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Contributions

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Vertical Contracts and Mandatory Universal Distribution

Abstract: An upstream monopoly that provides a new good to a downstream oligopoly might prefer to sell to a single rather than to multiple downstream firms. For example, Apple initially sold its iPhone through one vendor. If a monopoly uses a single vendor, the government may impose a mandatory universal distribution (MUD) requirement that forces the monopoly to sell to all downstream vendors. However, if the income elasticity of demand for the new good is greater than the income elasticity of the existing generic good, the MUD requirement leads to a higher equilibrium price for both the new good and the generic and lowers consumer welfare.

Keywords: vertical restrictions, mandatory universal distribution, new product, oligopoly
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1 Introduction

Apple signed a contract in 2007 that granted one U.S. wireless phone provider, AT&T, the exclusive right to distribute its iPhone for 5 years.[1] Consumer organizations such as Consumers Union called on the government to require that the iPhone be available through many or all downstream providers. In 2009, a Senate antitrust panel held hearings, and Senators listed steps that they wanted

1 "Supporting Memorandum of Points and Authorities," In Re Apple & AT&TM Anti-trust Litigation, U.S. District Court, Northern District of California, San Jose Division, Case no. C 07–5152 JW, 12 September 2008. In 2011, Apple signed contracts allowing AT&T's competitors Verizon and Sprint to start selling iPhones.

the FCC and the Department of Justice to take to make the downstream industry more competitive (*Consumer Reports 2009*). We examine the desirability of such a requirement.

The issue of mandatory universal distribution (MUD) has arisen in many markets (e.g. movies, video games, and other durables) in the past and will arise with new, disruptive inventions. We define MUD as the requirement that the monopoly offers identical contracts to all potential vendors, and we identify conditions under which MUD helps or hurts consumers and society. One of the chief arguments by proponents of MUD appeals to the conventional wisdom that the equilibrium price falls when there are more firms in the market. It is, of course, well known that if the upstream industry is competitive, then raising the number of identical Cournot oligopolistic downstream firms lowers the price to final consumers. However, this relation may not hold if the upstream provider is a monopoly that can adjust the wholesale price (or other contract terms) that it charges downstream firms depending on the number of vendors that carry its product.

We assume that there is a vertical industry structure, with two types of upstream firms. A monopoly produces a new product (e.g. Apple's iPhone). A competitive industry produces a generic product. Downstream, a quantity-setting oligopoly sells the generic, and some or all of the firms also sell the new product.

We use a two-stage model. In the first stage, an upstream monopoly that has a new product decides whether it wants one or more downstream vendors to distribute its product. The upstream firm charges a constant wholesale price, but charges each downstream firm a lump-sum fee for the right to carry its product, which allows the monopoly to capture downstream profits. In the second stage, the downstream firms resell the product to final consumers using a fixed-proportion production process. One or more of the downstream firms also sell the new product. All downstream firms sell a generic product. The firms choose how many units of the new and the generic products they sell and a Cournot equilibrium results.

The upstream firm may want to sell to only one downstream firm, and consumers may be better off with either one or two (or more) vendors downstream. Similarly, the upstream firm may want to sell to two (or more) downstream firms, and consumers may or may not be better off with one vendor. Which of the four possible outcomes occurs depends on the combination of fixed cost and degree of substitution between the phones.

We focus on two issues that determine the outcome: the size of the fixed cost to enable each downstream vendor to sell the new product and the degree to which consumers are willing to substitute the new product for the generic product. AT&T incurred a substantial cost to enable the iPhone to work on its network. We first discuss the case where the products are not substitutes and then the case where they are substitutes.

If the new and generic goods are not substitutes, we can consider the new product in isolation from the old. If the monopoly or the downstream firms incur a fixed cost to establish a relation, the monopoly sells to a single downstream firm. The upstream monopoly is able to capture all of the rents, because it has the same number of instruments (the wholesale price and the lump-sum fee) as targets (maximizing downstream profit and capturing it). In contrast, when the two goods are substitutes, the upstream monopoly still has two instruments but has three targets. The monopoly wants to control the sales of both the new and the generic goods, and it wants to capture profits. In this second best setting, results are ambiguous; we need to work through the model to determine how MUD affects the monopoly's actions and consumer welfare.

Many articles examine vertical relations, and some consider substitution between products downstream. However, we are not aware of any article that analyzes the MUD policy. Our model is similar to those of several literatures that show upstream firms can use vertical contracts (or vertical integration) to soften competition by raising rivals' costs (possibly through sabotage) or foreclosing entry strategically (Salop and Scheffman 1983, Aghion and Bolton 1987, Economides 1998, Ordover, Salop, and Saloner 1990, Hart and Tirole 1990, Riordan 1998, Weisman 2001, White 2007, and Bustos and Galetovic 2008).

In many of these articles, vertical foreclosure occurs because an upstream firm controls some "essential facility" or "bottleneck resource" to which competing firms need access at equal prices to compete downstream. A key point in many of these articles is that firms can collectively earn only a single monopoly profit, so that the upstream firm, by charging a monopoly price for access to the essential facility, can extract all of the monopoly rents without further harming consumers.

Our article captures this same insight, though we focus on a model in which the upstream monopoly captures rents through a transfer payment as well as through per-unit charges. Some of the foreclosure literature examines government policies that forbid explicit foreclosure, which is similar to an MUD policy. However, our results differ from most of that literature, because our upstream product competes with another product downstream.

Although the modern exclusive-dealing literature and our article examine very different questions, we use similar models. That literature asks whether an incumbent monopoly can profitably use an exclusive contract to inefficiently deter entry. The models in Fumagalli and Motta (2006), Simpson and Wickelgren (2007), Wright (2008), Abito and Wright (2008), Argenton (2010), Doganoglu and

Wright (2010), and Kitamura (2010, 2011) have an incumbent monopoly and one or more potential entrants that produce identical or differentiated products and imperfect downstream competition, possibly with differentiation. Both they and we consider two-part tariffs, as a means of avoiding double marginalization problems.

Similarly, Inderest and Shaffer (2010) examine market-share contracts, where discounts depend on the share that a supplier receives of a retailer's total purchases. In its extreme form, this policy is an exclusive-dealing restriction. Their model has two differentiated upstream goods and two differentiated downstream firms. One upstream good is sold at cost, as in our model. The manufacturer of the other good makes simultaneous take-it-or-leave offers to both downstream firms, which differs from the game in our model. In their model, the manufacturer's contract depends either on only how much the retailer buys of the good or on the share of the retailer's overall purchases, which contrasts with the two-part contract in our model.

The literature on slotting allowances and other vertical restrictions (Shaffer 2005, and Innes and Hamilton 2006, 2009) deals with a very different policy question but uses models with similar vertical structures. Slotting allowances are fees that grocery chains receive from manufacturers to provide shelf-space for their goods. Established upstream firms may encourage the use of such fees to prevent entry by other upstream competitors. As in many of these models, our model allows upstream and downstream firms to sign contracts in the first stage that affects the degree of competition in the final stage. These models differ from ours, because they concentrate on the competition among oligopolistic upstream firms, whereas we look at competition among oligopolistic downstream firms. Moreover, the direction of lump-sum transfers in their models is the opposite of ours.

The literature on wholesale non-discrimination rules is similar to our article in spirit. MUD could be viewed as a particular non-discrimination rule that forbids setting the price to some downstream firms prohibitively high. Indeed, in an argument analogous to the current debate, Bork (1978) suggested that total welfare would increase if new markets are served and wholesale price discrimination is allowed. However, these articles look at a very different vertical model. Typically in these models, the upstream monopoly wants to discriminate, because the downstream firms have different costs or serve markets with different demand elasticities (Schmalensee 1981, Varian 1985, Katz 1987, De-Graba 1990, Ireland 1992, Yoshida 2000, and Villas-Boas 2009). We abstract from those considerations by assuming that all downstream firms are identical and all sell in the same market. This simplification allows us to focus attention on the strategic reasons for selling to one or more downstream firms, reasons not discussed in detail in the discrimination literature.

In short, while many articles examine vertical relations, some consider substitution between products downstream, and a few examine contracting issues and lump-sum transfers, we are unaware of any article that covers all these features as we do, and no other article examines the MUD policy question.

2 No substitutes for the new good

We start by considering an extreme case where an MUD restriction does not affect consumer welfare but lowers industry profit and hence social welfare. Here, the upstream monopoly sells a good that is not a substitute for existing goods. We assume that the downstream firms incur no additional cost of selling the good. There are a limited number of potential downstream firms, N. When more than one firm sell the new good, the outcome is a Cournot equilibrium.

If the upstream monopoly's only instrument is its wholesale price, then it faces the traditional double marginalization problem where the monopoly marks up its wholesale price over its marginal cost of production, and the downstream vendor or vendors add a second markup to the wholesale price. The monopoly can avoid the double marginalization problem by vertically integrating downstream. Alternatively, it can quasi-vertically integrate, if it has two instruments. For example, it can use a two-part tariff where it charges a vendor T for the right to carry its product and a constant wholesale unit price.

