Equilibrium Vertical Foreclosure with Investment

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Abstract

One of the most enduring controversies in antitrust concerns the potential foreclosure effects of vertical integration. In a recent paper, Ordover, Saloner and Salop (1990) construct a model of vertical integration in which vertical foreclosure emerges as the equilibrium outcome. However, as is well-known, OSS's result breaks down if the vertically integrated firm cannot make the price commitment. In this paper, we reexamine the foreclosure theory of vertical integration by extending OSS's model to include upstream market power and investments. Cost-reducing investments introduce a channel through which the integrated firm can credibly commit itself to a higher input price at which it is willing to supply the unintegrated downstream firm. We show that a profitable but anticompetitive (both for consumer welfare and for aggregate efficiency) vertical integration does arise in equilibrium without triggering counter-merger by the unintegrated firms or causing hold-out problems between the input suppliers. In contrast to OSS's model, where vertical integration (even with commitment) is not effective under Cournot downstream competition, vertical integration in our model can be both effective and anticompetitive even under Cournot downstream competition.

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1. Introduction

One of the most enduring controversies in antitrust concerns the potential foreclosure effects of vertical integration. The harsh treatment of vertical mergers by the enforcement agencies and courts in the 1960s, epitomized by the *Brown Shoe* case (1962) and the 1968 Merger Guidelines[1], was based on a poorly conceived classical vertical foreclosure doctrine. In the classical theory, the integrated firm withdraws from the input market, thereby allowing the unintegrated input suppliers to raise prices to unintegrated output producers.

This classical vertical foreclosure theory was heavily criticized by Chicago school commentators for the lack of firm theoretical foundations (e.g., Bork, 1978). The Chicago school questioned the rationality of the merged firm's decision to withdraw from the input market. Furthermore, even if the merged firm does refuse to supply the competing output producers, the foreclosed output producers can neutralize the negative effects of vertical integration of competitors by counter-merging with the remaining upstream input suppliers. Finally, even if counter-merger does not take place, there may be hold-out problems among the input suppliers in carrying out the initial merger with an output producer. These potential hold-out problems arise because the initial merger increases the remaining input suppliers' profits by allowing them to raise prices to the remaining output producers.[2] In sum, the Chicago school argued that vertical integration in itself cannot possibly result in vertical foreclosure.

Over the last two decades, the Chicago school has exerted an enormous influence both on academic economists and on antitrust practitioners. For example, the 1984 Department of Justice Merger Guidelines and the 1985 Vertical Restraints Guide take a much more favorable view on the competitive effects of vertical mergers and restraints than the 1968 Guidelines did.

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[1] In the *Brown Shoe Co. v. United States, 370 US 294* (1962) case, the U.S. Supreme Court indicated that a combined share of 5 percent by the merging companies was excessive in light of the increasing concentration in the industry (Carlton and Perloff, 1994, p. 819). Under the 1968 Merger Guidelines, the Justice Department would challenge a vertical merger between a supplier with at least 10% of sales and a purchaser with at least 6% (Reiffen and Vita, 1995).

[2] See Ordover, Saloner and Salop (1990) for a detailed discussion of the Chicago school's criticisms of the classical vertical foreclosure theory.

The criticisms of the Chicago school has also led to new theoretical attempts to put the vertical foreclosure doctrine on solid foundations.[3] For example, Ordover, Saloner and Salop (OSS) (1990) construct an ingenious model of vertical integration in which vertical foreclosure emerges as the equilibrium outcome. OSS show that, if the vertically integrated firm can commit itself to selling its input to the unintegrated downstream firm at or above a specified price, vertical integration can raise the combined profits of integrating firms by allowing the unintegrated upstream firm to charge a higher price to the unintegrated downstream firm. This profitable vertical integration is anticompetitive, because it forecloses the unintegrated firm and raises output price.

However, as is well-known, OSS's result breaks down if the vertically integrated firm cannot make the price commitment (Hart and Tirole, 1990; Reiffen, 1992). The integrated firm has a strong incentive to renege on its price commitment and undercut the unintegrated upstream firm's price by a small amount, thus stealing the competing upstream firm's profit without changing the equilibrium outcome of the downstream market. As a result, the only *credible* price the integrated firm can commit to is its marginal cost, rendering vertical integration ineffective.[4]

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[3] A brief review of this new literature follows at the end of this section.

[4] In their reply to Reiffen's (1992) comments, OSS (1992) argue that vertical integration changes the integrated firm's incentives to engage in price-cutting in the input market. They model the input pricing game as a descending-bid auction in which upstream firms bid to supply the downstream firms. They show that the integrated firm drops out at a price strictly above the input cost in the bidding game to supply the unintegrated downstream firm, thereby allowing the unintegrated upstream firm to raise its price above cost. (In contrast, in the absence of vertical integration, both upstream firms stay in the auction until the price reaches their common cost.) We find OSS's logic unsatisfactory, because it requires that the unintegrated downstream firm be restricted in its choice of the precise form of the auction in which it selects its input supplier. In the absence of vertical integration, the standard auctions (such as the descending-bid auction and the first-price sealed-bid auction) yield the same outcome (input price equals cost), and thus a downstream firm is indifferent between them. However, once vertical integration takes place, the unintegrated downstream firm strictly prefers the first-price sealed-bid auction (with equilibrium input price equal to cost) to the descending-bid auction (with price above cost). Hence, the unintegrated downstream firm can negate the competitive effects of vertical integration simply by switching to the first-price sealed-bid auction. Just as the Chicago school questions the rationality of the integrated firm's refusal to supply the unintegrated rivals, one can question the rationality of the unintegrated downstream firm's rationality to stick to the descending-bid auction in OSS's model. In other words, the integrated firm needs to *commit* that it will not participate in a first-price sealed-bid auction. Again, in the absence of the commitment by the integrated firm, vertical integration is ineffective.

Partly because of this weakness of the OSS's model, some antitrust practitioners still express doubts that vertical integration can result in vertical foreclosure (Reiffen and Vita, 1995).

In this paper, we reexamine the foreclosure theory of vertical integration by extending OSS's model in two directions. First, we assume that upstream firms possess *market power* in a non-integrated industry structure (i.e., an industry structure in which no firms are integrated). We model the upstream market power in the following simple way. A downstream firm needs to make *input-specific* investments in order to use a particular upstream firm's input. We examine a situation in which the downstream firms have already made relationship-specific investments. Because of these relationship-specific investments, a downstream firm needs to incur *switching costs* if it wants to use the other upstream firm's input (for example, retooling costs of machines for using different inputs). Due to the switching cost, upstream firms enjoy some ex-post market power to raise prices over costs. Thus, in our model, vertical integration eliminates a double markup of profits on the part of integrating firms. Our assumption enriches OSS's model by allowing the vertically integrated firm to eliminate socially inefficient double marginalization.

Second, we introduce cost-reducing (or, equivalently, quality-enhancing) investments by the upstream firms. Upstream investments are assumed to be *industry-specific* (rather than relationship-specific) so that they lower the cost of supplying *both* downstream firms (and not just the current buyer). Our key idea in this paper is that cost-reducing upstream investments introduce a channel through which the integrated firm can credibly commit itself to a higher input price at which it is willing to supply the unintegrated downstream firm. We show that, in the presence of upstream investments, profitable but anticompetitive vertical integration arises in equilibrium.

In general, vertical integration has ambiguous effects on investments by the merging upstream firm. First, the elimination of the double markup increases the output of the merging downstream firm. Since the *direct* benefit of cost-reducing investment is proportional to the output produced, the direct effect of vertical integration is to *raise* the investment incentives of

the merging firm. If the upstream markup (which equals the switching cost) is small, however, this positive direct effect is small.

Second, vertical integration has a more subtle strategic effect. Due to the lack of any commitment power on the part of the merging firms, cost-reducing investments by the merged firm lower the price at which it is willing to supply the unintegrated downstream firm. As a result, the equilibrium input price of the unintegrated downstream firm decreases, thereby reducing the merged firm's output. An analogous effect arises for an unintegrated upstream firm under a non-integrated industry structure, but with one key difference. In an unintegrated industry structure, an upstream firm's equilibrium profit margin is equal to the supplier switching cost incurred by a downstream firm. Then, for a small switching cost, the profit margin of an unintegrated firm in the non-integrated industry structure is smaller than the profit margin of the integrated firm in a partially-integrated industry structure. Since the loss from the reduction in output is proportional to the profit margin, vertical integration has a *negative* strategic effect on investment incentives of the merging upstream firm.

We show that for a small upstream markup (i.e., supplier switching cost), the negative strategic effect dominates the positive direct effect so that vertical integration reduces investments of the integrating upstream firm. Lower investments raise the integrating upstream firm's production costs. The price at which the integrating upstream firm is willing to supply the unintegrated downstream firm rises in tandem, thereby enabling the unintegrated upstream firm to raise its input price to the unintegrated downstream firm: *Foreclosure of the unintegrated downstream firm arises in equilibrium despite the absence of any price commitment power on the part of the merging firms.*

Due to the elimination of the double markup, the effect of vertical integration on consumers is in general ambiguous. However, for small upstream markups, we show that both downstream prices rise, making consumers uniformly worse off and reducing overall social welfare. Hence, a privately profitable but socially anticompetitive vertical integration can indeed arise in equilibrium.

4

As is emphasized by the Chicago school (and examined in OSS's model), a complete theory of vertical integration should allow for a counter-merger by the unintegrated firms and also address potential hold-out problems among the upstream firms. We show that counter-integration by the unintegrated firms does not occur in our model for small double markups, because it reduces their joint profits. When the counter-merger takes place, the input cost of the newly-integrated downstream firm is equal to its upstream division's per-unit production cost. Hence, counter-merger destroys the linkage between the already-integrated upstream firm's investments and the newly-integrated downstream firm's input costs. As a result, the already-integrated upstream firm increases its investments, which results in lower input costs for its downstream division. The increased competition in the downstream product market reduces the counter-integrating firms' joint profits below their unintegrated level.

Finally, we address the potential hold-out problems among the upstream firms. Hold-out problems may arise, because the vertical integration by a subset of firms typically raises the remaining upstream firm's profits. Since the examination of the hold-out problems requires the comparison of the integrated firms' joint profits and unintegrated firms' joint profits in a partially integrated industry structure, we examine a simple Hotelling model in order to obtain explicit solutions for firm profits. We show that a profitable but anticompetitive vertical integration can arise in equilibrium without causing hold-out problems.

An important difference between our model and OSS's model is that our results hold both under Cournot downstream competition and Bertrand downstream competition. In contrast, vertical integration (with commitment) is ineffective in OSS's model because the remaining firms always find it profitable to counter-merge.

Before introducing our model, we briefly and selectively review the related literature in order to put our contribution into context. In addition to OSS's model, which is the starting point of our work, several authors have recently proposed models of anticompetitive vertical integration. Salinger (1988) examines the competitive effects of a vertical merger by Cournot oligopolists. As in our model, upstream firms under non-integration earn positive profit margins

5

in Salinger's model. Hence, the elimination of double markups by the integrating firms play an important role in both models. However, Salinger does not examine the possibility of a counter-merger of unintegrated firms or hold-out problems among upstream firms.

Hart and Tirole (1990) allow for more complicated input supply contracts (in particular, two-part tariff contracts) than simple linear prices considered in our model. The unrestricted use of two-part tariff contracts has an important implication in Hart and Tirole's model: the low-cost upstream firm supplies both downstream firms at marginal production costs (plus fixed fees) in the non-integrated industry structure.[5] Hence, vertical integration does not eliminate double marginalization of prices. In our model, upstream firms charge above-cost input prices under non-integration so that the elimination of the upstream margin is an important consequence of vertical integration. Since the elimination of double markups tends to be procompetitive, our model allows for a richer analysis of the competitive effects of vertical integration than in Hart and Tirole's model (or in OSS's model), where vertical integration can be only anticompetitive.[6]

Bolton and Whinston (1993) focus on the supply assurance motives of vertical integration. Bolton and Whinston show that vertical integration results in the foreclosure of the unintegrated downstream firm by *raising* the integrating downstream firm's (relationship-specific) investments. In contrast, we focus on the mechanism through which vertical integration results in *lower* (industry-specific) investments by the integrating upstream firm.

More recently, Church and Gandal (1995) extend OSS's model to a setting where the final good consists of a system composed of a hardware good and complementary software and the value of the system depends on the availability of software. Church and Gandal show that the integrated firm can increase its profits by making its software incompatible with the competing hardware firm (without triggering counter-merger or causing hold-out problems). However, the

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[5] Thus, as Klass and Salinger (1995) point out, Hart and Tirole (1990) can be better characterized as a model of a upstream monopoly constrained by a potential entrant rather than as a model of an active upstream duopoly.

[6] Indeed, Klass and Salinger (1995) argue that the recent literature on anticompetitive vertical integration (such as OSS (1990) and Hart and Tirole (1990)) does not provide any foundation for distinguishing between procompetitive and anticompetitive vertical mergers. Our work is a step toward providing such a foundation. See Riordan (1996) as well.

integrated firm in Church and Gandal's model must make a *commitment* not to make its software compatible with the hardware of the unintegrated firm. In the absence of such a commitment, the integrated firm may be tempted to sell its software to the remaining customers of the foreclosed firm, thereby undermining the purpose of vertical integration.[7]

Riordan (1996) examines vertical integration by a dominant firm which faces price-taking fringe firms. Riordan shows that vertical integration by a dominant firm necessarily results in the foreclosure of fringe firms and a higher output price. However, fringe firms in Riordan's model are not allowed to merge with the upstream input suppliers.

