_1^2 + \frac{t_u}{N}}{t_u} \quad :$$

This is proportional to a firm's profits in a standard circular city model, and hence generates the same best-response function as in such a model. In particular, within a given channel, suppliers' second-period best-response functions are independent of the revenue shares r_i.

It follows that the (symmetric) second-period equilibrium prices are independent of channel, and given by

$$p^2 = p_A^2 = p_B^2 = \frac{t_u}{N};$$

and the demand served by each supplier is 1=N.

Now consider the first period from the perspective of supplier 1, given that all other suppliers are charging p_A^1 and p_B^1 through the respective channels. Firm 1's profit function is

$$r_A y \ p_{A1}^1 x_{A1}^1 + p_{A1}^2 x_{A1}^2 \ + r_B (1 \quad y) \ p_{B1}^1 x_{B1}^1 + p_{B1}^2 x_{B1}^2 \ ;$$

[1] This interpretation also requires that consumers believe each firm is charging the same price within a given retailer.

where y is the mass of consumers who purchase from retailer A, given by Equation (4), and x_{A1} and x_{B1} give the proportion of consumers who demand this firm's product contingent on selecting either retailer A or B, $\in \{1; 2\}$.

Incorporating what is known about second-period pricing and demand, this reduces to

$$r_A y \left(p^1_{A1} x^1_{A1} + \frac{t_u}{N^2} \right) + r_B (1 - y) \left(p^1_{B1} x^1_{B1} + \frac{t_u}{N^2} \right) :$$

Because consumers are not yet locked into a retailer in period one, each supplier's prices influence which retailer consumers purchase from. Indeed, the same basic effect is in play as in Section 2, so that each supplier has an incentive to bias prices to drive demand to whichever channel is offering it a greater revenue share.

The following condition provides a more precise statement.

Proposition 5.

that the number of consumers y buying from A and 1 y buying from B has no e ect on the pricing. Rather, these are simply level e ects, and so I ignore them herein.

Consider a representative interval of length 1=N between, say, products 1 and 2. Suppressing time and retailer-speci c notation, the indi erent consumer x_1 satis es

$$p_1 + \frac{t_u}{N} = p_2 + t_u \quad \frac{1}{N} \quad x_1 \quad () \quad x_1 = \frac{p_2 \quad p_1 + \frac{t_u}{N}}{2t_u}; \tag{5}$$

which is of course the demand given the price di erence $p_2 \quad p_1$ from a hotelling interval of length 1=N. However, unlike in a standard hotelling model, the retailer sets both prices and hence internalizes any pricing externalities. To maximize its pro ts, it chooses

$$p_1 = v \quad t_u x_1$$

and time notation. The indi erence condition of the marginal consumer implies that

$$p_2 = p_1 \quad \frac{t_u}{N} + 2t_u x_1:$$

Incorporating this into the constraint

$$\frac{p_1 + p_2}{2} = p$$

gives

$$p_1 = p + \frac{t_u}{2N} \quad t_u x_1:$$

De ne $\forall = p + \frac{t_u}{2N}$, and observe that within this interval the retailer wishes to maximize

$$(p_1 \quad w_1)x_1 + (p_2 \quad w_2) \quad \frac{1}{N} \quad x_1 \quad :$$

subject to the constraints in Equations (5) and (6) with $\forall$ replacing v. Thus, this is the same maximization program from period two, with $v = \forall$. However, the optimal choice x_1 from that problem does not involve v, and so the optimal choice here does not involve $\forall$ (or, more particularly, p) and moreover coincides with the earlier solution.

Ergo, suppliers face the same within-retailer objective function as in period two, but with an overall objective function of

$$w_{An} x_{An} y + w_{Bn} x_{Bn} (1 \quad y);$$

where y depends on the underlying wholesale prices (via their determination of retail prices).

I now argue that there exists a solution to the rst-period wholesale pricing problem that coincides with the one in the second period. Suppose that all suppliers other than 1 are charging the same price both within and across platforms. Then, it is optimal for 1 to charge the (identical) static best-response wholesale price to each retailer, regardless of how y might vary. In other words, because rivals' prices are the same across retailers, 1 is indi erent to which retailer consumers go.

This means that it is an equilibrium for suppliers to charge the same wholesale prices they would if they ignored the impact of their pricing on consumer retailer choice. These are the same as the equilibrium second-period wholesale prices, given by $2t_u$=N. Hence, equilibrium rst-period wholesale prices are

$$w_{in}^1 = \frac{2t_u}{N}:$$

The only remaining question is what rst-period retail price levels p_i^1 are. To answer this question, note that A chooses p_A^1 to maximize

$$p_A^1 \quad w_A^1 + p_A^2 \quad w_A^2 \quad y = p_A^1 \quad w_A^1 + w_A^2 \quad p_A^2 \quad \frac{p_B^1 \quad p_A^1 + t_d}{2t_d} \quad :$$

other investments in the franchise, giving it limited strength to renegotiate if the supplier then o ers a more attractive wholesale o er to the second franchisee. The incentive to o er the second franchisee a better deal only exists in those models if two-part tari s are used.