Because the monopoly can use T to capture a vendor's profit, the monopoly wants its vendor to maximize this profit. If the monopoly sells to only one firm, it sets its wholesale price equal to its production cost so that the vendor charges the same price that an integrated monopoly would use. If the monopoly sells to N downstream firms, it sets its wholesale price so that the resulting downstream price is the same as that of the integrated monopoly. The upstream monopoly captures all downstream profits by setting T appropriately.

Because the upstream monopoly can control the downstream price with its wholesale price regardless of the number of downstream firms, it is indifferent as to the number of vendors if there is no fixed cost, F, associated with each vendor carrying its product (e.g. to enable a new phone to work on a network). Given $F > 0$, it does not matter whether the fixed cost is paid by the upstream or downstream firm, as the upstream firm captures downstream profit and hence ultimately bears this cost. Consequently, if $F > 0$, the upstream monopoly wants to sell to only one downstream vendor. If an MUD requirement forces the upstream monopoly to sell to N downstream firms, the retail price and consumer welfare do not change, but the upstream monopoly's profit falls by $(N-1)F$, and hence social welfare would drop by the same amount.

3 A model with a substitute good

We now consider a market in which the new good and the generic good are substitutes. There are only two downstream firms with identical costs. We continue to assume that the downstream firms use a fixed-proportion production function and have no additional marginal cost. The monopoly's wholesale price is the sum of its cost of production plus a constant markup, m. A competitive industry with constant average costs produces the generic good, so that the downstream firms buy the generic at its cost of production.

The downstream duopoly firms, $i = 1$ and 2, are quantity setters. The quantity q_{ji} is the amount that Firm i sells of product j, where $j = g$ is the generic good and $j = n$ is the new product. For notational simplicity and to avoid the need to keep track of upstream marginal production costs, we express the generic price p_g and the new good price p_n net of their constant upstream marginal production costs.

There are four possible welfare outcomes. The upstream monopoly may prefer either one or two downstream vendors, and in either case consumer welfare may be higher with one or two firms. We show that even with a linear model, all four of these outcomes are possible.

3.1 Two-stage game

The firms play a two-stage game; the downstream firms behave non-cooperatively in both stages. In the first stage, the interaction between the monopoly and the downstream firms determines: the number of vendors; the amount by which the wholesale price exceeds the upstream monopoly's marginal cost of production, m; and the lump-sum transfer from the vendor(s) to the upstream monopoly, T. In the second stage, the downstream firms play a Cournot game in which they decide how many units of the new and generic products to sell.

The monopoly offers a contract to either one or both firms. We assume that if the monopoly offers a contract to both firms, and either rejects the contract, then we move to a subgame in which the monopoly offers a contract to a single vendor. To determine the equilibrium when the monopoly offers a contract to both firms, we need to know the equilibrium outcome of the subgame where it contracts with a single vendor. We, therefore, begin with that subgame.

In this single-vendor subgame, Firm i's equilibrium sales function for product j is $q_{ji}(m)$ if i is not the vendor, and its sales function is $\hat{q}_{ji}(m)$ if it is the vendor. Given these sales functions, the equilibrium prices are $p_g(m)$ and $p_n(m)$. If Firm i is the vendor, its profit is net revenue minus the transfer fee, $p_g\hat{q}_{gi} + (p_n - m)\hat{q}_{ni} - T$. If Firm i is not the vendor, its profit is $p_g q_{gi}$.

In the bidding stage of this single-vendor subgame, the monopoly announces a markup m and then firms alternate in making bids, T, for the right to be the sole vendor. The first bidder can offer any bid. The monopoly considers only subsequent bids that exceed the previous bid by an amount greater than $\varepsilon > 0$, which is the cost to the monopoly of evaluating a bid. Bidding stops when no firm raises the previous bid.

We adopt the tie-breaking assumption that if a firm is indifferent between being the non-vendor and the vendor, it chooses to be the non-vendor. If $T = p_g\hat{q}_{gi} + (p_n - m)\hat{q}_{ni} - p_g q_{gj}$, the vendor and non-vendor earn the same profit. Thus, a firm will raise any previous bid lower than

$$T(m;\varepsilon) \equiv p_g\hat{q}_{gi} + (p_n - m)\hat{q}_{ni} - p_g q_{gj} - \varepsilon \qquad [1]$$

and will not raise any bid at or greater than this level.

Consider a firm that is either the first to bid or faces a previous bid strictly less than $T(m;\varepsilon)$. Suppose that this firm believes that in the event that it offers a bid strictly less than $T(m,\varepsilon)$, its rival will offer $T(m;\varepsilon)$ in the next stage. Given these beliefs, the unique equilibrium first-stage action, and the unique equilibrium response to a bid less than $T(m;\varepsilon)$ is for the current bidder to offer $T(m;\varepsilon)$, thereby preempting its rival. These beliefs, therefore, constitute an equilibrium, and the outcome equals the bid $T(m;\varepsilon)$.[2] We suppose that Firm 1 has the first bid and, therefore, wins the contract in the one-vendor subgame.

Using the results of this one-vendor subgame, the monopoly decides the number of contracts to offer. A monopoly that sells to both firms must offer them the same contract, (m, T). This contract is contingent on both firms accepting; if either firm rejects the contract, they enter the one-vendor subgame. MUD requires that the monopoly begin by offering both firms a contingent contract (m, T) that they are willing to accept, given their belief that rejection sends them

2 We do not claim that the equilibrium is unique, merely that the beliefs described in the text are consistent with equilibrium, and that the equilibrium action given those beliefs (and our tie-breaking assumption) is unique. A discussion of uniqueness of equilibrium beliefs would require a description of the consequences of neither firm making a bid and would take us far afield.

to the one-vendor subgame. Under MUD, the monopoly sells to both firms in equilibrium.

We begin by finding the equilibrium to the one-vendor subgame, in the limiting game as $\varepsilon \to 0$. Letting $\varepsilon \to 0$ and using eq. [1], the equilibrium T satisfies

$$T = p_g\hat{q}_{gi} + (p_n - m)\hat{q}_{ni} - p_g q_{gj}. \quad [2]$$

Using the equilibrium sales rules, $\hat{q}_{gi}$, $\hat{q}_{ni}$, q_{gj}, and eq. [2], the monopoly's profit is its sales revenue plus the transfer, T, minus the fixed cost F:

$$\begin{aligned} m\hat{q}_{ni} + T - F &= m\hat{q}_{ni} + \left[p_g\hat{q}_{gi} + (p_n - m)\hat{q}_{ni} - p_g q_{gj}\right] - F \\ &= p_g\hat{q}_{gi} + p_n\hat{q}_{ni} - p_g q_{gj} - F. \end{aligned}$$

Thus, the monopoly's problem is

$$\Pi(1) = \max_m \left\{p_g\hat{q}_{gi} + p_n\hat{q}_{ni} - p_g q_{gj} - F\right\}, \quad [3]$$

where the argument of $\Pi(1)$ indicates that the monopoly offers a single contract.

Let $m(1)$ be the solution to this problem. The vendor's revenue net of production costs equals $p_g\hat{q}_{gi} + p_n\hat{q}_{ni}$, and the non-vendor's profits equal $p_g q_{gj}$. The monopoly wants to maximize the difference between $p_g\hat{q}_{gi} + p_n\hat{q}_{ni}$ and $p_g q_{gj}$. It benefits not only by increasing its vendor's revenue minus production costs but also by decreasing the non-vendor's profit.

Firm 1 is the first bidder and thus wins the contract. The equilibrium $m(1)$ satisfies the first-order condition

$$\frac{d\left(p_g\hat{q}_{g1} + p_n\hat{q}_{n1}\right)}{dm} - \frac{d\left(p_g q_{g2}\right)}{dm} = 0. \quad [4]$$

An increase in m causes Firm 1 to reduce sales of the new product, thereby increasing Firm 2's profit, so $\frac{d(p_g q_{g2})}{dm} > 0$. This inequality and the assumed concavity of the monopoly's maximand imply that $m(1)$ is strictly less than the level of m that maximizes $p_g\hat{q}_{gi} + p_n\hat{q}_{ni}$.