Finally, in an informal discussion of antitrust guidelines toward vertical mergers, Riordan and Salop (1995, footnote 63 and pp. 548-550) suggest that vertical mergers may prevent cost reductions by rivals. In our model, vertical mergers can indeed reduce cost-reducing investments by the unintegrated upstream firm (see Proposition 1 for precise conditions). However, the mechanism through which foreclosure arises in our model is through lower investments by the *integrated* upstream firm, not the unintegrated upstream firm.

The current paper is organized in the following way. Section 2 introduces the model and the assumptions on the downstream product market. Our key assumption is that the upstream profit margin is small compared to the downstream profit margin. In Section 3, we examine vertical integration without investments (or equivalently, with fixed investments). We show that vertical integration does not take place for small upstream margins, because it reduces the integrating firms' combined profits (regardless of whether or not vertical integration triggers

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[7] In other words, in the absence of a commitment by the foreclosing firm, the existing customers of the foreclosed firm may not switch to the foreclosing firm's hardware in the expectation that the foreclosing firm will make its software available to them again. There are some other differences between Church and Gandal's results and ours. First, Church and Gandal's analysis is limited to a linear Hotelling downstream model; we examine general downstream demand functions under both Bertrand and Cournot competition. Second, Church and Gandal show that the hardware price of the integrating firm falls in the foreclosure equilibrium (unless the demand for software variety is very inelastic). Hence, the welfare effects of vertical integration in Church and Gandal's model is ambiguous, because the existing consumers of the foreclosing firm are better off (although total social surplus is reduced). We obtain cleaner welfare results. Under our conditions, vertical integration is anticompetitive on all accounts: all consumers are made uniformly worse off and total social surplus is lowered.

counter-integration by the remaining firms). In Section 4, we introduce upstream investments and show that both the profitability and the welfare implications of vertical integration change dramatically in the presence of investments. Our key results establish that a privately profitable but socially anticompetitive vertical integration can arise in equilibrium without triggering counter-integration by the remaining firms or causing hold-out problems. We then illustrate these results in a Hotelling model. In Section 5, we examine the robustness of our results. The analysis in the preceding sections assumes that an upstream firm can price discriminate between its current customer and the competitor's customer. In Section 5.1, we relax this assumption and show that our basic results carry over to the case of no price discrimination. In Section 5.2, we examine Cournot downstream competition in which the output producers compete by choosing their quantities simultaneously. In contrast to OSS (1990), where vertical integration (even with commitment) is ineffective under Cournot downstream competition, vertical integration in our model can be both profitable and anticompetitive. Section 6 concludes.

2. The Model

As in OSS (1990), there are two upstream firms ($U1$ and $U2$) and two downstream firms ($D1$ and $D2$). We introduce two changes to OSS's basic model. First, the upstream firms are assumed to possess some market power in a non-integrated industry structure. We model the upstream market power in the following simple way. The inputs produced by the two upstream firms are *ex ante* identical, but production of a final output using a particular input requires *input-specific* investments by a downstream firm (which cost some fixed amount). We examine a situation where output producers have already made relationship-specific investments. As a result of the input-specific investments, switching the input supplier costs a downstream firm s per output produced. (Units are normalized so that one unit of input is used for producing one unit of output.) Due to the *ex-post* switching cost, upstream firms have market power to raise input prices over costs. Thus, vertical integration eliminates a double markup of profits on the

part of integrating firms. Our assumption enriches OSS's model by allowing the vertically integrated firm to eliminate socially inefficient double marginalization. (In contrast, since there are no switching costs in the OSS's model, price competition between the unintegrated upstream firms brings the input prices to costs. Hence, there are no double markups that vertical integration corrects.) Without loss of generality, suppose that Di has made a relationship-specific investment with Ui, $i = 1, 2$.

Second, we introduce investments by the upstream firms which reduce their cost of supplying *both* downstream firms. (Hence, the upstream investments are *industry-specific*, in contrast to the downstream investments which are *relationship-specific*.) As we show below, the vertically integrated firm succeeds in raising the unintegrated downstream firm's input costs by reducing its cost-reducing investments. Hence, investments provide a credible channel through which a profitable but anticompetitive (both for consumer welfare and for overall social welfare) vertical integration occurs.

Throughout the paper, we consider the case where the upstream margin (i.e., supplier switching cost) is not "too high". We make this assumption, because it is well known that the elimination of a large double markup raises both the profits of the merging firms and consumer surplus under oligopoly.[8] This finding carries over to the case with investments: the elimination of a large double markup results in higher investment and lower prices. (See the discussion following Proposition 1.) Since our analysis focuses on the potential anticompetitive effects of vertical integration, we restrict our attention to a small upstream margin.[9] (Assumption 4 below provides the precise threshold value of the upstream margin.)

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[8] Under monopoly, the elimination of a double markup is always profitable and procompetitive, regardless of the size of the double markup.
[9] One can appeal to the relationship-specific investments incurred by the downstream firms for justifying our assumption of small upstream margins. In our model, the equilibrium upstream margin under non-integration is equal to the supplier switching cost. If the switching cost is very high, the existence of another potential input supplier does not put any constraint on the current supplier's ex-post opportunistic behavior. If a downstream firm expects that its supplier will charge very high input prices, it may not make input-specific investments in the absence of integration (Klein, Crawford and Alchian, 1978; Williamson, 1979). Our implicit assumption is that the supplier switching cost is low enough for a non-integrated downstream firm to recoup its relationship-specific investment.

The game consists of four stages.

Stage 1: Merger decisions

First, $U1$ and $D1$ decide to merge. If $U1$ and $D1$ merge, then $U2$ and $D2$ have a chance to counter-merge.[10]

Stage 2: Investment decisions

$U1$ and $U2$ simultaneously decide how much to invest in cost-reducing investments. Ui's initial constant marginal cost of production is $\overline{m}$. Ui can reduce its marginal cost of production to $m_i \equiv \overline{m} - K_i$ by spending $I(K_i)$. Assume that $I(0) = 0$, $I'(K_i) > 0$ and $I''(K_i) > 0$ for $K_i > 0$: the investment cost function is increasing and convex. The upstream division of the merged firm maximizes the joint profit of the upstream and downstream divisions.

Stage 3: Input-pricing decisions

$U1$ and $U2$ simultaneously announce the input prices at which they are prepared to supply $D1$ and $D2$. Each upstream firm announces two prices: one price for $D1$ and one price for $D2$. As in the investment decision, the upstream division of the merged firm maximizes the joint profit of the upstream and downstream divisions. Unlike in OSS's model, *no commitment by the merged firm is allowed*.

Stage 4: Output-pricing decisions

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[10] When we examine the potential hold-out problems, we modify Stage 1 to include a bidding game between $D1$ and $D2$ for the control of $U1$'s assets. For details, see Section 4.5.

Let c_i be Di's (constant) marginal cost of production. For expositional simplicity, we assume that there are no production costs other than the input costs. $D1$ and $D2$ simultaneously announce the output prices at which they are prepared to supply the consumers.

Let $q_i(p_1, p_2)$ be the twice-continuously differentiable demand function for Di, with $\partial q_i(p_1, p_2)/\partial p_i < 0$ for $q_i > 0$ and $\partial q_i(p_1, p_2)/\partial p_j > 0$, $j \neq i$, for $q_i, q_j > 0$. Further assume that the two demand functions are symmetric: $\partial q_1(p_1, p_2)/\partial p_2 = \partial q_2(p_2, p_1)/\partial p_1$. Let $p_i(c_1, c_2)$ be Di's equilibrium price and let $q_i(c_1, c_2) \equiv q_i(p_1(c_1, c_2), p_2(c_1, c_2))$ be Di's equilibrium output. (For simplicity, we assume that a unique equilibrium exists in the downstream product market.) Let $\pi_{Di}(c_1, c_2) = [p_i - c_i]q_i$ be Di's profit and $\pi_{Ui}(m_1, m_2) = [c_i - m_i]q_i$ be Ui's profit (assuming that Ui supplies Di). We make the following assumptions on the downstream equilibrium:

Assumption 1 $0 < \dfrac{\partial p_i(c_1, c_2)}{\partial c_j} \leq \dfrac{\partial p_i(c_1, c_2)}{\partial c_i} < 1$ and $0 < \dfrac{\partial q_i(c_1, c_2)}{\partial c_j} \leq -\dfrac{\partial q_i(c_1, c_2)}{\partial c_i} \leq Z$, where $j \neq i$, and Z is finite. $\dfrac{\partial \pi_{Di}(c, c)}{\partial c_i} + \dfrac{\partial \pi_{Di}(c, c)}{\partial c_j} \leq 0$, $j \neq i$, and $\lim_{c \to \infty} \pi_{Di}(c, c) = 0$.

Assumption 2 (1) $\dfrac{\partial}{\partial c_i}\left[\dfrac{\partial q_i}{\partial c_i}\right] \geq 0$, $\dfrac{\partial}{\partial c_j}\left[\dfrac{\partial q_i}{\partial c_i}\right] \leq 0$ and $\dfrac{\partial}{\partial c_j}\left[\dfrac{\partial q_i}{\partial c_j}\right] \leq 0$, $j \neq i$.

(2) $\dfrac{\partial}{\partial p_i}\left[\dfrac{\partial q_i}{\partial p_i}\right] \geq 0$, $\dfrac{\partial}{\partial p_j}\left[\dfrac{\partial q_i}{\partial p_i}\right] \geq 0$, $\dfrac{\partial}{\partial p_j}\left[\dfrac{\partial q_i}{\partial p_j}\right] \geq 0$ and $\dfrac{\partial}{\partial c_j}\left[\dfrac{\partial p_i}{\partial c_j} + \dfrac{\partial p_j}{\partial c_j}\right] \geq 0$, $j \neq i$.

Assumption 3 (1) $2\left[\dfrac{\partial q_i}{\partial p_j}\right]\left[\dfrac{\partial p_j}{\partial c_i}\right] > -\left[\dfrac{\partial q_i}{\partial p_i}\right]\left[\dfrac{\partial p_i}{\partial c_i} - \dfrac{\partial p_i}{\partial c_j}\right]$, $j \neq i$.

(2) $2\left[\dfrac{\partial q_i}{\partial p_j}\right]\left[\dfrac{\partial p_j}{\partial c_j}\right] > -\left[\dfrac{\partial q_i}{\partial p_i} + \dfrac{\partial q_i}{\partial p_j}\dfrac{\partial p_j}{\partial c_i}\right]$, $j \neq i$.

Assumption 4 (1) $p_1(m, m + s) - m \geq s$. (2) $-[p_1(m, m) - m]\dfrac{\partial q_1(m, m)/\partial p_1}{\partial q_1(m, m)/\partial c_2} \geq s$.

For notational simplicity, arguments are dropped from Assumptions 2 and 3. Under Assumption 1, a downstream firm's equilibrium price is more sensitive to changes in its own cost than to changes in the competitor's cost. An equal cost increase (weakly) reduces both downstream firms' equilibrium outputs and profits. And a downstream firm's equilibrium profit vanishes as both its cost and the competitor's cost approach infinity.

Assumption 2 concerns the curvatures of demand functions. Under Assumption 2.1, a change in a downstream firm's unit cost has a (weakly) greater impact on its equilibrium output when its cost is low or when the competitor's cost is high (that is, when its output is large). A change in a downstream firm's unit cost has a (weakly) greater impact on the competitor's equilibrium output when its cost is low. Under Assumption 2.2, a change in a downstream firm's price has a (weakly) greater impact on its demand when its price is low or when the competitor's price is low. A change in a downstream firm's price has a (weakly) greater impact on the competitor's demand when its price is high. Finally, an equal increase in both firms' costs has a (weakly) greater effect on a downstream firm's equilibrium price when its cost is high. Note that Assumption 2 is trivially satisfied for a linear demand function $q_i = a - bp_i + dp_j$, $a > 0$ and $b \geq d > 0$. (This demand function satisfies Assumption 1 as well.) For this linear demand function, d/b is a measure of the "competitiveness" of the output market: as d/b increases, a change in the competitor's price has a greater impact (relative to a change in own price) on a downstream firm's demand.

Assumptions 3 and 4 are the key conditions in our paper. Assumption 3 requires that a downstream firm's demand is significantly affected by a change in the competitor's price. For the above linear demand function, it is not difficult to show that $p_i(c_1, c_2) = \dfrac{a(2b + d) + b(2bc_i + dc_j)}{4b^2 - d^2}$. A straightforward derivation shows that Assumption 3.1 is satisfied if and only if $2d^2 + bd - 2b^2 > 0$, or $d/b > [-1 + \sqrt{17}]/4 \approx 0.78$. Assumption 3.2 is satisfied if and only if $d^2 + 2bd - 2b^2 > 0$, or $d/b > -1 + \sqrt{3} \approx 0.72$.

Assumption 4 requires that the switching cost (which is the upstream profit margin under non-integration) is small relative to the downstream profit margin. Under Assumption 4.1, the integrated downstream firm, which enjoys a cost advantage of s over the unintegrated firm (assuming that the two upstream firms have the same marginal costs), has a profit margin greater than s. Assumption 4.2 states that an integrated downstream firm in a fully integrated industry structure has an adjusted profit margin greater than s. For the above linear demand function with $d = b$, Assumption 4.1 is satisfied if and only if $s \leq 3a/2b$ and Assumption 4.2 if and only if $s \leq 3a/b$. In summary, Assumptions 1 - 4 are satisfied for $q_i = a - bp_i + bp_j$ if $s \leq 3a/2b$. (In the Hotelling model examined in Section 5, $a = 1$ and $b = 1/3t$, where t is the unit transportation cost. Hence, all four assumptions are satisfied if $s \leq (3/2)t$.)[11]

We begin our analysis by establishing that, in the absence of cost-reducing investments, vertical integration is *not* profitable for a small but positive switching cost. This follows from the lack of the input price commitment by the integrated firm. We then show that vertical integration can become profitable in the presence of (industry-specific) investments by the upstream firms. We establish conditions under which vertical integration results in uniformly lower investments by both upstream firms, a higher input cost for the unintegrated downstream firm, uniformly higher consumer prices, and a lower overall social welfare.