4. The wholesale model versus the agency model of sales

Here I use the model with supplier competition and consumer lock-in developed above to examine how moving from a wholesale model of pricing to an agency model in uences the market equilibrium and the payo s of consumers, retailers, and suppliers. Throughout, I take the revenue shares as given and equal under the agency model, so that $r_A = r_B = r < 1$.

My rst result deals with market prices, and follows directly from Propositions 5 and 6.

Corollary 2. For v su ciently large, moving from the wholesale model to the agency model raises rst-period retail prices but lowers second-period retail prices.

It is certainly the case that e-book prices rose following the move to the agency model, so that the prediction regarding rst-period prices in Corollary 2 is consistent with the facts. The prediction that future prices might be lower under the agency model, however, is novel and suggests that the e ect of moving to that sales model is somewhat subtle.

There are two distinct intuitions for why retail prices within the two periods move in di erent directions as the market moves to an agency model. The reason that rst-period prices rise under the agency model follows from the fact that suppliers and retailers value consumer lock-in very di erently. From a retailer's perspective, having a consumer locked into its channel rather than its rival's is valuable as this allows it to monopolize the consumer in the future. Suppliers, however, have no preference whatsoever as to whether consumers are locked into retailer A or instead B. After all, retailers sell their products, at the same per-unit pro ts, through both retailers.

Consequently, when retailers set prices they compete very aggressively in the rst period, leading to low prices in that period. In contrast, suppliers have no incentives to subsidize rst-period prices. So long as the second-period market is su ciently valuable (as measured by v), the incentive to subsidize in period one is su ciently strong that rst-period prices are higher under agency than under wholesale.

The reason that the opposite conclusion on prices holds in the second period follows readily from the fact that consumers are locked into a retailer at that time. This means that under the wholesale model, each retailer internalizes price competition between suppliers and ensures that retail prices are high. Under the agency model, this lock does not have the same e ect because suppliers continue to compete directly with one another in retail prices, leading to lower retail prices.

In other words, the model predicts that second-period prices should be lower under the agency model because the agency model ensures that retail competition is left in the hands of all N suppliers as opposed to monopoly retailers.

4.1. Retailer pro ts. I now show that competing retailers may prefer either model, where the preference is driven strongly by the relative strength of downstream and upstream differentiation.

Proposition 8. The pro ts of retailers A and B are higher under the agency model than under the wholesale model if and only if

$$2(1 \quad r)\frac{t_u}{N} > t_d:$$

Proposition 8 says the retailers prefer the agency model so long as the share of pro ts that they claim from the market under the agency model exceeds the measure t_d of the di erentiation between retailers. Given that t_u=N is a measure of suppliers' (gross) pro ts in the agency model | which is the same as the model in which they sell through a perfectly competitive downstream | this Proposition also says that agency is preferred by retailers so long as supplier di erentiation is relatively large compared to retailer di erentiation (and r is not too big).

An intuition for why retailers might prefer the agency model follows from the fact that the agency model kills the intense rst-period price competition that would otherwise prevail, leading to higher rst-period prices. More precisely, by placing pricing power in the hands of suppliers (who do not care to which retailer consumers become locked), retailers avoid the intense upfront competition for consumers that leads to the dissipation of second-period pro ts. Hence, even though second-period pro ts are lower for retailers under the agency model, these pro ts are not dissipated. This force pushes for overall retailer pro ts to be higher under agency.

However, there is also a force that pushes for overall pro ts to be lower under the agency model. First-period prices under agency do not incorporate the di erentiation that exists between retailers, measured by t_d. Intuitively, because suppliers sell through both channels, the equilibrium outcome of their pricing con ict ignores retailer di erentiation, and discarding retailer di erentiation in this manner pushes towards lower retailer pro ts.

Under the wholesale model, retailers dissipate second-period rents and so their pro ts are solely determined by their inherent di erentiation.