To obtain the equilibrium when the monopoly sells to both firms, we use the symmetric Cournot equilibrium sales rules, which we denote $q_j^*(m)$; because of firm symmetry, we drop the firm subscript here. If the firms reject the two-vendor contract, they each earn their equilibrium profit in the one-vendor subgame, which we denote as $\pi(1)$. We adopt a second tie-breaking assumption that if firms are indifferent between accepting the two-vendor contract and entering the one-vendor subgame, they choose to accept the two-vendor contract. Thus, a firm accepts a two-vendor contract, if and only if acceptance results in a profit no less than $\pi(1)$. Consequently, the monopoly's two-vendor problem is

$$\Pi(2) = \max_{m,T} 2[mq_n^* + T - F] \quad \text{subject to } p_g^* q_g^* + \left(p_n^* - m\right)q_n^* - T \geq \pi(1). \quad [5]$$

Eliminating the constraint, we rewrite the monopoly's maximization problem when it uses two vendors as

$$\Pi(2) = \max_m 2\left[p_g^* q_g^* + p_n^* q_n^* - (\pi(1) + F)\right]. \qquad [6]$$

Because $\pi(1)$ is a constant in this problem, maximization of the right side of eq. [6] is equivalent to maximizing downstream revenue minus production costs, $p_g^* q_g^* + p_n^* q_n^*$. We denote the solution to this problem as $m(2)$ and denote the equilibrium profits of the duopolists as $\pi(2)$. Because the constraint in problem [5] is binding, $\pi(1) = \pi(2)$.

In summary, we have

Proposition 1 *(i) The monopoly that sells to one firm captures the profit of only its vendor and chooses a markup lower than the level that maximizes the vendor's revenue minus production costs. (ii) The monopoly that sells to two firms chooses a markup that maximizes the sum of vendors' revenue minus production costs. (iii) Equilibrium duopoly profits are the same regardless of whether the monopoly sells to one firm or two*: $\pi(1) = \pi(2)$.

This proposition provides the basis for the intuition for several of our main results. The monopoly that sells to two vendors wants to maximize the sum of their gross profits (i.e. profits inclusive of the markup), because the rent that the monopoly captures using T is increasing in the sum of their gross profits. In contrast, the monopoly that sells to a single vendor can use T to capture rents equal to the difference in the downstream firms' gross profits. That monopoly, therefore, does not choose m to maximize its vendor's gross profits.

3.2 Linear model assumptions

We now assume that the inverse demand functions for both the new and the generic products are linear; these functions are approximations to a more general system of demand functions.[3,4]

3 The quadratic utility function produces linear demand functions. However, symmetry of the cross partials of the Hicksian demand functions requires $c = C$ (Singh and Vives 1984).

4 Gabszewicz and Thisse (1979), Shaked and Sutton (1982), and Bonanno (1986) used a model of consumer behavior that generates a system of linear demand functions similar to this model, though with a slightly different interpretation of the demand system parameters. Products have a physical characteristic (location) that measures quality. Consumers have identical preferences but different incomes and buy at most one unit of a product.

$$\begin{aligned} p_g &= a - b(q_{g1} + q_{g2}) - c(q_{n1} + q_{n2}), \\ p_n &= A - B(q_{n1} + q_{n2}) - C(q_{g1} + q_{g2}). \end{aligned} \tag{7}$$

The intercepts a and A equal the intercept of the inverse demand curve minus the constant marginal production cost. All parameters are non-negative. Because these linear demand equations lead to closed-form expressions for the equilibrium sales rules, we can solve for the equilibrium levels of $m(1)$ and $m(2)$ and then compare the price levels and consumer welfare in the two scenarios.[5]

The model has seven parameters, $a, A, b, B, c, C,$ and F. By choosing the units of the quantities, we set the own-quantity slopes of the inverse demand functions to be equal, $B = b$, without loss of generality. The coefficient a is a scaling parameter, and its value does not affect our results. We restrict $A = a$ (a genuine restriction, not a normalization) and refer to the model with this restriction as "almost symmetric". (Section 6 discusses the model without the restriction $A = a$.) The inverse demand equations in the almost symmetric model are

$$\begin{aligned} p_g &= a - b(q_{g1} + q_{g2}) - c(q_{n1} + q_{n2}), \\ p_n &= a - b(q_{n1} + q_{n2}) - C(q_{g1} + q_{g2}). \end{aligned} \tag{8}$$

That is, the intercepts and own-quantity slopes of the two products are identical. However, the cross-quantity effects, the degree to which one good substitutes for the other, differ. We now concentrate on the role of the three parameters, $c, C,$ and F. The almost symmetric model allows for all four possible outcomes, where the monopoly wants to sell to one firm or two firms, and monopoly and consumer interests are aligned or opposed.

We invert eqs [8] to write the demand system as

$$\begin{pmatrix} \mathbf{q}_g \\ \mathbf{q}_n \end{pmatrix} = \begin{pmatrix} \dfrac{ab - ac}{b^2 - cC} \\ \dfrac{ab - aC}{b^2 - cC} \end{pmatrix} - \begin{bmatrix} \dfrac{b}{b^2 - cC} & -\dfrac{c}{b^2 - cC} \\ -\dfrac{C}{b^2 - cC} & \dfrac{b}{b^2 - cC} \end{bmatrix} \begin{pmatrix} p_g \\ p_n \end{pmatrix}, \tag{9}$$

where aggregate quantities, $\mathbf{q}_j = q_{j1} + q_{j2}$, are functions of prices. Because the two goods are substitutes, we want the aggregate quantity demanded of a good

5 Moner-Colonques, Sempere-Monerris, and Urbano (2004) examine a market in which two upstream firms decide whether to sell their products through one or both of the downstream vendors. Their model allows the upstream firms to charge only a per-unit price, whereas our upstream firm also uses a transfer. In addition, we allow the cross-price coefficients c and C to differ. The difference in these coefficients is key to our results.

to decrease as its own-price increases and rise with respect to the other price. In addition, we require that the aggregate demand for both goods be positive if both prices (which are net of their production costs) are zero: $p_g = p_n = 0$. These two conditions imply the parametric restrictions that the own-quantity parameter is greater than either of the other-quantity parameters:

$$b > c, \quad b > C. \qquad [10]$$

An increase in the own-quantity has a larger effect on price than a comparable increase of the other-quantity.

The relative magnitude of c and C plays a major role in the analysis. We use the indirect utility function to provide an economic interpretation of the sign of $c - C$. Denoting $\mathbf{q}_j^{\text{Hicksian}}$ as the Hicksian demand and $\mathbf{q}_j$ as the Marshallian demand (as above), the Slutsky equation (with y equal to income) is

$$\frac{\partial \mathbf{q}_j}{\partial p_i} = \frac{\partial \mathbf{q}_j^{\text{Hicksian}}}{\partial p_i} - \mathbf{q}_i \frac{\partial \mathbf{q}_j}{\partial y}.$$

We obtain the partial derivatives, $\frac{\partial \mathbf{q}_j}{\partial p_i}$, from eq. [9]. We, then, use the symmetry relation

$$\frac{\partial q_g^{\text{Hicksian}}}{\partial p_n} = \frac{\partial q_n^{\text{Hicksian}}}{\partial p_g},$$

and the Slutsky equation to show that the parameters of the demand equation satisfy

$$\frac{\partial \mathbf{q}_g}{\partial p_n} - \frac{\partial \mathbf{q}_n}{\partial p_g} = \frac{c - C}{b^2 - cC} = \frac{\mathbf{q}_g \mathbf{q}_n}{y} \left(\eta_n - \eta_g \right), \qquad [11]$$

where η_j is the income elasticity of demand for commodity j. Inequalities [10] imply $b^2 - cC > 0$. This inequality and eq. [11] imply

Proposition 2 *The sign of $c - C$ is the same as that of the difference between the income elasticities, $\eta_n - \eta_g$. If consumers view a new product as more of a luxury than a generic product so that the income elasticity of the new product is greater than that of the generic, then $c > C$.*

Because the new good is almost certainly more income-elastic than the generic, we consider $\eta_n > \eta_g$, or $c > C$, to be the interesting case. If $\eta_n > \eta_g$, so that $c > C$, then, using eq. [9], we learn that the demand intercept or choke price of the new good exceeds that of the generic, and the demand for the generic is more sensitive to the price of the new good than vice versa.

4 Equilibria

To compare the equilibrium with linear inverse demand functions where the monopoly sells to two firms to the equilibrium where it sells to only one firm, we first determine the downstream firms' Cournot equilibrium quantities given m. We then use that information to solve the upstream monopoly's profit maximizing problem to determine m.

Using the inverse demand equations [7], the profit of downstream Firm i, exclusive of any transfer (T) is

$$\pi_i = [a - b\mathbf{q}_g - c\mathbf{q}_n]q_{gi} + [a - b\mathbf{q}_n - C\mathbf{q}_g - m]q_{ni}. \qquad [12]$$

Because Firm 1 always sells both goods, its first-order conditions are

$$\frac{\partial \pi_1}{\partial q_{g1}} = a - 2bq_{g1} - bq_{g2} - c\mathbf{q}_n - Cq_{n1} = 0, \qquad [13]$$

$$\frac{\partial \pi_1}{\partial q_{n1}} = a - 2bq_{n1} - bq_{n2} - C\mathbf{q}_g - cq_{g1} - m = 0. \qquad [14]$$

If Firm 2 does not sell the new product, $q_{n2} = 0$ in eq. [14], and hence $\mathbf{q}_n = q_{n1}$ in eq. [13].