Let π_{Ui}^{NI} and π_{Di}^{NI} respectively denote Ui's and Di's profits under a non-integrated industry structure, and let π_{Ui}^{PI} and π_{Di}^{PI} respectively denote Ui's and Di's profits under a partially integrated industry structure where $U1$ and $D1$ are integrated but $U2$ and $D2$ are not. Let m_i^{NI} and m_i^{PI} be Ui's input cost under non-integration and partial integration, and let c_i^{NI} and c_i^{PI} be Di's input price under non-integration and partial integration, respectively. We begin by characterizing equilibrium input prices under the two industry structures. As stated earlier, we

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[11] The reader may observe that we employ a long list of assumptions whereas OSS makes Assumption 1 only. The absence of assumptions in OSS is more apparent than real, because they assume that the upstream profit margin is equal to zero under non-integration. Hence, Assumption 4 is trivially satisfied. Assumptions 2 and 3 are needed in our model because we examine cost-reducing investments.

assume that s is small, in particular, that $m_j + s$ is below Ui's monopoly price to $Di, j \neq i$ (under all industry structures).

Lemma 1 (1) Assume that $m_2^{NI} - s < m_1^{NI} < m_2^{NI} + s$. $c_1^{NI} = m_2^{NI} + s$ and $c_2^{NI} = m_1^{NI} + s$.
(2) Assume that $m_2^{PI} - s < m_1^{PI} < m_2^{PI} + s$. $c_1^{PI} = m_1^{PI}$ and $c_2^{PI} = m_1^{PI} + s$.

Proof. See Appendix A.

Lemma 1 follows from our assumption that each upstream firm can engage in price discrimination between its current customer and the competitor's customer. Our main reason for allowing for price discrimination is as follows. Suppose that $U1$ and $D1$ integrate and that $U1$'s cost stays unchanged at m_1. Then, the integration between $U1$ and $D1$ has no effect on $D2$'s input price in the absence of commitment by $U1$-$D1$: it stays fixed at $m_1 + s$. We obtain OSS's result when $s = 0$. Thus, price discrimination allows us to stay as close as possible to OSS's setup even after adding supplier switching costs. Furthermore, in the presence of supplier switching costs, allowing price discrimination by the suppliers seems reasonable.[12] Finally, price discrimination by the upstream firms is not essential for our results. See Section 5.1.

3. Vertical integration without investments

We examine the profitability of vertical integration without investments. As the following result makes clear, in the absence of price commitment, vertical integration does not raise the combined profits of the merging firms for small switching costs.

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[12] In the computer software industry, price discrimination between current customers and the competitor's customers is prevalent (albeit for final consumers).

14

Lemma 2 Suppose that there are no upstream investments so that both upstream firms' costs are fixed at m^{NI}. Further suppose that $q_1(m^{NI}, m^{NI}) > 0$. Under Assumption 1, there exists $s_1(m^{NI}) > 0$ such that $\pi_{U1}^{NI} + \pi_{D1}^{NI} \leq \pi_{U1}^{PI} + \pi_{D1}^{PI}$ for $0 < s \leq s_1(m^{NI})$, with the equality holding if and only if $s = s_1(m^{NI})$.

Proof. Under non-integration, $c_1^{NI} = c_2^{NI} = m^{NI} + s$ by Lemma 1. Since $q_1(m^{NI}, m^{NI}) > 0$, by continuity, $q_1(m^{NI} + s, m^{NI} + s) > 0$ for s close to 0. Hence, $\pi_{U1}^{NI} + \pi_{D1}^{NI} > 0$ for a small s. By the envelope theorem, the effect of eliminating a small s on $\pi_{U1} + \pi_{D1}$ is given by

$$-[p_1(c_1, c_2) - c_1]\frac{\partial q_1}{\partial p_2}\frac{\partial p_2}{\partial c_1} < 0, \tag{1}$$

where $c_1 = m^{NI}$ and $c_2 = m^{NI} + s$. Thus, for s close to 0, vertical integration by $U1$ and $D1$ reduces their combined profits. On the other hand, by Assumption 1, the combined profits of $U1$ and $D1$ under non-integration approaches zero as s increases without bound. Since $q_1(m^{NI}, m^{NI} + s) > q_1(m^{NI}, m^{NI}) > 0$, the integrated firm $U1$-$D1$ earns a positive profit for a large s. Therefore, by continuity of the profit function, there exists $s_1(m^{NI}) > 0$ such that $\pi_{U1}^{NI} + \pi_{D1}^{NI} = \pi_{U1}^{PI} + \pi_{D1}^{PI}$ for $s = s_1(m^{NI})$ and $\pi_{U1}^{NI} + \pi_{D1}^{NI} > \pi_{U1}^{PI} + \pi_{D1}^{PI}$ for $0 < s < s_1(m^{NI})$. Q.E.D.

The idea behind Lemma 2 is simple. Eliminating a small double markup has no first-order effect on the combined profits of the merging firms *if* the price of the competing downstream firm is fixed. However, the competing downstream firm decreases its price in response to the price reduction by the merging downstream firm. This price reduction by the competing downstream firm has a negative first-order effect on the profits of the merging firms.

Interestingly, in OSS's model (with price commitment), a profitable vertical integration arises without triggering a counter-integration precisely for the same reason as in Lemma 2. In OSS's model, the integrated firm $U1$-$D1$ commits to the input price of $m^{NI} + s(m^{NI})$, allowing $U2$

to raise its price to the same level.[13] Thus, vertical integration by $U1$ and $D1$ *creates* a small double markup for $U2$ and $D2$ without affecting $D1$'s input cost (which is set at the efficient level). The resulting increase in p_2 raises $U1$'s and $D1$'s combined profits. In contrast, in our model, vertical integration by $U1$ and $D1$ *eliminates* a small double markup for themselves without affecting $D2$'s input cost. The resulting decrease in p_2 reduces $U1$'s and $D1$'s combined profits.

From now on, we examine the case $s \leq s_1(m^{NI})$ so that vertical integration does not occur in the absence of investments. (A "forward-looking" $U1$ and $D1$ may carry out an unprofitable merger (without investments) if (1) $U2$ and $D2$ merge in response; and (2) if the counter-merger of $U2$ and $D2$ makes $U1$ and $D1$ jointly better .f than under no merger. However, the counter-merger of $U2$ and $D2$ reduces $U1$'s and $D1$'s joint profits under Assumption 1. Thus, if $s \leq s_1(m^{NI})$, vertical integration does not take place regardless of whether or not it triggers a counter-integration.)

4. Vertical integration with investments

4.1. Investments and profits under a non-integrated industry structure

Assuming that $K_2 - s < K_1 < K_2 + s$, the equilibrium input prices are given by $c_1 = m_2 + s = \overline{m} - K_2 + s$ and $c_2 = m_1 + s = \overline{m} - K_1 + s$. (See Lemma 1.) $U1$ solves

$$\underset{K_1}{Max} \ \pi_{U1}^{NI} = [c_1 - m_1]q_1(c_1, c_2) - I(K_1) = [K_1 - K_2 + s]q_1(\overline{m} - K_2 + s, \overline{m} - K_1 + s) - I(K_1). \quad (2)$$

We assume that there exists a symmetric interior equilibrium (K^{NI}, K^{NI}). K^{NI} is implicitly defined by the first-order condition

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[13] It is assumed that $D2$ breaks a tie in favor of the low-cost supplier, including the switching cost.

16

$$\frac{\partial \pi_{U1}^{NI}}{\partial K_1} = q_1(m^{NI}+s, m^{NI}+s) - s\frac{\partial q_1}{\partial c_2} - I'(K^{NI}) = 0,^{14} \tag{3}$$

where $m^{NI} = \overline{m} - K^{NI}$. Cost-reducing investments by unintegrated upstream firm $U1$ have two effects on its profits. First, there are production cost savings, which are proportional to its output. Second, since the equilibrium input price of $D2$ is equal to $m_1 + s$, c_2 falls by the same margin as m_1. (However, c_1 stays unchanged.) The reduction in c_2 reduces $U1$'s sales.

In the symmetric equilibrium, the upstream firms earn

$$\pi_{U1}^{NI} = \pi_{U2}^{NI} = s q_1(m^{NI}+s, m^{NI}+s) - I(K^{NI}) \tag{4}$$

and the downstream firms earn

$$\pi_{D1}^{NI} = \pi_{D2}^{NI} = [p_1(m^{NI}+s, m^{NI}+s) - (m^{NI}+s)]q_1(m^{NI}+s, m^{NI}+s).^{15} \tag{5}$$

4.2. Investments and profits under a partially integrated industry structure

Suppose that $U1$ and $D1$ integrate, but $U2$ and $D2$ remain unintegrated. Again assuming that $K_2 - s < K_1 < K_2 + s$, Lemma 1 shows that equilibrium input prices are given by $c_1 = m_1 =$

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[14] Assumption 2.1 (with $I''(K) > 0$) guarantees that π_{U1}^{NI} is strictly concave in K_1. However, due to the switching cost s, the concavity of π_{U1}^{NI} in K_1 does *not* guarantee that (K^{NI}, K^{NI}) is an equilibrium. We need to check that $U1$ cannot increase its profit by investing $K_1 < K^{NI} - s$ or $K_1 > K^{NI} + s$. We check these deviations in detail later in the linear Hotelling model. In the general case, we assume that the investment equilibrium is characterized by the first-order conditions derived under the assumption that neither upstream firm has a cost advantage exceeding s against the other upstream firm.

[15] Since we are assuming an interior equilibrium, it must be the case that $s > I(K^{NI})/[q_1(m^{NI}+s, m^{NI}+s)]$: the switching cost is not "too small." Recall the earlier discussion that we focus our attention to "small" switching costs: $s < s_1(m^{NI})$. In Section 4.6, we show that these two inequalities are compatible with each other in the Hotelling model.

$\overline{m} - K_1$ and $c_2 = m_1 + s = \overline{m} - K_1 + s$.[16] Vertical integration by $U1$ and $D1$ changes c_1 from m_2 $+ s$ to m_1. But due to the lack of any commitment power on the part of the combined firm $U1$-$D1$, c_2 is still equal to $m_1 + s$. The integrated firm $U1$-$D1$ solves

$$\underset{K_1}{Max}\ \pi_{U1}^{PI} + \pi_{D1}^{PI} = [p_1(m_1, m_1 + s) - m_1]q_1(m_1, m_1 + s) - I(K_1). \tag{6}$$

Notice that the integrated firm $U1$-$D1$'s maximization problem does *not* depend on K_2. We assume that the profit function is strictly concave in K_1.[17] The integrated firm's optimal investment, denoted by K_1^{PI}, is defined by

$$\frac{\partial(\pi_{U1}^{PI} + \pi_{D1}^{PI})}{\partial K_1} = q_1(m_1^{PI}, m_1^{PI} + s) - [p_1 - m_1]\frac{\partial q_1}{\partial p_2}\left\{\frac{\partial p_2}{\partial c_1} + \frac{\partial p_2}{\partial c_2}\right\} - I'(K_1^{PI}) \le 0, \tag{7}$$

where $m_1^{PI} = \overline{m} - K_1^{PI}$, with equality holding if $K_1^{PI} > 0$. Cost-reducing investments have two effects on the integrated firm's profits. First, production cost falls by the amount of the integrated firm's output. Second, because the integrated firm cannot make price commitments, c_2 falls by the same margin as c_1. The reduction in input costs results in a lower p_2, which reduces the integrated firm's output. (Because p_1 is set optimally, the change in p_1 has no first-order effects on $U1$-$D1$'s profits.) The combined firm's profit is

$$\pi_{U1}^{PI} + \pi_{D1}^{PI} = [p_1(m_1^{PI}, m_1^{PI} + s) - m_1^{PI}]q_1(m_1^{PI}, m_1^{PI} + s) - I(K_1^{PI}). \tag{8}$$

The unintegrated upstream firm $U2$ solves

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[16] Since we do not give any commitment power to the integrated firm, for logical consistency, we allow the integrated firm to use the input of the competing upstream firm if its own input is sufficiently more expensive than the competing upstream firm's input. However, if $K_2 - s < K_1$, internal supply arises in equilibrium.

[17] For example, $I''(K) > 0$ guarantees the strict concavity of the profit function in the case of the linear demand function.

$$Max_{K_2} \ \pi_{U2}^{PI} = [c_2 - m_2]q_2(c_1, c_2) - I(K_2) = [K_2 - K_1 + s]q_2(m_1, m_1 + s) - I(K_2). \qquad (9)$$

The unintegrated upstream firm's equilibrium investment, denoted by K_2^{PI}, satisfies

$$\frac{\partial \pi_{U2}^{PI}}{\partial K_2} = q_2(m_1^{PI}, m_1^{PI} + s) - I'(K_2^{PI}) \leq 0, \qquad (10)$$

with equality holding if $K_2^{PI} > 0$. We assume that $K_2^{PI} > 0$.[18] Since neither downstream firm's input cost is affected by K_2, the unintegrated upstream firm sets its investments where production cost savings are equal to the incremental investment cost. The unintegrated upstream firm $U2$'s profit is equal to

$$\pi_{U2}^{PI} = (K_2^{PI} - K_1^{PI} + s)q_2(m_1^{PI}, m_1^{PI} + s) - I(K_2^{PI}) \qquad (11)$$

and the unintegrated downstream firm earns

$$\pi_{D2}^{PI} = [p_2(m_1^{PI}, m_1^{PI} + s) - (m_1^{PI} + s)]q_2(m_1^{PI}, m_1^{PI} + s). \qquad (12)$$

We are now prepared to examine the effect of vertical integration on investments, profits, and consumer surplus.