Turning to the agency model, Proposition 5 implies that the sum of retailers' pro ts is simply their share 1 r of pro ts that would be generated if suppliers competed in both periods through a perfectly competitive retail segment, given by

$$2(1 \quad r)\frac{t_u}{}$$

Proposition 13. Suppose that a retail monopolist can impose wholesale prices w_M, and that retail competition exists only if the agency model is adopted. Then suppliers prefer the agency model if and only if

$$w_M < r\,\frac{t_u}{N}.$$

Recall that rt_u/N is the per-unit profit that accrues to suppliers in a single period under the duopoly agency model. Thus, Proposition 13 is extremely simple and merely says that if a monopolist retailer has sufficient bargaining leverage, suppliers prefer the agency model so long as it ensures the presence of another viable retailer.

to an Amazon app and a Google app (and in principle Apple could provide an app on that platform as well). Additionally, with the possible exception of early devices produced by

Setting this equal to zero at the values $r_A = r_B = r^*$ and $x = 1/2$, and using the fact that

$$\frac{\partial x}{\partial r_A} = \frac{v - 2tx}{2t(r_A + r_B)};$$

it is clear there is a unique solution given by

$$r^* = \frac{(v - t)^2}{v^2}.$$

The third step involves showing two properties of the best-response function BR, the first of these being that it is increasing with a slope less than one at r^*. Using the facts that

$$\begin{aligned}\frac{\partial^2 x}{\partial r_A^2} &= \frac{4t^2(r_A + r_B)\frac{dx}{dr_A} - 2t(v - 2tx)}{4t^2(r_A + r_B)^2} \\ &= \frac{2t(v - 2tx) - 2t(v - 2tx)}{4t^2(r_A + r_B)^2} \\ &= \frac{(v - 2tx)}{t(r_A + r_B)^2} < 0;\end{aligned}$$

and

$$\begin{aligned}\frac{\partial^2 \pi_A}{\partial r_B \partial r_A} &= -(v - 2tx)\frac{\partial x}{\partial r_B} - (1 - r_A)t\frac{\partial x}{\partial r_B}\frac{\partial x}{\partial r_A} - (1 - r_A)tx\frac{\partial^2 x}{\partial r_B \partial r_A} \\ &\quad - (1 - r_A)t\frac{\partial x}{\partial r_B}\frac{\partial x}{\partial r_A} + (1 - r_A)(v - tx)\frac{\partial^2 x}{\partial r_B \partial r_A} \\ &= -(v - 2tx)\frac{\partial x}{\partial r_B} - 2(1 - r_A)t\frac{\partial x}{\partial r_B}\frac{\partial x}{\partial r_A} + (1 - r_A)(v - 2tx)\frac{\partial^2 x}{\partial r_B \partial r_A} \\ &= -(v - 2tx)\frac{\partial x}{\partial r_B} + \frac{(1 - r_A)(v - 2tx)(v - 2t(1 - x))}{2t(r_A + r_B)^2} + \frac{(1 - r_A)(v - 2tx)(2x - 1)}{(r_A + r_B)^2}\end{aligned}$$

the implicit function theorem shows that

$$BR'(r^*) = \frac{r^* + 1}{r^* + 3} \in (0; 1).$$

Note that this fact, along with the fact that there is a unique symmetric equilibrium, implies that for $r < r^*$, it is the case that $BR(r) > r$ (and that if $r_B < r^*$, then $x > 1/2$). Similarly, if $r > r^*$, it is the case that $BR(r) < r$ (and that if $r_B > r^*$, then $x < 1/2$).

The second property of the best-response functions is that they are also increasing for all $r < r^*$. Because it was shown above that $\partial^2 \pi_A / \partial r_A^2 < 0$, it is sufficient to show that

$\partial^2\Pi^A/\partial r_B\partial r_A > 0$. It is the case that

$$\frac{\partial^2\Pi^A}{\partial r_B\partial r_A} = (v - 2tx)\frac{\partial x}{\partial r_B} - (1 - r_A)t\frac{\partial x}{\partial r_B}\frac{\partial x}{\partial r_A} - (1 - r_A)tx\frac{\partial^2 x}{\partial r_B\partial r_A}$$

$$-(1 - r_A)t\frac{\partial x}{\partial r_B}\frac{\partial x}{\partial r_A} + (1 - r_A)(v - tx)\frac{\partial^2 x}{\partial r_B\partial r_A}$$

$$= (v - 2tx)\frac{\partial x}{\partial r_B} - 2(1 - r_A)t\frac{\partial x}{\partial r_B}\frac{\partial x}{\partial r_A} + (1 - r_A)(v - 2tx)\frac{\partial^2 x}{\partial r_B\partial r_A}$$

$$= (v - 2tx)\frac{\partial x}{\partial r_B} + \frac{(1 - r_A)(v - 2tx)(v - 2t(1 - x))}{2t(r_A + r_B)^2} + \frac{(1 - r_A)(v - 2tx}{}$$

$r_A + r_B)^2$

Comparing this condition with the corresponding one under MFNs, and defining $\forall = v/t$, it is clear that more investment occurs when there are MFNs so long as

$$\frac{t^2(2v - t)}{v^3} < 1 \Leftrightarrow \frac{(2\forall - 1)}{\forall^3} < 1 \Leftrightarrow \forall^3 - 2\forall + 1 > 0.$$

Because $v(e) \in (t, 2t)$ for all values of e, $\forall \in (1, 2)$, and it is readily show that this condition holds.

References

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