If Firm 2 sells both goods, then its first-order conditions are the same as eqs [13] and [14] with the subscripts 1 and 2 reversed. However, if Firm 2 sells only the generic good, it has a single first-order condition for the generic good:

$$\frac{\partial \pi_2}{\partial q_{g2}} = a - 2bq_{g2} - bq_{g1} - cq_{n1} = 0. \qquad [15]$$

Thus, if the monopoly sells to both firms, there are four first-order conditions: eqs [13] and [14] and the same pair of equations with the subscripts 1 and 2 reversed. However, given symmetry across firms, these four equations collapse into two first-order conditions, where the quantity for each firm is replaced by $\mathbf{q}_j/2$. When the monopoly sells to both firms, it is indifferent about the division of sales between the two firms. It has one instrument, m, to affect two targets: aggregate new product and aggregate generic quantities, $\mathbf{q}_g$ and $\mathbf{q}_n$.

In contrast, if the monopoly sells to only Firm 1, then there are three relevant first-order conditions, eqs [13–15]. Thus, when the monopoly sells to a single firm, it uses the same single instrument to control three targets: new-product sales by Firm 1, aggregate generic sales, and Firm 1's share of generic sales (or equivalently, q_{n1}, q_{g1}, and q_{g2}). For a given level of aggregate generic sales, the monopoly prefers its agent, Firm 1, to have a larger share so as to increase Firm 1's pre-transfer profit, which the monopoly captures through the transfer T.

When the monopoly sells to only Firm 1, we can solve the first-order conditions, eqs [13–15], to obtain the duopoly sales as functions of m. Differentiating these expressions with respect to m and using the parameter restrictions in inequalities [10], some calculations produce the comparative statics results:

$$\frac{dq_{n1}}{dm} < 0 < \frac{dq_{g1}}{dm}. \qquad [16]$$

(This inequality also holds when the monopoly sells to two firms.) An increase in m reduces Firm 1's marginal profit from each new-product sale, causing it to reduce sales in that market. That reduction in new-product sales causes Firm 1's marginal revenue curve in the generic market to shift out, increasing sales in that market. The equilibrium level of Firm 2's generic sales (when the monopoly sells only to Firm 1) is

$$q_{g2} = -\frac{(C-c)}{(6b^2 - 4cC - C^2 - c^2)} m + \text{a constant}. \qquad [17]$$

Consequently,

$$\frac{dq_{g2}}{dm} \left\{ \begin{array}{c} < \\ = \\ > \end{array} \right\} 0 \quad \text{for} \left\{ \begin{array}{c} C > c \\ C = c \\ C < c \end{array} \right\}. \qquad [18]$$

The value of m has only an indirect effect on Firm 2's profit due to the changes in Firm 1's sales, described in inequality [16]. The changes in Firm 1's sales of the two goods, resulting from a change in m, have counteracting effects on Firm 2's marginal revenue curve. As m increases, Firm 1 sells fewer units of the new good, which helps Firm 2, but more units of the generic product, which hurts Firm 2. Proposition 2 suggests that it is reasonable to expect that $C < c$, so $dq_{g2}/dm > 0$.

An increase in m affects only the term $bq_{g1} + cq_{n1}$ within Firm 2's marginal revenue, eq. [15]. Straightforward calculations show that

$$\frac{d(bq_{g1} + cq_{n1})}{dm} = 2b \frac{C-c}{6b^2 - 4Cc - C^2 - c^2}.$$

The denominator of the right-hand-side term is positive by inequalities [10]. Thus, an increase in m shifts up Firm 2's marginal revenue curve, if and only if $C < c$, which makes the numerator of the right-hand-side term negative. If Firm 2's marginal revenue shifts up, it chooses to sell more units of the generic good.

If $C = c$, then a change in m does not affect the marginal revenue curve, so q_{g2} is a constant. Here, the monopoly has two targets – the same number as when the monopoly sells to both firms. However, if $C \neq c$, when the upstream monopoly sells to a single firm, it realizes that its choice of m affects the equilibrium choice of Firm 2's generic sales; it then has three targets compared to two when it sells to both firms. These comparative statics results help to explain the relation between parameter values and the manner in which the choice of one vendor or two vendors affects prices.

The ability to obtain explicit formulae for the equilibrium decision rules enables us to compare the new-product and the generic prices in the two regimes (see "Proof of Proposition 3" in Appendix). The following summarizes the comparison.

Proposition 3 *If the upstream monopoly sells to two firms rather than one, the generic price is higher for $c \neq C$ and is unchanged for $c = C$, while the new-product price is higher for $C < c$, equal for $c = C$, and smaller for $C > c$.*

The one- and two-vendor markets lead to different outcomes, if and only if the monopoly is able to use competition between the new product and the generic to exercise leverage. If $c = C$, the demand curves for the new product and the generic are symmetric, eliminating the possibility of leverage and leading to the same equilibrium price regardless of whether the monopoly sells to one firm or to two.

In contrast, if $c \neq C$, the dual-vendor monopoly has a greater incentive than a single-vendor monopoly to choose a markup that shifts sales away from the generic, thus leading to a higher equilibrium price for the generic. Proposition 1 provides the intuition for this result: a monopoly that sells to both downstream firms chooses the markup m to maximize the sum of the firms' profits gross of the markup (downstream revenue minus production costs). In contrast, a monopoly that sells to a single firm uses a markup that is lower than the level that maximizes its vendor's profit, gross of the markup.

The intuition for the effect of a second vendor on the new good price is more complicated. To provide intuition where $c \neq C$, we consider two limiting cases, first where $c > C = 0$ and then where $C > c = 0$. For the first limiting case, where $C = 0$, demand for the new good in eq. [9] does not depend on the generic price, but the demand for the generic increases with the new good price. The single-vendor monopoly has a greater incentive than the dual-vendor monopoly to lower the new good price, as a means of lowering the non-vendor's profit. Consequently, the single-vendor monopoly chooses an m that leads to a lower new good price than does the dual-vendor monopoly. Figure 1 shows this relation for $c > C$.

We use the second limiting case, $c = 0$, to provide intuition for the price comparison when $C > c$. Here, the new good price does not affect demand for the

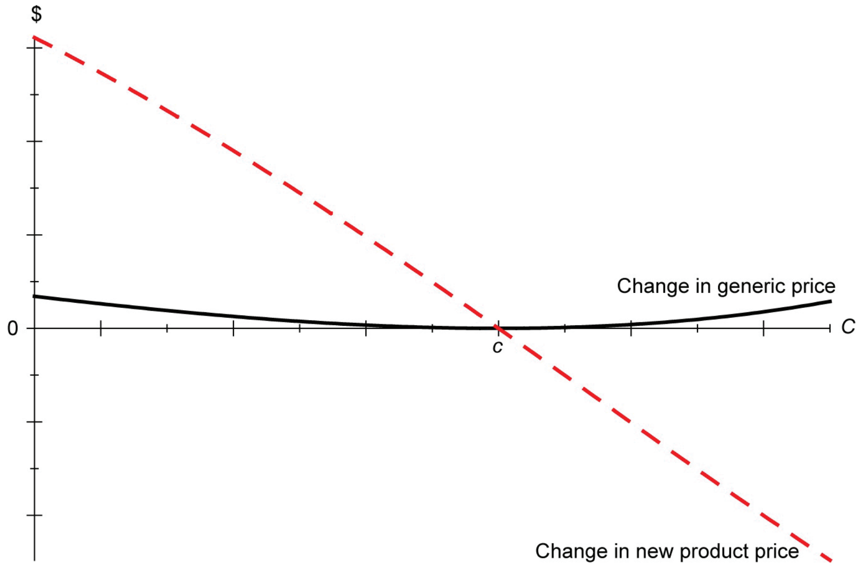

Figure 1: Changes in prices from adding a second vendor

generic, but an increase in the generic price causes the new good demand to increase. Thus, a vendor has an incentive to restrict its generic sales to increase the new good price; a non-vendor lacks such an incentive. When both firms are vendors, they both have an incentive to shift sales from the generic to the new good. A reduction in generic sales raises the new good price, but an increase in new good sales lowers the price. The second effect dominates, so the equilibrium new good price is lower when there are two vendors.

Although we obtain all our main results analytically, we illustrate the more important ones using simulations.[6] Figure 1 shows how the generic and new-product prices change, as a function of C, if the upstream monopoly adds a second vendor (where we fix $c, F > 0$, and the other parameters). When two firms sell the new product, each firm internalizes some portion of the effect of generic sales on the new-product price. As a result, the generic price increases (when two rather than one firm sells the new product) for $C \neq c$. Having two firms sell

6 Given our earlier assumptions, we have three free parameters, $c, C,$ and F, but only c and C have a direct effect on the equilibrium quantities for a given number of downstream vendors. We set $a = 10$ and $b = 10/9$in all our simulations. Given inequalities [10], these parameter choices imply that c and C must each be less than $10/9$. For specificity, we set $c = 0.5$ and $F = 0.2$ and examine how the results vary with C.

the new product increases the price of the new product for $C < c$ and decreases the price for $C > c$. By Proposition 2, if the income elasticity for the new good is greater than that of the generic, then $c > C$, so the prices of both goods rise as the number of downstream vendors increases from one to two.