4.2.1. The effect of vertical integration on investments

Proposition 1 Under Assumptions 1 - 4, $K_1^{PI} < K^{NI}$ and $K_2^{PI} \leq K^{NI}$.

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[18] For example, if $I'(0) = 0$ and if $q_2(\overline{m}, \overline{m} + s) > 0$, then $K_2^{PI} > 0$. Notice that π_{U2}^{PI} is strictly concave in K_2 if and only if $I''(K_2) > 0$.

Proof. We first establish that $K_1^{PI} < K^{NI}$. We then show that $K_2^{PI} \leq K^{NI}$ by using the fact that $K_1^{PI} < K^{NI}$. By the concavity of the profit function, $K_1^{PI} < K^{NI}$ if $\dfrac{\partial [\pi_{U1}^{PI} + \pi_{D1}^{PI}]}{\partial K_1} < 0$ for

$K_1 = K^{NI}$. By the mean value theorem and by Assumption 2.1, $q_1(m^{NI}, m^{NI} + s) -$

$q_1(m^{NI} + s, m^{NI} + s) = -s \dfrac{\partial q_1(m^{NI} + s', m^{NI} + s)}{\partial c_1} \leq -s \dfrac{\partial q_1(m^{NI}, m^{NI} + s)}{\partial c_1}$, where $0 < s' < s$.

Hence,

$$\left. \frac{\partial [\pi_{U1}^{PI} + \pi_{D1}^{PI}]}{\partial K_1} \right|_{K_1 = K^{NI}} = q_1(m^{NI}, m^{NI} + s) - [p_1(m^{NI}, m^{NI} + s) - m^{NI}] \frac{\partial q_1}{\partial p_2} \left\{ \frac{\partial p_2}{\partial c_1} + \frac{\partial p_2}{\partial c_2} \right\}$$

$$- q_1(m^{NI} + s, m^{NI} + s) + s \frac{\partial q_1(m^{NI} + s, m^{NI} + s)}{\partial c_2}$$

$$\leq -s \left\{ \frac{\partial q_1}{\partial c_1} - \frac{\partial q_1}{\partial c_2} \right\} - [p_1(m^{NI}, m^{NI} + s) - m^{NI}] \frac{\partial q_1}{\partial p_2} \left\{ \frac{\partial p_2}{\partial c_1} + \frac{\partial p_2}{\partial c_2} \right\}$$

$$\leq -s \left\{ 2 \frac{\partial q_1}{\partial p_2} \frac{\partial p_1}{\partial c_2} + \frac{\partial q_1}{\partial p_1} \frac{\partial p_1}{\partial c_1} - \frac{\partial q_1}{\partial p_1} \frac{\partial p_1}{\partial c_2} \right\} < 0.$$

The first equality follows from equations (3) and (7). The first inequality follows from the first-order Taylor expansion to q_1 and the first two parts of Assumption 2.1 (all terms in the third and fourth lines are evaluated at $(m^{NI}, m^{NI} + s)$). The second inequality follows from Assumption 4.1, and the final inequality from Assumption 3.1. Next,

$$\left. \frac{\partial \pi_{U2}^{PI}}{\partial K_2} \right|_{K_2 = K^{NI}} = q_2(m_1^{PI}, m_1^{PI} + s) - q_2(m^{NI} + s, m^{NI} + s) + s \frac{\partial q_2(m^{NI} + s, m^{NI} + s)}{\partial c_1}$$

$$\leq q_2(m^{NI}, m^{NI} + s) - q_2(m^{NI} + s, m^{NI} + s) + s \frac{\partial q_2(m^{NI} + s, m^{NI} + s)}{\partial c_1}$$

$$= -s\frac{\partial q_2(m^{NI}+s', m^{NI}+s)}{\partial c_1} + s\frac{\partial q_2(m^{NI}+s, m^{NI}+s)}{\partial c_1} \leq 0,$$

where the first equality follows from equations (3) and (10), the first inequality from Assumption 1 and $K_1^{PI} < K^{NI}$, the second equality from the first-order Taylor expansion ($0 < s' < s$), and the last inequality from the last part of Assumption 2.1.   *Q.E.D.*

In general, vertical integration has conflicting effects on investment incentives of both integrated and unintegrated upstream firms. First, the elimination of a double markup for the integrated firms increases the output of the integrated downstream firm and decreases the output of the unintegrated downstream firm. Since the production cost savings are proportional to the output produced, the elimination of a double markup has the direct effect of *raising* the investment incentives of the integrated upstream firm and *reducing* the investment incentives of the unintegrated upstream firm.

Second, vertical integration has a more subtle strategic effect on investment incentives. Consider the integrated firm first. Due to the lack of any commitment power on the part of the integrated firm $U1$-$D1$, c_2 falls by the same margin as c_1 ($= m_1$). The lower input costs result in lower p_2, which reduces the $U1$-$D1$'s profits by $[p_1 - m_1]\frac{\partial q_1}{\partial p_2}\left\{\frac{\partial p_2}{\partial c_1} + \frac{\partial p_2}{\partial c_2}\right\}$. On the other hand, when $U1$ and $D1$ are not integrated, only c_2 falls as $U1$ makes cost-reducing investments. Since $U1$'s equilibrium profit margin under non-integration is equal to s, the loss from lower c_2 is given by $s\frac{\partial q_1}{\partial c_2} = s\left\{\frac{\partial q_1}{\partial p_1}\frac{\partial p_1}{\partial c_2} + \frac{\partial q_1}{\partial p_2}\frac{\partial p_2}{\partial c_2}\right\}$. Under Assumptions 1 and 4.1, the profit loss through a lower output is greater for $U1$-$D1$ than for $U1$. Assumptions 2.2 (the first two parts) and 3.1 ensure that the indirect negative effect dominates the direct positive effect so that vertically integrated upstream firm reduces its investments.

For the unintegrated firm $U2$, vertical integration by $U1$ and $D1$ eliminates the negative strategic effect of investments $(-s\frac{\partial q_2}{\partial c_1})$, because c_1 no longer depends on K_2. However, under

Assumption 2.1 (the last part), the direct effect of a lower q_2 (weakly) dominates the strategic effect, thereby reducing U_2's investments. The reduction in K_1 (weakly) reduces the equilibrium output of $D2$, further reducing U_2's investments.[19]

Figure 1 graphically illustrates the effect of vertical integration on investments. The best response curves are drawn under the assumption that $K_2 - s < K_1 < K_2 + s$. Under Assumptions 1 and 2, best response functions under the non-integrated industry structure, denoted by $K_i^{NI}(K_j)$, slope upward.[20] $U1$-$D1$'s best response function under the partially integrated industry structure, denoted by $K_1^{PI}(K_2)$, is vertical. (Under Assumption 1-4, it lies to the left of $K_1^{NI}(K^{NI})$, as illustrated in Figure 1.) $U2$'s best response function under a partially integrated industry structure, denoted by $K_2^{PI}(K_1)$, slopes upward under Assumption 1 and lies below $K_2^{NI}(K_1)$ at $K_1 = K_{NI}$, under Assumptions 1 and 2. (For simplicity, the best response curves of the unintegrated firms are drawn as linear lines.)

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[19] Under Assumptions 1 - 4, the positive direct effect is dominated by the negative strategic effect for $U1$, while the opposite is true for $U2$. This particular result is not necessary for our main points (i.e., privately profitable vertical integration with investments can be socially anticompetitive). As will become clear, what is crucial for our results is that vertical integration reduces K_1. There are two senses in which this is true. First, since K_2 does not affect the input prices of downstream firms under partial integration, K_2 does not affect either the integrated firm's profits, the unintegrated downstream firm's profits, or the consumer surplus. Hence, whether or not vertical integration reduces K_2 has no relevance for the private profitability of vertical integration and for its effect on final consumers. Second, in the Hotelling model examined in Section 5, vertical integration has no net effect on K_2, but still can be anticompetitive. The only role that reduced investment by $U2$ plays in our model is that it enables us to obtain a clean result on overall social surplus (Proposition 6).

[20] An increase in K_1 reduces c_2. Thus, q_2 increases, thereby raising the direct benefit of increasing K_2 to $U2$. Assumptions 1 and 2 ensure that the potentially negative strategic effects are dominated by the positive direct effect.

Figure 1 The effect of vertical integration on equilibrium investments
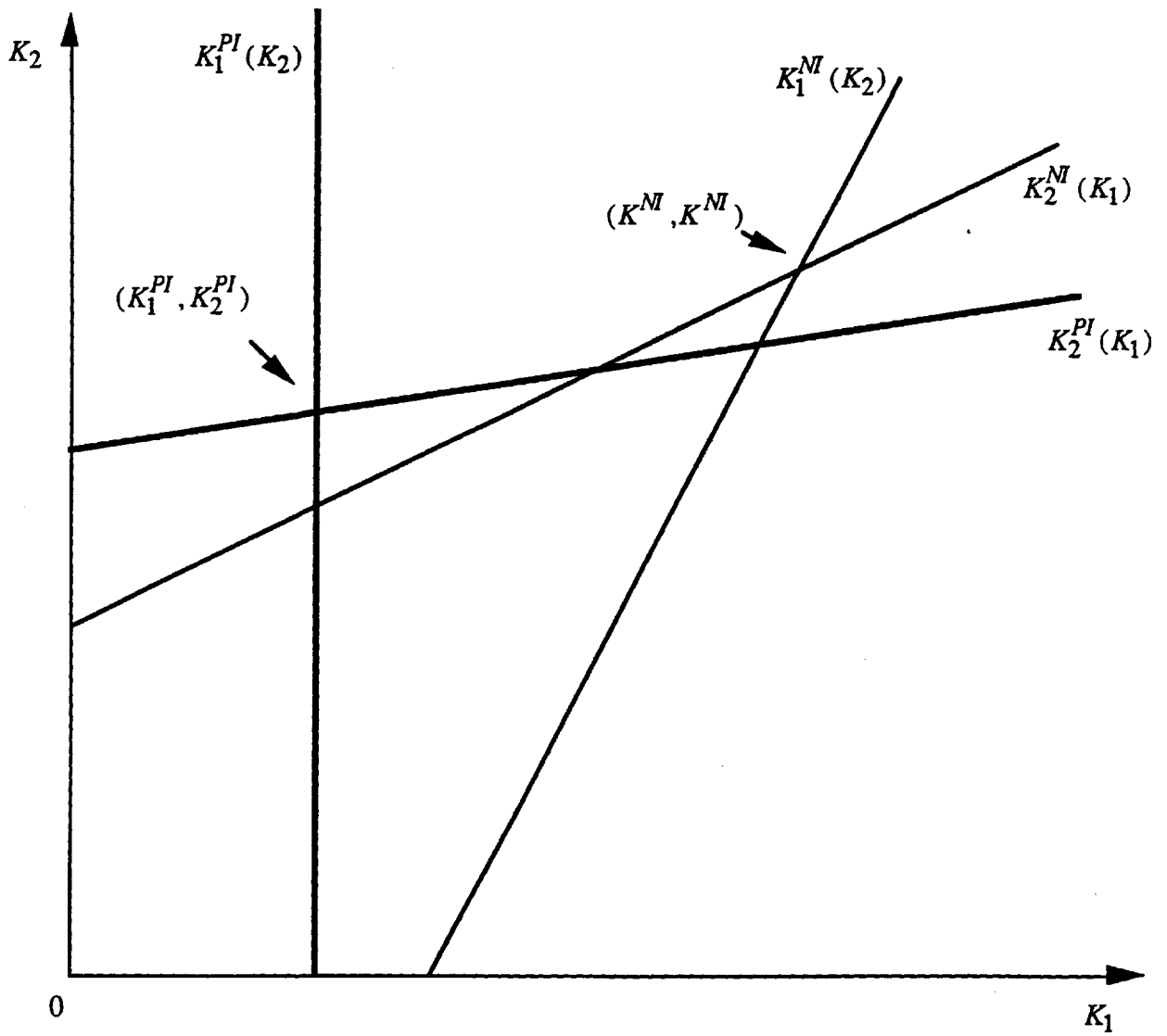
4.2.2. The profitability of vertical integration

We now show that investments can turn an otherwise unprofitable vertical integration into a profitable one.

Proposition 2 Under Assumptions 1 - 4, there exists $\bar{s}_1(m^{NI})$ such that $\pi_{U1}^{PI} + \pi_{D1}^{PI} > \pi_{U1}^{NI} + \pi_{D1}^{NI}$ for $\bar{s}_1(m^{NI}) < s \leq s_1(m^{NI})$.

Proof. See Appendix A.

Recall that for $s = s_1(m^{NI})$, vertical integration *without* investments (or equivalently, vertical integration with fixed investments K^{NI}) does not change the combined profits of $U1$ and $D1$ (Lemma 2). Since the combined firm $U1$-$D1$ chooses investments in order to maximize their joint profits, the resulting change in their investments must increase their joint profits. (Under a partially integrated industry structure, any change in the unintegrated upstream firm's investments does not affect the integrated firm's profits.)

It is instructive to use the terminology of Fudenberg and Tirole (1984) in discussing the effects of vertical integration in our model. Given that $D2$ does not exit the industry, $U1$-$D1$ can increase its profits by adopting a "puppy dog" strategy which reduces price competition. Vertical integration without investments is not profitable for small switching costs because it intensifies price competition. In contrast, vertical integration with investments can be profitable because the integrated firm succeeds in raising the rival downstream firm's costs (Salop and Scheffman, 1983; Krattenmaker and Salop, 1986) by reducing its investments.

We now turn to the conditions under which counter-integration does not occur.

4.3. Investments and profits under a fully integrated industry structure

4.3.1. The effect of counter-integration on investments

Suppose that $U2$ and $D2$ integrate in response to the merger of $U1$ and $D1$. Again assuming that $K_2 - s < K_1 < K_2 + s$, the equilibrium input prices are given by $c_1 = m_1 = \overline{m} - K_1$ and $c_2 = m_2 = \overline{m} - K_2$. Counter-integration by $U2$ and $D2$ changes c_2 from $m_1 + s$ to m_2. $U1$-$D1$ solves

$$\underset{K_1}{Max} \; \pi_{U1}^{FI} + \pi_{D1}^{FI} = [p_1(m_1, m_2) - m_1]q_1(m_1, m_2) - I(K_1). \tag{13}$$

A symmetric equilibrium (K^{FI}, K^{FI}) is implicitly defined by the first-order condition

$$\frac{\partial(\pi_{U1}^{FI} + \pi_{D1}^{FI})}{\partial K_1} = q_1(\overline{m} - K^{FI}, \overline{m} - K^{FI}) - [p_1 - m_1]\frac{\partial q_1}{\partial p_2}\frac{\partial p_2}{\partial c_1} - I'(K^{FI}) \leq 0, \tag{14}$$

where $m^{FI} = \overline{m} - K^{FI}$, with equality holding for $K^{FI} > 0$. Under Assumption 1, an interior symmetric equilibrium exists if $I'(0) = 0$. We assume that indeed $K^{FI} > 0$. The equilibrium profits of the merged firms are given by

$$\pi_{U1}^{FI} + \pi_{D1}^{FI} = \pi_{U2}^{FI} + \pi_{D2}^{FI} = [p_1(m^{FI}, m^{FI}) - m^{FI}]q_1(m^{FI}, m^{FI}) - I(K^{FI}). \tag{15}$$

The next result shows that counter-integration by $U2$ and $D2$ increases investments by the already-integrated firm $U1$-$D1$.

Proposition 3 Under Assumptions 1 - 4, $K_1^{PI} < K^{FI}$.

Proof. See Appendix A.

25

In general, counter-integration by $U2$ and $D2$ has two conflicting effects on $U1$-$D1$'s investment incentives. First, counter-integration by $U2$ and $D2$ eliminates double markup for themselves, thereby reducing c_2 and q_1. Hence, counter-integration reduces the *direct* benefit of investments for $U1$-$D1$. Second, however, c_2 is equal to m_2 under counter-integration so that c_2 no longer decreases with K_1. This second effect raises $U1$-$D1$'s investment incentives. Intuitively, when s is small (Assumption 4.2) and when $D1$'s demand is significantly affected by the competitor's price (Assumption 3.2), the second positive effect dominates the first negative effect so that $U1$-$D1$'s investments increase under counter-integration by $U2$ and $D2$.

Counter-integration by $U2$ and $D2$ has generally ambiguous effects on $U2$'s incentives as well. First, the elimination of double markup increases q_2. Second, the unintegrated $U2$ in the partially integrated industry structure sets its investments where the direct benefit is equal to marginal investment costs (equation (10)). In contrast, the integrated firm $U2$-$D2$ now takes into account the negative effect through a lower p_1 (equation (14)). However, when s is small and when a competitor's price has a significant effect on a downstream firm's demand, counter-integration reduces $U2$'s investments.[21] Figure 2 illustrates the effect of counter-integration on investments, assuming that $K_2^{PI} > K^{FI}$. Figure 2 also assumes that the best response functions under the fully integrated industry structure slope downward.[22][23]

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[21] One can establish precise conditions under which $K_2^{PI} > K^{FI}$. These conditions are analogous to Assumptions 3 - 4. However, since our subsequent analysis does not depend on this particular result, we do not report the conditions here.

[22] As K_2 increases, c_2 falls without any effect on c_1. Hence, q_1 decreases, thereby reducing the direct benefit of investments to $U1$-$D1$.

[23] The reader will notice that counter-integration changes investments from strategic complements into strategic substitutes (Bulow, Geanakoplos, and Klemperer, 1985). This particular result is irrelevant for the foreclosure effects of vertical integration. In Section 5.1, we examine the case of no price discrimination in which investments are always strategic substitutes. It will become clear that what is crucial is the effect of counter-integration on equilibrium K_1, not the effect on the slope of $K_1(K_2)$.

Figure 2 The effect of counter integration on equilibrium investments
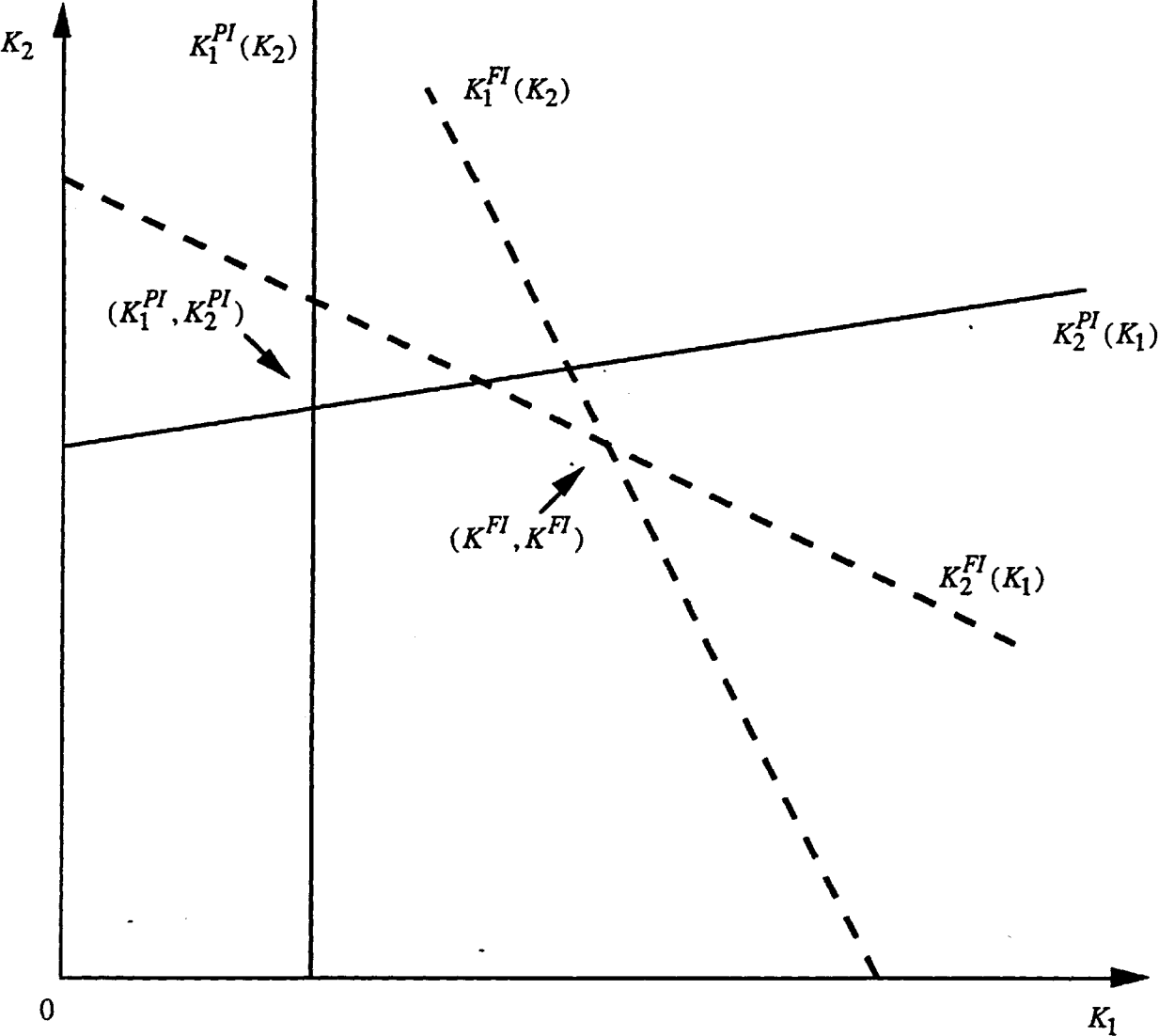
4.3.2. The profitability of counter-integration

We now establish conditions under which counter-integration is not profitable for $U2$ and $D2$. Let $s_2(m_1^{PI})$ be the critical value of the switching cost such that the counter-merger of $U2$ and $D2$ does not change their joint profits when marginal costs are *fixed* at (m_1^{PI}, m_1^{PI}). (Recall Lemma 2.) We now show that counter-integration is not profitable for a small s.

Proposition 4 Under Assumptions 1 - 4, there exist $\hat{s}_2(m_1^{PI}) > s_2(m_1^{PI})$ such that $\pi_{U2}^{FI} + \pi_{D2}^{FI} < \pi_{U2}^{PI} + \pi_{D2}^{PI}$ for $0 < s < \hat{s}_2(m_1^{PI})$.

Proof. See Appendix A.

Intuitively, there are two components to the effects of counter-integration on $U2$'s and $D2$'s combined profits. First, holding investments (and thus marginal production costs) constant, counter-integration eliminates the double markup. For small switching costs $(0 < s < s_2(m_1^{PI})$, to be precise), however, the elimination of the double markup reduces $U2$'s and $D2$'s combined profits. Second, both $U1$ and $U2$ adjust their investments. Since $U1$ increases its investments, c_1 is lower under counter-integration. As a result, $U2$'s and $D2$'s joint profits decrease.

Propositions 2 and 4 together show that a profitable vertical integration can occur in equilibrium without triggering counter-integration, provided that the two intervals $[\tilde{s}_2(m_1^{PI}), \hat{s}_2(m_1^{PI})]$ and $[\tilde{s}_1(m^{NI}), s_1(m^{NI})]$ overlap. In Section 4.6, we show that these two intervals indeed overlap in the Hotelling model.

4.4. Welfare effects of vertical integration with investments

This subsection examines the effects of vertical integration on competitors, final consumers and overall welfare. W show that profitable vertical integration can make final consumers uniformly worse off and reduce overall social welfare.

4.4.1. The effect of vertical integration on unintegrated firms

Comparison of equations (5) and (12) show that vertical integration by $U1$ and $D1$ makes the unintegrated downstream firm unambiguously worse off.

Proposition 5 Under Assumptions 1 - 4, $\pi_{D2}^{PI} < \pi_{D2}^{NI}$ for $s > 0$.

Proof. See Appendix A.

Since the input cost of the unintegrated downstream firm rises by a greater amount than the input cost of the integrated downstream firm (if it rises at all), the unintegrated downstream firm earns a lower profit.

The effect of vertical integration on the unintegrated upstream firm is less clear. Recall that vertical integration by $U1$ and $D1$ reduces q_2. Since the direct benefit of investments is proportional to output produced, the reduction in q_2 reduces $U2$'s profits. Hence, if $K_2^{PI} < K_1^{PI}$, then vertical integration by $U1$ and $D1$ lowers $U2$'s profits. However, K_2^{PI} may be greater than K_1^{PI}. (For example, $K_2^{PI} > K_1^{PI}$ in the Hotelling model examined in the next section.) If K_2^{PI} is sufficiently bigger than K_1^{PI}, $U2$ earns higher profits as a result of vertical integration by $U1$ and $D1$.

4.4.2. The effect of vertical integration on final consumers and overall social welfare

Vertical integration by $U1$ and $D1$ raises c_2 by $K^{NI} - K_1^{PI}$ and changes c_1 by $K^{NI} - K_1^{PI} - s$. If $K^{NI} - K_1^{PI} > s$, then both c_1 and c_2 are higher under the partially integrated industry structure than under the non-integrated industry structure. In this case, both p_1 and p_2 rise, making final consumers uniformly worse off. Even if $K^{NI} - K_1^{PI} < s$ so that vertical integration reduces c_1, final consumers end up uniformly worse off if $K^{NI} - K_1^{PI}$ is sufficiently large compared to s. The next assumption states the precise conditions under which vertical integration results in uniformly higher output prices.

Assumption 5 If $K^{NI} - K_1^{PI} < s$, then $K^{NI} - K_1^{PI} > s/(1 + \alpha)$, where $\alpha = \dfrac{\partial p_1(c_1,c_2)/\partial c_2}{\partial p_1(c_1,c_2)/\partial c_1} > 0$

for $\overline{m} - K_1^{PI} \le c_1 \le \overline{m} - K^{NI} + s$ and $\overline{m} - K_1^{PI} + s \le c_2 \le \overline{m} - K^{NI} + s$.

Assumption 5 is satisfied in the Hotelling model $[q_i = 1 + (p_j - p_i)/3t]$ if and only if $K^{NI} - K_1^{PI} > (2/3)s$. For the case of the quadratic investment cost function $[I(K) = (\gamma/2)K^2]$, we show that Assumption 5 is satisfied if and only if $s < 3t/(2t\gamma + 1)$. (See Section 4.6.)

Proposition 6 (1) Under Assumptions 1 - 5, vertical integration by $U1$ and $D1$ makes final consumers uniformly worse off by raising both output prices.
(2) Under Assumptions 1 - 5, vertical integration by $U1$ and $D1$ reduces overall social welfare.