5 Welfare

By Proposition 1(iii), the downstream firms' profits are the same regardless of whether the monopoly uses one vendor or two. Therefore, the total welfare effect of an MUD requirement depends on only its effects on consumer welfare and monopoly profit. We consider first the monopoly's profit and then consumer welfare.

If $F = 0$, the monopoly strictly prefers to sell to two vendors for $c \neq C$, and it is indifferent between selling to one vendor and two vendors if $c = C$. For $F > 0$, the monopoly prefers to sell to a single vendor, if and only if $|c - C|$ is small. To demonstrate this claim, we examine the two cases, where the upstream monopoly sells to one firm and where it sells to two firms. In both cases, we use the firms' necessary conditions to write their sales as functions of m. For each of the two cases, we substitute these sales rules into the monopoly's profit functions, given by eqs [3] and [6]. Each of these profit functions is quadratic in m. We maximize each function with respect to m to obtain the equilibrium monopoly profits in the two cases, $\Pi^*(1; F)$ and $\Pi^*(2; F)$. Subtracting the former from the latter, we find that

$$\Pi^*(2; F) - \Pi^*(1; F) = \frac{[a(b + C)(c - C)(c - 2b + C)]^2}{9b(Cc - b^2)^2(9b^2 - 2c^2 - 2C^2 - 5Cc)} - F. \qquad [19]$$

The denominator of the right-hand side of this equation is positive by inequalities [10], eq. [19] implies

Proposition 4 *(i) When $F = 0$, the difference in profits is positive for $c \neq C$ and zero for $c = C$. (ii) For $F > 0$, $\Pi^*(2; F) - \Pi^*(1; F) < 0$ for small $|c - C|$. A larger F decreases $\Pi^*(2; F) - \Pi^*(1; F)$ and, therefore, increases the measure of parameter space (c, C, b) for which it is not profitable for the monopoly to sell to a second firm. In this sense, the larger is F, the "more likely" is it that the upstream monopoly prefers to sell to a single firm. All else the same, using two vendors rather than one reduces the monopoly's profit by F.*

As the discussion of Proposition 3 notes, the monopoly is able to leverage the competition between the new and the old goods, only if there is asymmetry in the demand functions for the two goods: $c \neq C$. If $c = C$, the monopoly has no leverage and, therefore, is indifferent between selling to one vendor and two vendors. Proposition 1 provides the intuition for why the monopoly has leverage if $c \neq C$. When selling to both firms, the monopoly sets the markup to maximize their gross profits, but when selling to a single firm it is not in the monopoly's interest to maximize the vendor's gross profits. Therefore, by selling to two firms instead of one and using the transfer fee T, the monopoly is able to directly extract rent from both firms, and that rent is maximized. In contrast, when selling to a single firm, the monopoly extracts rent from a single firm, and, moreover, that rent is not maximized.

We can use Proposition 3 to establish

Proposition 5 *(i) For $C < c$, consumers prefer the monopoly to use a single vendor. (ii) For $C > c$ and $C - c$ sufficiently small, consumer welfare is higher when the monopoly sells to two vendors.*

Part (i) follows because consumers face higher prices for both products when the monopoly uses two vendors rather than a single vendor and $C < c$. For $C > c$, adding a second vendor increases the generic price and decreases the new-product price, so that the effect on consumer welfare of the second vendor is ambiguous in general.

"Consumer welfare" in Appendix provides a formal statement and proof of Proposition 5(ii), but the intuition is clear from Figure 1. The generic price under two vendors minus the generic price with one vendor is minimized at $C = c$, where the price difference is zero. Therefore, in the neighborhood of $C = c$, this price difference is of second order in $C - c$ (i.e. the first-order Taylor expansion, with respect to C, of the price difference, evaluated at $C = c$ is zero).[7] Consequently, the loss in consumer welfare arising from the higher generic price (when the monopoly moves from one vendor to two vendors) is a second-order effect. However, as is evident from Figure 1, adding a second vendor creates a first-order decrease in the new-product price and, therefore, creates a first-order welfare gain for $C > c$. Therefore, the first-order approximation of the change in consumer welfare (evaluated at $C = c$) from the addition of a second vendor is positive.

7 This claim can be verified immediately using the equation for the difference in generic prices, eq. [20] in the Appendix. Similarly, the claim regarding the difference in new-product price can be verified by using eq. [21].

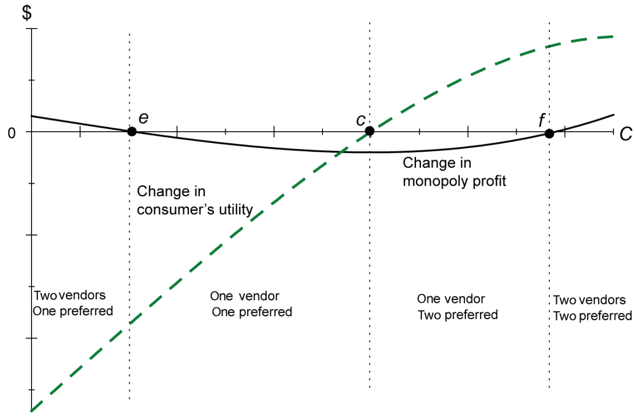

Figure 2: Change in monopoly profit (solid) and consumer's surplus (dashed) from adding a second vendor

Figure 2 illustrates the effect on the monopoly's profit and consumer welfare of adding a second vendor, given that $F > 0$.[8] The dashed curve is the change in a representative consumer's utility from having two rather than one vendor of the new product. Proposition 5 implies that this curve crosses the axis at $C = c$ from below. This curve is independent of F. The solid curve is the change in the monopoly's profit from having two downstream vendors rather than one. It illustrates Proposition 4, which states that the change in monopoly profit from selling to two firms rather than to one is negative in the neighborhood of $C = c$ for $F > 0$, but is positive where $|c - C|$ is large relative to F.

The previous propositions establish that the shapes and relative positions of the two curves in Figure 2 are general. Therefore, this figure can be used to help establish

Proposition 6 *Given parameters values $a, b,\ c$, and for $F > 0$, there is a value $e < c$ such that (i) for $C < e$, the monopoly prefers to sell to two firms, but consumers are better off when the monopoly sells to a single firm; (ii) for $e < C < c$, both consumers and the monopoly are better off when the monopoly sells to a single firm; (iii) for $C > c$ with $C - c$ sufficiently small, consumers are better off when the monopoly sells to two firms, but the monopoly prefers to sell to a single firm. In addition, (iv) for sufficiently small F, there is a value $f > c$ such that for $C > f$ with*

8 We use the same parameters as above to produce this figure. This figure uses the *change in consumer surplus* only to illustrate the change in consumer welfare. Neither our heuristic argument in the text nor the formal statement and proof in "Consumer welfare" in Appendix use consumer surplus to determine the change in consumer welfare.

$C - f$ small, the monopoly prefers to sell to two firms, and consumers also prefer that the monopoly sells to two firms.

Claims (i)–(iii) in Proposition 6 follow immediately from inspection of Figure 2 and from Propositions 4 and 5. To demonstrate (iv), we denote Γ as the closure of the set of $C > c$ at which consumers prefer that the monopoly uses two vendors. From Proposition 5, Γ has positive measure. Because we can make f arbitrarily close to c by choosing $F > 0$ but small, we can insure that $f \in \Gamma$ for small $F > 0$. Such a value of f corresponds to the value shown in Figure 2.

We have seen that adding a second vendor increases the new-product price when $C < c$ and decreases that price when $C > c$. At a given markup, the increased competition arising from the presence of a second vendor tends to decrease the new-product price. However, the monopoly adjusts the markup, when it adds a second vendor.

The following summarizes the relation between the parameter C and the equilibrium markup:

Proposition 7 *(i) If the monopoly sells to a single vendor, it subsidizes its vendor ($m < 0$) if $C < c$ and uses a positive markup if $C > c$. The markup is an increasing function of C. (ii) If the monopoly sells to two vendors, it uses a positive markup, which is a decreasing function of C.*

Figure 3 illustrates this proposition; "Proof of Proposition 7" in Appendix confirms it. The monopoly subsidizes a single vendor ($m < 0$) if $C < c$, where generic sales have a relatively small effect on new-product price. The monopoly uses the subsidy to assist its agent in increasing its share of generic sales. The monopoly then extracts its agent's profits from generic sales using the licensing fee, T. The monopoly uses a positive markup, when it sells to a single firm and $C > c$. The monopoly always uses a positive markup, when it sells to two firms. As C increases, the new-product price becomes more sensitive to generic sales; the equilibrium markup rises with C if the monopoly sells to a single firm, and it decreases with C if it sells to two firms. Figure 3, by illustrating how m varies with respect to C for one or two vendors, helps explain why selling to a second vendor increases the new-product price when $C < c$ and decreases that price for $C > c$, as Figure 1 shows. For example, when $C < c$, m is negative with one vendor and positive with two vendors, so adding a second vendor raises the price of the new good.