Proof. (1) We show that both output prices rise when $s > K^{NI} - K_1^{PI} > s/(1 + \alpha)$. Starting from $(c_1, c_2) = (\overline{m} - K^{NI} + s, \overline{m} - K^{NI} + s)$, consider an infinitesimal change in input costs (dc_1, dc_2) $= (\beta dc, dc)$, where $\beta = \dfrac{K^{NI} - K_1^{PI} - s}{K^{NI} - K_1^{PI}} < 0$ and $dc > 0$. The resulting change in p_1 is given by

$$dp_1 = \left\{ \beta \frac{\partial p_1}{\partial c_1} + \frac{\partial p_1}{\partial c_2} \right\} dc = \frac{\partial p_1}{\partial c_1} \{\beta + \alpha\} dc > 0 \text{ if and only if } K^{NI} - K_1^{PI} > s/(1 + \alpha). \text{ We can}$$

obtain the effect of vertical integration on p_1 by integrating dp_1/dc from 0 to $K^{NI} - K_1^{PI}$.

Hence, p_1 rises as a result of the vertical integration by $U1$ and $D1$. Now, by symmetry, the

actual change in p_2 will be the same as the *hypothetical* change in p_1 *if* c_1 were to increase by $K^{NI} - K_1^{PI}$ and c_2 were to decrease by $s - K^{NI} + K_1^{PI}$. Since the *actual* change in p_1 is positive (when c_1 falls by $s - K^{NI} + K_1^{PI}$ and c_2 rises by $K^{NI} - K_1^{PI}$), and since $0 < \partial p_1/c_2 \le \partial p_1/c_1$, the above hypothetical change in p_1 is positive.

(2) Decompose the effects of vertical integration into two steps. First, reduce both investments to the new lower levels. Second, increase both output prices to the new higher levels. We show that both changes reduce social welfare. First, *holding* prices constant at the levels under non-integration, the socially optimal level of symmetric investments K_i ($= K_j = K^*$) equate the direct marginal benefit (q_i) with marginal costs of investments ($I'(K_i)$). Equation (3) shows that $K^{NI} < K^*$. Hence, a reduction in investments reduces social welfare (holding prices constant). Second, holding investments fixed at the new lower levels, the increase in prices reduces social welfare, because equilibrium outputs are further decreased from socially efficient levels (at which prices equal marginal production costs). *Q.E.D.*

Under Assumptions 1 - 5, vertical integration raises output prices (which are already too high for efficient consumption) and reduces investments (which are already too low for production cost minimization), thereby lowering social welfare unambiguously. Notice that Assumption 5 is *not* necessary for vertical integration to reduce overall social welfare. Even if Assumption 5 is violated (so that consumers of good 1 are better off), overall social welfare may be lower as a result of vertical integration.

4.5. Hold-out problems

Finally, we examine the potential hold-out problems between the upstream firms. Hold-out problems may arise if the integration by $U1$ and $D1$ raises $U2$'s profits. Indeed, in the Hotelling model examined in the next section, the merger by $U1$ and $D1$ benefits $U2$. In order to examine this issue, we modify Stage 1 of the game, where the merger decisions occur. *Before*

31

incurring relationship-specific investments, $D1$ and $D2$ engage in a first-price bidding game for $U1$.[24] A tie is broken in favor of $D1$. If $U1$ agrees to be acquired by a downstream firm, the losing downstream firm makes a take-it-or-leave-it offer to $U2$. (If $U1$ rejects both offers, and thus remains unintegrated, $U2$ does not have a chance to merge with a downstream firm.) Then, each downstream firms make relationship-specific investments for one upstream firm. (A merged downstream firm makes relationship-specific investments for its upstream division.)

In the bidding game for the control of $U1$, each downstream firm is willing to bid up to $(\pi_{U1}^{PI} + \pi_{D1}^{PI}) - \pi_{D2}^{PI}$, the difference between the winner's payoff and the loser's payoff. By the tie-breaking rule, $U1$ accepts $D1$'s bid of $(\pi_{U1}^{PI} + \pi_{D1}^{PI}) - \pi_{D2}^{PI}$. Since $U2$'s resulting payoff is π_{U2}^{PI}, hold-out problems between the upstream firms do not arise if $\pi_{U1}^{PI} + \pi_{D1}^{PI} > \pi_{U2}^{PI} + \pi_{D2}^{PI}$. For general demand and cost functions, it is hard to compare profits across firms. In order to derive explicit conditions under which hold-out problems do not arise, we now turn to the Hotelling model.

4.6. An example: Hotelling model

Consider a linear city of length one. The consumers, with total measure 2, are uniformly distributed along the city. The two downstream firms are located at the two corner points. Consumers have identical valuations of the two goods, equal to v. Each consumer has a one unit of demand. A consumer incurs a transportation cost t per unit length. We assume that v is sufficiently high so that the entire market is covered under all industry structures. Then the demand for Di is given by $q_i(p_1, p_2) = 1 + (p_j - p_i)/t, j \neq i$. It is straightforward to derive the downstream equilibrium: $p_i(c_1, c_2) = t + (2c_i + c_j)/3$ and $q_i(c_1, c_2) = 1 + (c_j - c_i)/3t, j \neq i$. Notice that the equilibrium outputs (and profit margins) depend *only* on the cost differences but not on their levels. In particular, $q_i(c, c) = 1$ for *all* c: in a symmetric equilibrium, each downstream

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[24] We make this assumption to put $D1$ and $D2$ on equal footing in bidding for $U1$. If the downstream firms bid for $U1$ *after* they make relationship-specific investments, then $D1$ enjoys an undue advantage over $D2$ as a result of the switching cost.

firm's output is equal to 1 regardless of the production costs. This fact simplifies derivations greatly.

Under a non-integrated industry structure, the symmetric equilibrium investment K^{NI} is defined by $\frac{\partial \pi_{U1}^{NI}}{\partial K_1} = 1 - s/3t - I'(K^{NI}) = 0$. The upstream firms' profits are $\pi_{U1}^{NI} = \pi_{U2}^{NI} = s - I(K^{NI})$ and the downstream firms' profits are $\pi_{D1}^{NI} = \pi_{D2}^{NI} = t$.

Under a partially integrated industry structure, the integrated firm $U1$-$D1$ invests 0, because its first-order condition is given by $\frac{\partial(\pi_{U1}^{PI} + \pi_{D1}^{PI})}{\partial K_1} = -I'(K_1) < 0$, for all $K_1 > 0$. The unintegrated firm's equilibrium investment satisfies $\frac{\partial \pi_{U2}^{PI}}{\partial K_2} = 1 - s/3t - I'(K_2^{PI}) = 0$. Notice that

$K_2^{PI} = K^{NI}$: vertical integration by $U1$ and $D1$ does not change the unintegrated firm's investments. The integrated firm's profits are $\pi_{U1}^{PI} + \pi_{D1}^{PI} = t[1 + s/3t]^2$, the unintegrated upstream firm's profits are $\pi_{U2}^{PI} = (K_2^{PI} + s)[1 - s/3t] - I(K_2^{PI})$ and the unintegrated downstream firm's profits are $\pi_{D2}^{PI} = t[1 - s/3t]^2$.

Finally, in a fully integrated industry structure, the symmetric equilibrium investment K^{FI} is defined by $\frac{\partial(\pi_{U1}^{FI} + \pi_{D1}^{FI})}{\partial K_1} = 2/3 - I'(K^{FI}) = 0$. The equilibrium profits of the merged firms are given by $\pi_{U1}^{FI} + \pi_{D1}^{FI} = \pi_{U2}^{FI} + \pi_{D2}^{FI} = t - I(K^{FI})$.

Comparison of $U1$'s and $D1$'s joint profits under non-integrated and partially integrated industry structures show that $s_1(m^{NI}) = 3t$. (Notice that $s_1(m^{NI})$ does not depend on m^{NI}.) Similarly, $s_2(m_1^{PI}) = (3/2)t$. In order to obtain explicit solutions for the other critical values of the switching cost in Propositions 2 and 4, we examine the following two cost functions:

$$I(K) = \gamma K^2/2, \ \gamma > 0, \text{ for } K \le 1/\gamma \text{ and } I(K) = \infty, \text{ for } K > 1/\gamma, \tag{16}$$

with $\max\{\frac{1}{\gamma}, s_0\} < s < \frac{3t}{2t\gamma + 1}$, and $\frac{1}{\gamma} < t$, where $s_0 \equiv \frac{\left[-(t\gamma + 1) + \sqrt{(t\gamma)^2 + 8t\gamma}\right]3t}{(6t\gamma - 1)}$; and

$$I(K) = \gamma[e^K\text{-}1], \ \gamma > 0, \text{ for } K > 0, \tag{17}$$

with $s = 2$, $\gamma = 0.02$, and $2.77 < t < 16.76$.

Proposition 7 In the Hotelling model with the above two investment cost functions, a profitable but anticompetitive (both for consumers and for aggregate efficiency) vertical integration arises in equilibrium. Counter-integration by the remaining firms does not happen, because it reduces their joint profits. Hold-out problems among the upstream firms do not arise.

Proof. See Appendix A.

For the first investment cost function, no upstream firm (merged or unmerged) invests more than $1/\gamma$ due to the prohibitive costs. Since $s > 1/\gamma$, the first-order conditions derived in the text indeed characterize equilibrium investments. ($s > 1/\gamma$ also guarantees that the upstream firms earn positive profits under non-integration.) When $s < 3t/[2t\gamma + 1]$, vertical integration raises both $U1$-$D1$'s joint profits and all output prices. When $s > s_0$, hold-out problems do not arise. Finally, $t > 1/\gamma$ guarantees that the interval of switching costs for which anticompetitive vertical integration takes place is not empty. (Notice that all the conditions depend only on s/t and $t\gamma$.)

The first investment cost function is somewhat restrictive, because the investment cost function suddenly becomes very steep after a critical value.[25] The second cost function avoids

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[25] For the quadratic investment cost function without this sudden increase, whenever vertical integration by $U1$ and $D1$ raises their joint profits, the unintegrated firm $U2$ finds it profitable to increase its investment and supply both $D1$ and $D2$ under partial integration. While vertical integration by $U1$ and $D1$ still forecloses the unintegrated firm $D2$ and makes consumers uniformly worse off, overall social welfare is higher as a result of integration. Of course, this cannot happen if we assume that vertical integration is a commitment to internal supply by the integrating firms. Since we do not allow the integrated firm to make a price commitment, for logical consistency, we allow the integrated firm to buy its inputs from the competing upstream firm.

34

this discontinuous increase in marginal cost; instead investment cost increases exponentially.[26] The proof of Proposition 7 shows that one can find parameter values for which profitable but anticompetitive vertical integration arises in equilibrium.

5. Extensions

5.1. No price discrimination

The preceding analysis assumes that the upstream firms can exercise price discrimination between current and prospective customers. As we have pointed out earlier, the main reason for allowing for price discrimination is to keep the model as close as possible to OSS's original setup. In this section, we demonstrate that price discrimination is not essential to our results.

Under no price discrimination, the upstream profit margin under non-integration is not directly related to the supplier switching cost. However, as in the case of price discrimination, the unintegrated upstream firm's profit margin under partial integration is equal to the supplier switching cost. Hence, unless the upstream profit margin under non-integration happens to be equal to the supplier switching cost, vertical integration (without commitment) can increase or decrease the unintegrated downstream firm's input price in our model.

Since our purpose of introducing the supplier switching cost is to parametrize the upstream market power under non-integration in a simple way, it seems reasonable to assume that the upstream profit margin under non-integration is equal to the supplier switching cost. Then, vertical integration without investments (and without commitment) does not change the unintegrated upstream firm's market power over the unintegrated downstream firm.

In Appendix B, we show that our results in the previous sections continue to hold under no price discrimination when the upstream profit margin under non-integration is equal to the supplier switching cost. While we believe that this assumption is reasonable, one may still argue

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[26] But the analysis is much more complicated than in the first cost function, because we need to check "jumpy" deviations to a very high investment level or to a very low level. See the proof of Proposition 7.

that it is restrictive. We show that our results do not depend on this particular assumption. This is done in the Hotelling model. We demonstrate that anticompetitive vertical integration occurs in equilibrium under no price discrimination even when the upstream profit margin under non-integration is not equal to the supplier switching cost.

5.2. Cournot downstream competition

So far, we have assumed that the downstream firms compete in prices. In this section, we demonstrate that our results continue to hold even if the downstream firms compete in quantities. This is in sharp contrast to the standard result in OSS (1990), where vertical integration (even with commitment) is ineffective under Cournot downstream competition. In the Cournot oligopoly, outputs are strategic substitutes (see Bulow, Geanakoplos, and Klemperer, 1985) under mild conditions. Then, counter-integration (without investments) is always profitable, because the already-integrated firm reduces its output in response to the output expansion by the newly-integrated firm. Thus, in the absence of investments, vertical integration always triggers counter-integration. For small switching costs, the net effect is to reduce the joint profits of the firms which initiate vertical integration.[27]

We show that upstream investments can reverse the above result. Under conditions that parallel Assumptions 1 - 4, we show that the initial vertical integration reduces the integrating upstream firm's investment incentives but counter-integration restores them. (These results parallel Propositions 1 and 3 in Section 4.) If the already-integrated firm increases its investment by a substantial amount, counter-integrating firms' joint profits are reduced from the unintegrated levels.

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[27] This result follows from Assumption 1. The effect of full integration (compared with no integration) is to reduce the input transfer price of both downstream firms by the amount of switching cost. Both downstream firms expand their output, further reducing the industry profit from the monopoly level.

These results are reported in Appendix C. There, we begin by listing the modified assumptions. As in the earlier sections, the key assumption is that the upstream profit margin under non-integration (which equals the switching cost) is smaller than adjusted downstream profit margin. (For simplicity, we assume that price discrimination by the upstream firms is feasible.) Along with the effects of integration and counter-integration on investments, we derive conditions under which vertical integration raises the output price and reduce overall social surplus. Here, we illustrate these results in an example with linear demand functions and quadratic investment cost functions:

Proposition 8 Consider a homogeneous-good Cournot downstream oligopoly with linear demand functions $[P(Q) = a - Q$, where $Q = q_1 + q_2$ is the industry output] and quadratic investment cost functions $[I(K) = \gamma K^2/2]$. Suppose that $\gamma \geq 20/3$ and that $\dfrac{27\gamma^2 + 33\gamma - 10}{6\gamma} < A <$

$\dfrac{18\gamma^2 - 15\gamma + 5}{3\gamma}$, where $A \equiv \dfrac{a - \overline{m}}{s}$. Then, a profitable but anticompetitive (both for consumers and for aggregate efficiency) vertical integration arises in equilibrium without causing counter-integration by the remaining firms or causing hold-out problems among the upstream firms.[28]

Proof. See Appendix C.

Proposition 8 shows that a profitable but anticompetitive vertical integration arises in equilibrium for switching costs which are not "too small or too large". Intuitively, when the switching costs are high, counter-merger is always profitable, because the unintegrated firms have a high double markup. Eliminating a high double markup increases the combined profits of the counter-merging firms, even if the already-integrated firm responds by increasing its cost-reducing investments. The condition that the switching cost is not too small is required for a. more technical reason: it ensures that the investment game under non-integration has a pure-

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[28] Notice that there is no kink in the investment cost function.

strategy Nash equilibrium. (Since an upstream firm's profit margin under non-integration is equal to the switching cost, if the switching cost is too low, the upstream firms may earn a negative profit if both invest positive amounts in cost reduction.)

We conclude this section by drawing the reader's attention to the qualitative similarity between Proposition 7 (Hotelling downstream competition) and Proposition 8 (Cournot downstream competition). This similarity is particularly striking, because many results in oligopoly are known to be sensitive to the modes of competition (that is, price vs. quantity competition).

In both propositions, integrating firms succeed in raising the input price of the unintegrated downstream firm by reducing its investment in cost reduction. This profitable vertical merger is anticompetitive because it both raises output price(s) and reduces investments which already fall short of the socially optimal levels. Counter-merger is not profitable because it severs the linkage between the already-integrated firm's input cost and the newly-integrating downstream firm's input price. Thus, counter-merger induces the already-integrated firm to increase its cost-reducing investments, thereby reducing the newly-integrating firms' profits.

6. Conclusion

In this paper we have demonstrated that, even without any commitment power on the part of the merging firms, privately profitable but socially anticompetitive vertical integration can arise in equilibrium. We have shown that cost-reducing investments by upstream firms provide a credible channel through which the integrated firm can raise the input price of the unintegrated downstream firm. We have constructed a simple yet tight equilibrium model of anticompetitive vertical integration which addresses the main criticisms of the Chicago school on the classical vertical foreclosure theory, including the possibility of the counter-merger of the unintegrated firms and the potential hold-out problems among the upstream firms.

In sum, our analysis shows that the classical vertical foreclosure theory can be put on firm analytical foundations.[29] While our model builds upon the important contribution by OSS (1990), our results are substantially stronger than theirs. First, we have dispensed with the problematic assumption that the integrated firm can make a price commitment. Second, we have shown that anticompetitive vertical integration can occur in equilibrium even under Cournot downstream competition (without inducing counter-merger by the remaining firms or causing hold-out problems among the upstream firms).

While our model shows that a profitable but anticompetitive vertical integration can indeed arise in equilibrium, it is without question that a profitable vertical integration can be procompetitive at the same time. Even in our simple model, investments by the integrated upstream firm could *increase* (rather than decrease) if the double markups under non-integration are sufficiently high. In that case, vertical integration can result in both reduced output prices and higher overall social welfare.[30] Therefore, even our simple model indicates that the antitrust authorities should weigh the potential efficiency gains (including the elimination of double markups) of vertical integration against the possible anticompetitive effects (increased input prices for the unintegrated downstream firms).

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[29] In a related paper, we show that anticompetitive vertical integration can also arise in a setting where upstream firms choose input specifications. We show that the vertically integrated firm can succeed in raising the rival downstream firm's costs by tailoring its input to the specific needs of its downstream division. An unintegrated firm, on the other hand, chooses a "generalized" input which can be used for any downstream firm. For details, see Choi and Yi (1996).

[30] Of course, we do not need investments to obtain these results. The main novelty of our work is to establish conditions under which vertical integration with investments results in higher prices and a lower social surplus.

Appendix A

1. Proof of Lemma 1 (1) In equilibrium, $U1$ quotes m_1^{NI} to $D2$ and $m_2^{NI} + s$ to $D1$ (and similarly for $U2$). (2) Since the integrated firm $U1$-$D1$ cannot make any price commitment, it is willing to supply the competing downstream firm $D2$ at cost, i.e., at m_1^{PI}. Hence, $U2$ charges $m_1^{PI} + s$ to $D2$. Similarly, the internal transfer price of $U1$-$D1$ is given by its cost. *Q.E.D.*

2. Proof of Proposition 2 For $s = s_1(m^{NI})$, $\pi_{U1}^{PI} + \pi_{D1}^{PI}$

$$= [p_1(\overline{m} - K_1^{PI}, \overline{m} - K_1^{PI} + s) - (\overline{m} - K_1^{PI})]q_1(\overline{m} - K_1^{PI}, \overline{m} - K_1^{PI} + s) - I(K_1^{PI})$$

$$> [p_1(\overline{m} - K_1^{NI}, \overline{m} - K_1^{NI} + s) - (\overline{m} - K_1^{NI})]q_1(\overline{m} - K_1^{NI}, \overline{m} - K_1^{NI} + s) - I(K_1^{NI})$$

$$= [p_1(\overline{m} - K^{NI} + s, \overline{m} - K^{NI} + s) - (\overline{m} - K^{NI})]q_1(\overline{m} - K^{NI} + s, \overline{m} - K^{NI} + s) - I(K_1^{NI})$$

$$= \pi_{U1}^{NI} + \pi_{D1}^{NI}.$$

The first inequality follows from $K_1^{PI} < K^{NI}$ and the strict concavity of $U1$-$D1$'s profit function in K_1. The second equality follows from Lemma 2. By continuity, there exists a critical value of the switching cost $\tilde{s}_1(m^{NI})$ such that vertical integration with investments raises $U1$-$D1$'s joint profits for $\tilde{s}_1(m^{NI}) < s \leq s_1(m^{NI})$. *Q.E.D.*

3. Proof of Proposition 3

If $K_1^{PI} = 0$, then the proof follows from our assumption that $K^{FI} > 0$. Thus, suppose that $K_1^{PI} > 0$. It is straightforward to show that $\dfrac{(\partial q_1/\partial p_2)[(\partial p_2/\partial c_1) + (\partial p_2/\partial c_2)]}{(\partial q_1/\partial p_1)}$ is a weakly decreasing function of c_2 under Assumption 2.2. We have

$$\frac{\partial[\pi_{U1}^{PI} + \pi_{D1}^{PI}]}{\partial K_1}\bigg|_{K_1 = K^{FI}} = q_1(m^{FI}, m^{FI} + s)\left\{1 + \frac{(\partial q_1/\partial p_2)[(\partial p_2/\partial c_1) + (\partial p_2/\partial c_2)]}{(\partial q_1/\partial p_1)}\bigg|_{(m^{FI}, m^{FI} + s)}\right\}$$

$$- q_1(m^{FI}, m^{FI})\left\{1 + \frac{(\partial q_1/\partial p_2)(\partial p_2/\partial c_1)}{(\partial q_1/\partial p_1)}\bigg|_{(m^{FI}, m^{FI})}\right\}$$

$$\leq \left[q_1(m^{FI},m^{FI}) + s\frac{\partial q_1}{\partial c_2}\right]\left\{1 + \frac{(\partial q_1/\partial p_2)[(\partial p_2/\partial c_1) + (\partial p_2/\partial c_2)]}{(\partial q_1/\partial p_1)}\right\} - q_1(m^{FI},m^{FI})\left\{1 + \frac{(\partial q_1/\partial p_2)(\partial p_2/\partial c_1)}{(\partial q_1/\partial p_1)}\right\}$$

$$= q_1(m^{FI},m^{FI})\frac{(\partial q_1/\partial p_2)(\partial p_2/\partial c_2)}{(\partial q_1/\partial p_1)} + s\frac{\partial q_1}{\partial c_2}\left\{1 + \frac{(\partial q_1/\partial p_2)[(\partial p_2/\partial c_1) + (\partial p_2/\partial c_2)]}{(\partial q_1/\partial p_1)}\right\}$$

$$\leq s\frac{(\partial q_1/\partial c_2)}{(\partial q_1/\partial p_1)}\left\{2\frac{\partial q_1}{\partial p_2}\frac{\partial p_2}{\partial c_2} + \frac{\partial q_1}{\partial p_1} + \frac{\partial q_1}{\partial p_2}\frac{\partial p_2}{\partial c_1}\right\} < 0.$$

The first equality follows from equations (7) and (14). The first inequality follows from the first-order Taylor expansion to q_1 and the last part of Assumption 2.1 (all terms are now evaluated at (m^{FI},m^{FI})). The second inequality follows from Assumption 4.2, and the final inequality from Assumption 3.2. $Q.E.D.$

5. Proof of Proposition 4 Consider the following maximization problem of $U2$-$D2$:

$$\underset{K_2}{Max}\ \hat{\pi}_{U2} + \hat{\pi}_{D2} = [p_2(m_2,m_2) - m_2]q_2(m_2,m_2) - I(K_2). \tag{6'}$$

Notice the similarity between the above maximization problem and $U1$-$D1$'s problem given in (6). In both cases, the competing downstream firm's input price is controlled by the integrated firm's investment. The only difference is the competing downstream firm does not have a double markup in (6'). We assume that the maximization problem in (16) is strictly concave in K_2 so that it has a unique solution $\hat{K}_2$. The next result shows that $\hat{K}_2 \leq K_1^{PI}$.

Lemma A-1 Under Assumptions 1 and 2, $\hat{K}_2 \leq K_1^{PI}$.

Proof. $\left.\dfrac{\partial[\hat{\pi}_{U2} + \hat{\pi}_{D2}]}{\partial K_2}\right|_{K_2=K_1^{PI}}$

$$= q_1(m_1^{PI},m_1^{PI})\left\{1 + \frac{(\partial q_1/\partial p_2)[(\partial p_2/\partial c_1) + (\partial p_2/\partial c_2)]}{(\partial q_1/\partial p_1)}\Bigg|_{(m_1^{PI},m_1^{PI})}\right\} - I'(K_1^{PI})$$

$$\leq q_1(m_1^{PI}, m_1^{PI}) \left\{ 1 + \frac{(\partial q_1 / \partial p_2)[(\partial p_2 / \partial c_1) + (\partial p_2 / \partial c_2)]}{(\partial q_1 / \partial p_1)} \Bigg|_{(m_1^{PI}, m_1^{PI})} \right\}$$

$$- q_1(m_1^{PI}, m_1^{PI} + s) \left\{ 1 + \frac{(\partial q_1 / \partial p_2)[(\partial p_2 / \partial c_1) + (\partial p_2 / \partial c_2)]}{(\partial q_1 / \partial p_1)} \Bigg|_{(m_1^{PI}, m_1^{PI} + s)} \right\} < 0.$$

The first inequality follows from equation (7). The second inequality follows from

Assumption 1 (q_1 is an increasing function of c_2) and Assumption 2.2

($\dfrac{(\partial q_1 / \partial p_2)[(\partial p_2 / \partial c_1) + (\partial p_2 / \partial c_2)]}{(\partial q_1 / \partial p_1)}$ is a weakly decreasing function of c_2).   *Q.E.D.*

We now turn prove Proposition 4, using Lemma A-1. From equation (10) and $I''(K) > 0$,

$$[K_2^{PI} - K_1^{PI}] q_2(m_1^{PI}, m_1^{PI} + s) = [K_2^{PI} - K_1^{PI}] I'(K_2^{PI}) \geq I(K_2^{PI}) - I(K_1^{PI}). \text{ For } s = s_2(m_1^{PI}),$$

$$\pi_{U2}^{PI} + \pi_{D2}^{PI} =$$

$$[p_2(m_1^{PI}, m_1^{PI} + s) - (m_1^{PI} + s)] q_2(m_1^{PI}, m_1^{PI} + s) + [K_2^{PI} - K_1^{PI} + s] q_2(m_1^{PI}, m_1^{PI} + s) - I(K_2^{PI})$$

$$= [p_2(m_1^{PI}, m_1^{PI}) - m_1^{PI}] q_2(m_1^{PI}, m_1^{PI}) + [K_2^{PI} - K_1^{PI}] q_2(m_1^{PI}, m_1^{PI}) - I(K_2^{PI})$$

$$\geq [p_2(m_1^{PI}, m_1^{PI}) - m_1^{PI}] q_2(m_1^{PI}, m_1^{PI}) - I(K_1^{PI})$$

$$> [p_2(m^{FI}, m^{FI}) - m^{FI}] q_2(m^{FI}, m^{FI}) - I(K^{FI}) = \pi_{U2}^{FI} + \pi_{D2}^{FI}.$$

The second equality follows from $s = s_2(m_1^{PI})$. The first inequality follows from

$[K_2^{PI} - K_1^{PI}] q_2(m_1^{PI}, m_1^{PI} + s) \geq I(K_2^{PI}) - I(K_1^{PI})$. The second inequality follows from the strict

concavity of $\hat{\pi}_{U2} + \hat{\pi}_{D2}$ in K_2 and from $\hat{K}_2 \leq K_1^{PI} < K^{FI}$. By continuity, we can find $\hat{s}_2(m_1^{PI})$

$> s_2(m_1^{PI})$ such that counter-integration reduces $U2$'s and $D2$'s combined profits for $\hat{s}_2(m_1^{PI}) > s$