We now consider the effect of monopoly entry on duopoly profits. By Proposition 1(iii), the downstream firms have the same level of profits whether the upstream monopoly sells to one or to both firms. We calculate this profit

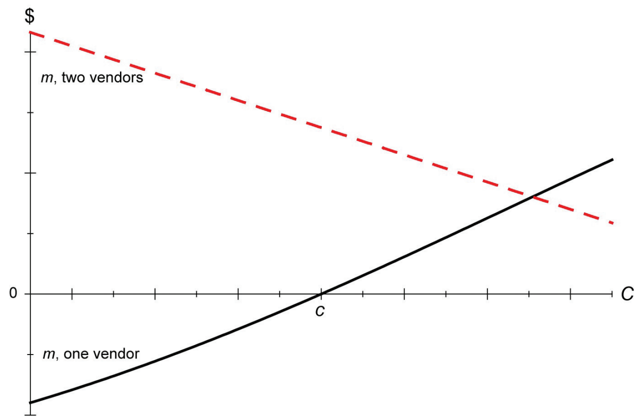

Figure 3: The upstream monopoly's markup with one or two vendors.

level and subtract the equilibrium duopoly profits prior to entry of the upstream monopoly, π^e. This difference is

$$\left[\frac{1}{36}a^2(b-C)\frac{4b^2-cb-3Cc+C(b-C)}{(Cc-b^2)^2 b}\right](C-c).$$

The term in square brackets is always positive, so the sign of the expression equals the sign of $C-c$, which implies

Proposition 8 *For $C<c$, the monopoly extracts some of the pre-entry oligopoly rent, in addition to all of the extra rent that arises from the new product. For $C>c$, the downstream firms obtain some of this additional rent.*

Figure 4 illustrates the effect of monopoly entry on duopoly profits.

That monopoly entry reduces duopoly profits is consistent with the comparative statics of the equilibrium markup. We noted that the monopoly uses a subsidy, when it sells to a single vendor given that $C<c$. This subsidy causes the non-vendor, Firm 2, to face strong competition, and it erodes that firm's profits. Our assumption about the first-stage equilibrium means that the monopoly uses the transfer to drive profits of its vendor(s) to the level received by a non-vendor in the one-vendor regime.[9]

9 The working paper on which this article is based shows that most of our qualitative results, with the exception of Proposition 8, continue to hold if we alter the original game by constraining m so that equilibrium duopoly profits do not fall below π^e.

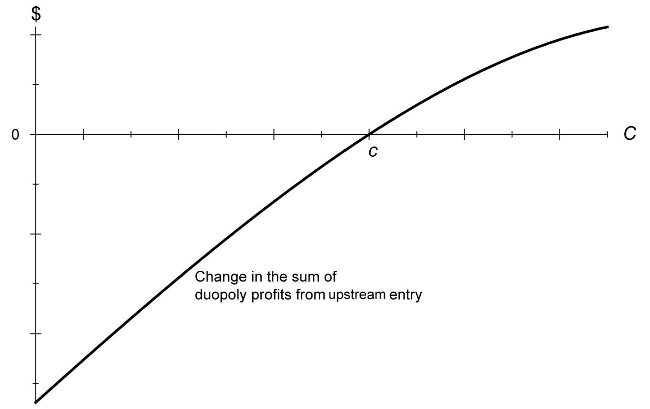

Figure 4: Change in the sum of the downstream profits from the entry of the upstream monopoly

We also have

Proposition 9 *For $C < c$, entry by the new-product monopoly increases consumer welfare, regardless of whether the monopoly sells to one firm or two.*

This claim follows immediately from Lemma 2 in "Consumer welfare" in Appendix, because $q_n = 0$ before the monopoly enters. Simulations indicate that even for $C > c$, consumer surplus is higher when the upstream monopoly enters the market. That is, consumers benefit from the new product.

6 A more general linear demand

Our assumption that the own-quantity effects in the two demand functions are equal amounts to a choice of units, but the assumption that the inverse demand function intercepts are equal is a parameter restriction. Here, we consider the effects of allowing the demand intercept of the new product (net of production costs), A, to differ from the demand intercept of the generic model (net of production costs), a, so that $A = a + \theta$. For example, if the production costs of the two products were the same, $\theta > 0$ means that consumers have a higher reservation price for the new product. "A more general linear demand" in Appendix contains the details.

The requirement that $A > 0$ bounds θ from below by $-a$. The empirically relevant case is where $\theta > 0$, so the reservation price minus the unit production cost is greater for the new product than for the generic. We emphasize that case here, but the "A more general linear demand" in Appendix provides the formulae

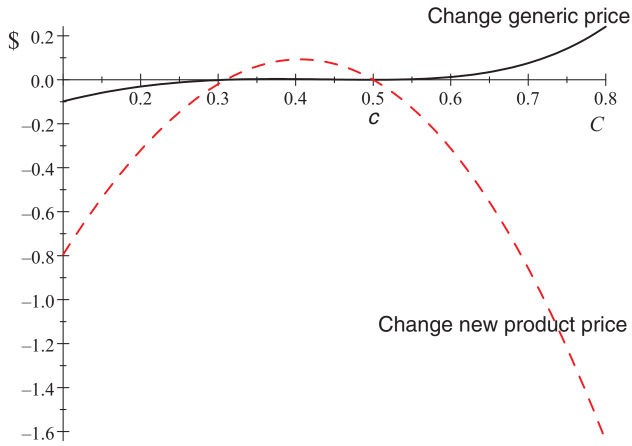

Figure 5: Change in prices if the monopoly sells to two rather than to one firm

for general θ. Proposition 4 does not depend on the sign of θ. The monopoly prefers to sell to two vendors if F is small and prefers to sell to a single vendor for large F.

Proposition 3 continues to hold for "moderate" θ, but if θ exceeds a critical value and C is sufficiently small, both the generic price and the new price are lower with two firms. ("A more general linear demand" in Appendix gives the formula for the critical value of θ.) Figure 5 illustrates this possibility with $\theta = 95$ and the parameter values used in the previous figures. Thus, Propositions 5 and 6 can be overturned, if θ is sufficiently large. We have

Proposition 10 *If the reservation price, net of production cost, of the new product is much greater than that of the generic (θ is large) and the income elasticity of the new product is sufficiently greater than that of the generic (C is small relative to c), then consumers prefer the monopoly to use two vendors. If F is sufficiently large, the monopoly prefers to use one vendor. In this circumstance, consumers benefit from MUD.*

Depending on the magnitude of F and other parameters, when the interests of consumers and the monopoly clash, an MUD rule might either increase or decrease total welfare. For example, F might be such that the monopoly's profit is only slightly greater with a single distributor, but consumers' welfare is much higher with two vendors.

When the monopoly sells to two vendors, the markup is positive and decreasing in C, as Proposition 7(ii) states for $\theta = 0$. In addition, the markup increases with θ, as we would expect. However, if the monopoly sells to a single firm and θ exceeds the critical value mentioned above, the markup is nonmonotonic in C. It is positive for large and for small values of C and negative for values of C close to but less than c.

7 Conclusions

We consider an industry where upstream firms sell to final consumers using downstream firms. Upstream, a competitive industry produces a generic product, and a monopoly produces a new good (such as Apple's iPhone). The upstream monopoly may use one or more downstream vendors. Our new results are based on a model in which the downstream market is oligopolistic with quantity-setting firms. The firms engage in a two-stage game. In the first stage, the upstream firm offers downstream firms contingent contracts and the downstream firms decide whether to accept those contracts.

An MUD requirement may or may not benefit consumers. If the new and the generic products are not substitutes, the MUD restriction does not help consumers and harms the upstream monopoly so that it lowers the sum of consumer and producer welfares.

If the products are imperfect substitutes and the reservation price net of production cost of the new and generic products are the same or close to each other, and there is a downstream duopoly, there are four possible outcomes. The monopoly may want one vendor or two vendors, and consumers might prefer either the monopoly's choice or the alternative. If the new product has a higher income elasticity of demand than the generic, then consumers always prefer a single vendor in our almost symmetric linear model. Thus, this model shows that although there are cases where consumers might benefit from requiring the upstream firm to use a second vendor, those cases are unlikely because they require that the new product has a lower income elasticity of demand, compared with the generic.

However, if the reservation price (net of production costs) of the new product is much greater than that of the generic and if the fixed cost of using a second vendor is sufficiently high, consumers might prefer the monopoly to use two vendors, while the monopoly prefers to use a single vendor. This possibility occurs in the empirically relevant case, where the income elasticity of the new product exceeds that of the generic. This combination of parameter values provides an example where the MUD benefits consumers, and possibly society. Of course, the MUD may also be desirable for reasons that we have not considered, such as if having multiple vendors induces desirable differentiation and innovation.

Appendix

Proof of Proposition 3

We consider the two cases, where the monopoly sells to a single vendor and two vendors. In both cases, we substitute the equilibrium markup, obtained from maximizing the monopoly's profits, into the firms' equilibrium decision rules. We then substitute these rules into the inverse demand functions to obtain the equilibrium generic and the new-product prices when the monopoly sells to one or two firms. These prices are

$$\text{generic, one firm}: \tau = \frac{1}{6}\frac{2ab^2 - cab + Cab - cCa - aC^2}{-Cc + b^2},$$

$$\text{new product, one firm}: \upsilon = -\frac{1}{6}\frac{-3ab^3 + b^2Ca - abC^2 + 4abCc - 2cC^2a + aC^3}{b(-Cc + b^2)},$$

$$\text{generic, two firms}: \delta = \frac{3}{2}\frac{2ab^2 - cab + Cab - cCa - aC^2}{9b^2 - 2c^2 - 2C^2 - 5Cc},$$

$$\text{new product, two firms}:$$
$$\zeta = \frac{1}{2}\frac{9ab^3 - 4abc^2 - abC^2 - 4abCc - 7b^2Ca + 4b^2ca + 2cC^2a + aC^3}{b(9b^2 - 2c^2 - 2C^2 - 5Cc)}.$$

For both generic and new-product prices, we subtract the equilibrium price with one firm from the equilibrium price with two firms:

$$\delta - \tau = \frac{1}{3}a(c - C)^2(b + C)\frac{2b - c - C}{(-cC + b^2)(-5cC + 9b^2 - 2c^2 - 2C^2)} \geq 0, \qquad [20]$$

$$\zeta - \upsilon = \frac{1}{3}a(c - C)(b + C)(2b - c - C)\frac{3b^2 - 2cC - C^2}{b(-cC + b^2)(-5cC + 9b^2 - 2c^2 - 2C^2)}. \qquad [21]$$

Inequalities [10] imply that the sign of $\zeta - \upsilon$ is the same as the sign of $c - C$.

Proof of Proposition 7

We first state a lemma that is also used in a proof in "Consumer welfare" in Appendix.

Lemma 1 *For all values of m, regardless of whether the monopoly uses one or two vendors, sales in the generic market and the new market satisfy the relation*:

$$\mathbf{q}_g = \frac{2a}{3b} - \frac{2c + C}{3b}\mathbf{q}_n. \tag{22}$$

Proof. When the upstream monopoly sells to both firms, we obtain the equilibrium conditions for aggregate sales in the two markets in a symmetric equilibrium, as functions of m using the linear model. We invert the formula for sales of the new product ($j = n$) to obtain an expression for m as a function of aggregate sales, $\mathbf{q}_n$:

$$m = -\frac{1}{6}\frac{9b^2 - 2c^2 - 2C^2 - 5Cc}{b}\mathbf{q}_n - \frac{1}{3}\frac{2Ca + ca - 3ab}{b}. \tag{23}$$

We, then, substitute this equation into the equilibrium condition for aggregate generic sales, $\mathbf{q}_g$, as a function of m to obtain aggregate generic sales as a linear function of aggregate sales of the new product. The resulting relation is eq. [22]. Given this constraint, a choice of, for example, $\mathbf{q}_n$ determines the value of $\mathbf{q}_g$ and also m. The values of these variables determine the monopoly's profits.

By its choice of m, the upstream monopoly selects a point on this line. The monopoly solves a maximization problem subject to two constraints, eqs [22] and [23].

When the monopoly sells to a single firm, its maximization is subject to the three equilibrium conditions: the two first-order conditions for generic sales and Firm 1's first-order condition for new-product sales, which can be written as functions of m. We invert the equation for Firm 1's new-product sales to write m as a function of $q_{n1} = \mathbf{q}_n$. The result is

$$m = -\frac{1}{3}\frac{6b^2 - 4Cc - C^2 - c^2}{b}\mathbf{q}_n - \frac{1}{3}\frac{2Ca + ca - 3ab}{b}. \tag{24}$$

We use this equation to eliminate m from the remaining two equations (generic sales of the two firms) to obtain expressions for q_{g1} and q_{g2} as functions of $\mathbf{q}_n$. By adding the resulting two equations, we obtain the expression for aggregate generic sales as a function of aggregate new-product sales, again leading to eq. [22]. ■

The equilibrium level of new-product sales when the upstream monopoly sells to a single firm, conditional on m, is

$$\frac{3ab - ca - 3mb - 2Ca}{6b^2 - 4Cc - C^2 - c^2},$$

and the monopoly's optimal level of m is

$$m(1) = \frac{1}{6}a(b+C)(C-c)\frac{2b-C-c}{b(b^2-Cc)}. \tag{25}$$

Conditional on the optimal level of m, the equilibrium level of new-product sales with one vendor is

$$\mathbf{q}_n(1) \equiv \frac{1}{2}\frac{ab-Ca}{b^2-cC}.$$

The equilibrium level of new-product sales when the monopoly sells to two firms, conditional on m, is

$$-2\left(\frac{2Ca+ca-ch-3ab-2Ch+3mb}{9bb-2c^2-2C^2-5Cc}\right),$$

and the optimal level of m is

$$m(2) = \frac{1}{4}\frac{a(b-C)}{b}. \tag{26}$$

Eq. [25] shows that when the monopoly sells to a single firm, it sets $m<0$ (a unit subsidy) if $C<c$ and $m>0$ (a positive markup) if $C>c$. Eq. [26] shows that the markup is always positive, when the monopoly sells to two firms. In view of these two results, $m(1)-m(2)<0$ for $C<c$. To show that the markup with a single firm is larger than the markup with two firms when C is close to its upper bound, b, we need to compare the markup for large C. We have

$$m(1)-m(2) = \frac{1}{6}a(b+C)(C-c)\frac{2b-C-c}{b(b^2-Cc)} - \frac{1}{4}\frac{a(b-C)}{b}$$
$$= \frac{1}{12}\frac{a}{b(Cc-b^2)}\left[2C^3-2C^2b+3C^2c-7Cb^2+Cbc-2Cc^2+3b^3+4b^2c-2bc^2\right].$$

Evaluating the term in square brackets at $C=b$ (the supremum of C), we have $(2C^3-2C^2b+3C^2c-7Cb^2+Cbc-2Cc^2+3b^3+4b^2c-2bc^2) = -4b(b-c)^2<0$.

Because $Cc-b^2<0$, we conclude that for C close to (but smaller than) b, $m(1)-m(2)>0$.

Consumer welfare

Proposition 11 *If $c>C$, then a representative consumer has higher utility when the monopoly sells to a single downstream firm. If $c<C$ and $C-c$ is "sufficiently small" (in a sense made precise in the proof), then consumers have higher welfare when the monopoly sells to two downstream firms. The consumer is indifferent between the two alternatives if $c=C$.*

The proof of this proposition relies on Lemma 1 and the following lemma that collects several properties of the indirect utility function that stem from the linear relationship described by Lemma 1. Let $V(p_g, p_n, y)$ be the indirect utility function for a representative agent, y be income, and λ (a function of prices and income) be the marginal utility of income.

Lemma 2 *(i) Holding y fixed, as aggregate sales of* $\mathbf{q}_n$ *increases and* $\mathbf{q}_g$ *adjusts as specified by eq. [22], the change in utility is*

$$\frac{1}{\lambda}\frac{dV}{dq_{n|\text{equation}}} = \frac{1}{9}\left(\frac{9b^2 - 5Cc - 2C^2 - 2c^2}{b}\mathbf{q}_n + 2a\frac{c - C}{b}\right). \qquad [27]$$

(ii) For $c \geq C$, $dV/dq_n > 0$ *at every point on the line given by eq. [22], so utility reaches its maximum at the intercept of eq. (22)*

$$(\mathbf{q}_g, \mathbf{q}_n) = \left(0, \frac{2a}{2c + C}\right). \qquad [28]$$

(iii) For $c < C$, $dV/d\mathbf{q}_n < 0$ *for small* $\mathbf{q}_n$, *and V reaches a minimum at an interior point on the line where*

$$\hat{\mathbf{q}}_n \equiv \frac{2a(C - c)}{9b^2 - 5Cc - 2C^2 - 2c^2}. \qquad [29]$$

The maximum of V might be at either intercept of eq. [22].

Proof. (Lemma 2) (i) Totally differentiating the indirect utility function, holding y constant, dividing the result by λ, and using Roy's identity implies

$$\frac{dV}{\lambda} = \frac{1}{\lambda}\frac{\partial V}{\partial p_n}dp_n + \frac{1}{\lambda}\frac{\partial V}{\partial p_g}dp_g$$

$$= -\left[\mathbf{q}_n dp_n + \mathbf{q}_g dp_g\right]$$

$$= \mathbf{q}_n\left(bd\mathbf{q}_n + Cd\mathbf{q}_g\right) + \mathbf{q}_g\left(bd\mathbf{q}_g + cd\mathbf{q}_n\right),$$

where the last line uses the total derivatives of the inverse demand equations [8]. Divide both sides of the final equation by $d\mathbf{q}_n$ to obtain

$$\frac{1}{\lambda}\frac{dV}{d\mathbf{q}_n} = \mathbf{q}_n\left(b + C\frac{d\mathbf{q}_g}{d\mathbf{q}_n}\right) + \mathbf{q}_g\left(b\frac{d\mathbf{q}_g}{d\mathbf{q}_n} + c\right).$$

Simplify this expression using eq. [22] to eliminate $\mathbf{q}_g$ and noting that along the line in eq. [22], $\frac{d\mathbf{q}_g}{d\mathbf{q}_n} = -\frac{2c + C}{3b}$.

(ii) Because $\lambda > 0$, the sign of the right-hand side of eq. [27] is the sign of the change in indirect utility due to an increase in $\mathbf{q}_n$, evaluated on the line given by eq. [22]. By inequalities [10], the coefficient of $\mathbf{q}_n$ on the right-hand side of eq. [27] is positive, so for $c \geq C$, V is maximized at the corner given by eq. [28].

(iii) For $c < C$, V is decreasing on this line in the neighborhood of the corner $(\mathbf{q}_g, \mathbf{q}_n) = \left(\frac{2a}{3b}, 0\right)$. Setting $dV = 0$ implies eq. [29]. Finally, we need to show that this value of q_n is less than the value at the intercept, $\frac{2a}{2c + C}$. Subtracting these two values, we have

$$\frac{2a(C - c)}{9b^2 - 5Cc - 2C^2 - 2c^2} - \frac{2a}{2c + C} = -6a\frac{3b^2 - 2Cc - C^2}{(9b^2 - 5Cc - 2C^2 - 2c^2)(2c + C)} < 0$$

where the inequality follows from inequalities [10]. ■

We now provide the proof of Proposition 11.

Proof. Conditional on the optimal level of m (see "Proof of Proposition 7" in Appendix), the equilibrium level of new-product sales with two vendors is

$$\mathbf{q}_n(2) \equiv \frac{1}{2}a\frac{9b - 5C - 4c}{9b^2 - 2c^2 - 2C^2 - 5Cc}.$$

The difference between new-product sales in the two cases is

$$\mathbf{q}_n(1) - \mathbf{q}_n(2) = a(b + C)(c - C)\frac{2b - c - C}{(b^2 - Cc)(9b^2 - 2c^2 - 2C^2 - 5Cc)}.$$

Inequalities [10] imply that the sign of $\mathbf{q}_n(1) - \mathbf{q}_n(2)$ is the same as the sign of $c - C$.

If $c > C$ so that $\mathbf{q}_n(1) > \mathbf{q}_n(2)$, consumer welfare is higher when the monopoly sells to a single firm, because utility is increasing in $\mathbf{q}_n$ by Lemma 2(ii).

If $C > c$ so that $\mathbf{q}_n(1) < \mathbf{q}_n(2)$, by Lemma 2(iii), V is increasing in $\mathbf{q}_n$ for $\mathbf{q}_n > \hat{\mathbf{q}}_n$. Therefore, for $C > c$, a sufficient condition for consumers to be better off with two downstream firms selling the new product is $\mathbf{q}_n(1) - \hat{\mathbf{q}}_n > 0$. Using the definition of $\hat{\mathbf{q}}_n$ in eq. [29], we have

$$\mathbf{q}_n(1) - \hat{\mathbf{q}}_n = \frac{1}{2}a\frac{\gamma}{(Cc - b^2)(-9b^2 + 2c^2 + 2C^2 + 5Cc)}, \qquad [30]$$

where

$$\gamma \equiv 9b^3 + (-13C + 4c)b^2 + \left(-2c^2 - 2C^2 - 5Cc\right)b - 2c^2C + 2C^3 + 9C^2c. \qquad [31]$$

Because the denominator in the last line of eq. [30] is positive, a necessary and sufficient condition for $\mathbf{q}_n(1) - \hat{\mathbf{q}}_n > 0$ is $\gamma > 0$. Define $\varepsilon \equiv C - c > 0$ and write γ in terms of ε:

$$\gamma = 2\varepsilon^3 + (-2b + 15c)\varepsilon^2 + \left(-9bc - 13b^2 + 22c^2\right)\varepsilon + 9(b + c)(-c + b)^2.$$

This expression shows that for small ε, $\gamma > 0$. A sufficient condition for $\gamma > 0$ is that ε is smaller than the smallest positive root of $\gamma = 0$.

If $c = C$, then $\mathbf{q}_n(1) - \mathbf{q}_n(2)$, so sales of both the new and the generic products are the same regardless of whether the monopoly sells to one firm or two firms. Consequently, consumer welfare is also the same in the two cases.

A more general linear demand

The monopoly still prefers to sell to two firms, if and only if the cost F is sufficiently small. Its increase in profits from selling to two rather than to one firm (exclusive of the additional cost F) is

$$\frac{1}{9}(c - C)^2 \frac{\left(-2ab^2 + aC^2 + Abc - AbC + acC\right)^2}{b(9b^2 - 2c^2 - 2C^2 - 5cC)\left(-cC + b^2\right)^2} > 0,$$

which is independent of θ.

Calculations parallel to those described in "Proof of Proposition 3" Appendix show that the increase in the generic price if Apple sells to two rather than to one firm is

$$\delta - \tau = \frac{1}{3} \frac{(c - C)^2}{(b^2 - cC)(9b^2 - 5cC - 2c^2 - 2C^2)} (a(C + b)(2b - C - c) + b\theta(C - c)).$$

The equation simplifies to eq. [20] for $\theta = 0$. A sufficient condition for the generic price to be higher when the monopoly sells to two rather than to one firm is $b\theta(C - c) > 0$. For $b\theta(C - c) < 0$ and sufficiently large in absolute value, the generic price is lower when the monopoly sells to two firms. For $C \neq c$, define

$$\bar{\theta} = \frac{a(C + b)(2b - C - c)}{b(c - C)},$$

which has the same sign as $c - C$.

The necessary and sufficient condition for $\delta - \tau > 0$ is

$$\theta \begin{Bmatrix} > \bar{\theta}(< 0) \\ < \bar{\theta}(> 0) \end{Bmatrix} \quad \text{for} \begin{Bmatrix} C - c > 0 \\ C - c < 0 \end{Bmatrix}. \qquad [32]$$

The empirically relevant case is where both $\theta > 0$ (the reservation price for the new product, net of production costs, exceeds the reservation price for the generic), and where $C < c$ (the income elasticity of the new product exceeds that of the generic). This situation corresponds to the second line of inequality [32]; here, the generic price is *lower* when the monopoly sells to two firms rather than to one firm, if $\theta > \bar{\theta}$.

The difference between the new-product price when the monopoly sells to two firms rather than to a single firm is

$$\zeta - \upsilon = \frac{1}{3}\frac{(3b^2 - 2Cc - C^2)(c - C)}{b(b^2 - Cc)(9b^2 - 5Cc - 2C^2 - 2c^2)}(a(C + b)(2b - C - c) + (C - c)b\theta),$$

which simplifies to eq. [21] for $\theta = 0$. The necessary and sufficient condition for $\zeta - \upsilon > 0$ is

$$\theta \begin{Bmatrix} < \bar{\theta}(< 0) \\ < \bar{\theta}(> 0) \end{Bmatrix} \quad \text{for} \begin{Bmatrix} C - c > 0 \\ C - c < 0 \end{Bmatrix} \qquad [33]$$

As noted above, the empirically relevant setting is $C < c$ and $\theta > 0$, corresponding to the second line of inequality [33]. In this case, the new-product price is higher when the monopoly sells to two firms rather than to one firm, if and only if θ is not greater than $\bar{\theta}$.

Consequently, if $C < c$ and $\theta > \bar{\theta}(> 0)$, both the new and generic prices are lower when the monopoly sells to two vendors.

The markup when the monopoly sells to a single firm is

$$m = \frac{(C - c)}{6b(b^2 - Cc)}(a(C + b)(2b - C - c) + b(C - c)\theta).$$

The necessary and sufficient condition for this markup to be positive is

$$\theta \begin{Bmatrix} > \bar{\theta}(< 0) \\ > \bar{\theta}(> 0) \end{Bmatrix} \quad \text{for} \begin{Bmatrix} C - c > 0 \\ C - c < 0 \end{Bmatrix}.$$

If Apple sells to both firms, its markup is

$$m = \frac{1}{4b}(b\theta + a(b - C)),$$

which is positive provided that $\theta > \frac{a}{b}(C - b)$, a negative number.

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