$> s_2(m_1^{PI})$. Recall that counter-integration with *fixed* investments reduces $U2$'s and $D2$'s

combined profits for $0 < s < s_2(m_1^{PI})$. Hence, the second equality becomes a strict inequality for

$0 < s < s_2(m_1^{PI})$.   *Q.E.D.*

6. Proof of Proposition 5 Under the conditions in Proposition 3, $K^{NI} > K_1^{PI}$. Vertical integration increases c_2 from $\overline{m} - K^{NI} + s$ to $\overline{m} - K_1^{PI} + s$ and changes c_1 from $\overline{m} - K^{NI} + s$ to $\overline{m} - K_1^{PI}$. Decompose the changes into two steps. First, raise both c_1 and c_2 from $\overline{m} - K^{NI} + s$ to $\overline{m} - K_1^{PI} + s$. Second, reduce c_1 by s. Both steps reduce $D2$'s profits by Assumption 1. *Q.E.D.*

7. Proof of Proposition 7

(1) $I(K) = \gamma K^2/2$, $\gamma > 0$, for $K \le 1/\gamma$ and $I(K) = \infty$, for $K > 1/\gamma$. Since no upstream firm invests more than $1/\gamma$ ($< s$), no upstream firm enjoys a cost advantage over s against the competitor. Hence, the first-order conditions derived in the main text indeed characterize equilibrium and $K^{NI} = (1 - s/3t)/\gamma$. Vertical integration with investments strictly increases $U1$'s and $D1$'s joint profits for $0 < s < \dfrac{3t}{2t\gamma + 1}$.[31] From the proof of Proposition 4, counter-integration reduces $U2$'s and $D2$'s joint profits for $0 < s < 3t/2$. (Assumptions 1 - 4 are satisfied if and only if $s < (3/2)t$.) Since $t\gamma > 1$, counter-integration does not occur for $0 < s < \dfrac{3t}{2t\gamma + 1}$. Assumption 5 is satisfied if and only if $K^{NI} > (3/2)s$, which in turn holds if and only if $s < \dfrac{3t}{2t\gamma + 1}$. And $\pi_{U1}^{PI} + \pi_{D1}^{PI} > \pi_{U2}^{PI} + \pi_{D2}^{PI}$ if and only if $(6t\gamma - 1)s^2 + 6(t\gamma + 1)ts - 9t^2 > 0$. Since $t\gamma > 1$, this inequality is satisfied if and only if $s > s_0$.

(2) $I(K) = \gamma[e^K - 1]$, $\gamma > 0$, for $K > 0$. $K^{NI} = \log\dfrac{1 - s/3t}{\gamma}$ and $K^{FI} = \log\dfrac{2}{3\gamma}$.

(Step 1) (K^{NI}, K^{NI}) is the unique symmetric Nash equilibrium under the non-integrated industry structure. We need to show that investing $K_2 > K^{NI} + s$ or $K_2 < K^{NI} - s$ is not a profitable deviation for $U2$. Investing $K_2 < K^{NI} - s$ is not feasible if $K^{NI} < s$, which holds if and only if $1 - s/3t < \gamma e^s$. This last inequality holds for $s = 2$ and $\gamma = 0.2$ for all $t > 0$, because $0.2e^2 \approx 1.48$. If $U2$ invests $K_2 > K_1 + s$, it supplies $D1$ at $m_1 - s$ and $D2$ at $m_1 + s$. It solves

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[31] Notice that Proposition 2 does not apply directly to the Hotelling model, because for $s = s_1(m^{NI}) = 3t$, we have $K^{NI} = 0$. (Proposition 2 requires that $K^{NI} > 0$.) Nonetheless, for the values of the switching costs identified in the text, vertical integration is profitable with investments but not without investments.

$$\underset{K_2}{Max}\ \hat{\pi}_{U2}^{NI} = [K_2 - K_1 - s]q_1(m_1, m_1 + s) + [K_2 - K_1 + s]q_2(m_1, m_1 + s) - I(K_2). \quad (2')$$

When $U1$ invests K^{NI}, $U2$'s best-response investment $\hat{K}_2^{NI}$ satisfies

$$\frac{\partial \hat{\pi}_{U2}^{NI}}{\partial K_2} = q_1(m^{NI}, m^{NI} + s) + q_2(m^{NI}, m^{NI} + s) - I'(\hat{K}_2^{NI}) = 0. \quad (3')$$

For the Hotelling model, $q_1 + q_2 = 2$. Hence, $\hat{K}_2^{NI} = \log(2/\gamma)$. However, $\hat{K}_2^{NI} < K^{NI} + s$ if and only if $1 - s/3t > 2/e^s$. This last inequality holds for $s = 2$ if and only if $t > 0.77$ (approximately).

(Step 2) $(0, K^{NI})$ *is the unique Nash equilibrium under the partially integrated industry structure.* If $U2$ invests $K_2 > K_1 + s$, it supplies $D1$ at $m_1 - s$ and $D2$ at $m_1 + s$, as in Step 1. Hence, $U2$'s profit function is given by (2') and its optimal investment is $\hat{K}_2^{PI} = \hat{K}_2^{NI}$. When $K_1 = 0$, $U2$'s profit from investing $\hat{K}_2^{PI}$ is $\hat{\pi}_{U2}^{PI} = (\hat{K}_2^{NI} - s)(1 + s/3t) + (\hat{K}_2^{NI} + s)(1 - s/3t) - I(\hat{K}_2^{PI})$ $= 2\log(2/\gamma) - 2s^2/3t - 2 + \gamma$. If $U2$ instead invests K^{NI}, then its profit is $\pi_{U2}^{PI} = (K^{NI} + s)(1 - s/3t)$ $- I(K^{NI}) = (s - 1)(1 - s/3t) + (1 - s/3t)\log\dfrac{1 - s/3t}{\gamma} + \gamma$. Comparison of these two profits shows that $U2$'s optimal investment is K^{NI} if and only if $(1 + s/3t)(1 + s) + (1 - s/3t)\log\dfrac{1 - s/3t}{\gamma} >$

$2\log(2/\gamma)$. For $s = 2$ and $\gamma = 0.2$, a tedious derivation shows that this last inequality is satisfied for all $t > 0$.

(Step 3) (K^{FI}, K^{FI}) *is the unique symmetric Nash equilibrium under the fully integrated industry structure.* If $U2$ invests $K_2 > K_1 + s$, it supplies $D1$ at $m_1 - s$ and $D2$ at m_2. It solves

$$\underset{K_2}{Max}\ \hat{\pi}_{U2}^{FI} + \hat{\pi}_{D2}^{FI} = [K_2 - K_1 - s]q_1(m_1, m_2) + [p_2 - m_2]q_2(m_1, m_2) - I(K_2). \quad (13')$$

When $U1$ invests K^{FI}, $U2$'s best-response investment $\hat{K}_2^{FI}$ satisfies

$$\frac{\partial(\hat{\pi}_{U2}^{FI} + \hat{\pi}_{D2}^{FI})}{\partial K_2} = q_1(\overline{m} - K^{FI}, \overline{m} - \hat{K}_2^{FI}) - [\hat{K}_2^{FI} - K^{FI} - s]\frac{\partial q_1}{\partial c_2}$$

$$+ q_2(\overline{m} - K^{FI}, \overline{m} - \hat{K}_2^{FI})\left\{1 + \frac{(\partial q_2/\partial p_1)(\partial p_1/\partial c_2)}{\partial q_2/\partial p_2}\right\} - I'(\hat{K}_2^{FI}) = 0. \quad (14')$$

$\hat{\pi}_{U2}^{FI} + \hat{\pi}_{D2}^{FI}$ is strictly concave in K_2 for the Hotelling model. Hence, if the partial derivative evaluated at $K_2 = K^{FI} + s$ is negative, then it follows that $\hat{K}_2^{FI} < K^{FI} + s$. We have

$$\left.\frac{\partial(\hat{\pi}_{U2}^{FI} + \hat{\pi}_{D2}^{FI})}{\partial K_2}\right|_{K_2 = K^{FI} + s} = 5/3 - s/9t - (2/3)e^s < 0 \tag{a-4}$$

for $s = 2, t > 0$.

(*Step 4*) *Vertical integration by U1 and D1 increases their joint profits.* $\pi_{U1}^{PI} + \pi_{D1}^{PI} > \pi_{U1}^{NI} + \pi_{D1}^{NI}$ if and only if $s + t - I(K^{NI}) < t(1 + s/3t)^2$, which in turn holds if and only if $(1 - s/3t)(1 - s/3) > \gamma$. For $s = 2$ and $\gamma = 0.2$, this last inequality holds if and only if $t > 5/3$.

(*Step 5*) *Vertical integration by U1 and D1 raises both output prices.* In the Hotelling model, both output prices rise if and only if $K^{NI} > (2/3)s$, or $1 - s/3t > \gamma e^{2s/3}$. For $s = 2$ and $\gamma = 0.2$, this last inequality holds if and only if $t > 2.77$ (approximately).

(*Step 6*) *Hold-out problems among the upstream firms do not arise.* $\pi_{U1}^{PI} + \pi_{D1}^{PI} > \pi_{U2}^{PI} + \pi_{D2}^{PI}$ if and only if $(1 + s/t)s > 3(1 - s/3t)\left[\log\frac{1 - s/3t}{\gamma} - 1\right] + 3\gamma$. For $s = 2$ and $\gamma = 0.2$, a tedious derivation shows that this last inequality holds if and only if $t < 16.76$ (approximately).
Q.E.D.

Appendix B. No price discrimination

Under no price discrimination, the upstream firms simultaneously announce one price each. We begin with non-integration. Assuming that $c_2 - s < c_1 < c_2 + s$, $U1$'s optimal price satisfies the first-order condition

$$q_1(c_1, c_2) - [c_1 - m_1]\frac{\partial q_1(c_1, c_2)}{\partial c_1} = 0. \tag{b-1}$$

(If $c_1 < c_2 - s$, then $U1$ also supplies $D2$. In the Hotelling example, we derive conditions under which this type of deviation is not profitable.) Let $\tilde{c}_i(m_1, m_2)$ be the equilibrium input price. Add the following condition to Assumption 1:

Assumption 1 (3) $0 < \partial \bar{c}_i(m_1, m_2)/\partial m_j \leq \partial \bar{c}_i(m_1, m_2)/\partial m_i < 1$.

Assumption 1.3 states that the equilibrium input prices, which increase with input costs, are more sensitive to its own costs than to competitor's costs. Furthermore, the input price equilibrium is "stable": a dollar increase in the input cost raises the input price by less than a dollar. Assumption 1.3 (which applies to the input market) parallels Assumption 1.1 (which applies to the output market).

$U1$'s investment problem is:

$$\underset{K_1}{Max} \ \tilde{\pi}_{U1}^{NI} = [\bar{c}_1(m_1, m_2) - m_1]q_1(\bar{c}_1(m_1, m_2), \bar{c}_2(m_1, m_2)) - I(K_1). \qquad (b\text{-}2)$$

The symmetric interior equilibrium investment under non-integration, denoted by $\tilde{K}^{NI}$, is implicitly defined by the first-order condition

$$\frac{\partial \tilde{\pi}_{U1}^{NI}}{\partial K_1} = q_1(\bar{c}^{NI}, \bar{c}^{NI}) - [\bar{c}^{NI} - \tilde{m}^{NI}]\frac{\partial q_1}{\partial c_2}\frac{\partial \bar{c}_2}{\partial m_1} - I'(\tilde{K}^{NI}) = 0, \qquad (b\text{-}3)$$

where $\tilde{m}^{NI} = \overline{m} - \tilde{K}^{NI}$ is the equilibrium input cost and $\bar{c}^{NI}$ is the equilibrium input price (defined by (b-1)). (Notice that the investments under non-integration are typically strategic substitutes in the case of no price discrimination. In contrast, investments under non-integration are typically strategic complements in the case of price discrimination.)

Now suppose that $U1$ and $D1$ integrate. As in the case of price discrimination, the combined firm transfers its input to the downstream division at cost and is willing to supply the non-integrated downstream firm $D2$ at cost. Hence, $D2$'s equilibrium input price is $m_1 + s$, as in the case of price discrimination. Thus, $U1$-$D1$'s and $U2$'s investment problems are exactly the same as in the case of price discrimination. The following result shows that, if the upstream profit margin under non-integration is equal to the supplier switching cost, vertical integration reduces upstream investments. Denote the integrated firm's optimal investment by $\tilde{K}_1^{PI}$ and the unintegrated upstream firm's optimal investment by $\tilde{K}_2^{PI}$. Then, $\tilde{K}_1^{PI} = K_1^{PI}$ and $\tilde{K}_2^{PI} = K_2^{PI}$

46

Proposition B-1 Under Assumptions 1 - 4, $\tilde{K}_1^{PI} < \tilde{K}^{NI}$ and $\tilde{K}_2^{PI} < \tilde{K}^{NI}$ for $s = \tilde{c}^{NI} - \tilde{m}^{NI}$.

Proof. For $s = \tilde{c}^{NI} - \tilde{m}^{NI}$, a comparison of (3) and (b-3) shows that $\tilde{K}^{NI} > K^{NI}$. (This result follows from Assumption 1.3.) There is no other difference from Proposition 1. *Q.E.D.*

Propositions 3 and 4 (which concern the effects of counter-integration) apply to the case of no price discrimination without *any* modification (even when s differs from $\tilde{c}^{NI} - \tilde{m}^{NI}$). To see why, simply notice that the investment problems under full integration are exactly the same under both price discrimination and no discrimination. Propositions 2, 5 and 6 apply to the case of no price discrimination for $s = \tilde{c}^{NI} - \tilde{m}^{NI}$. (This can be proved by using Proposition B-1.) Hence, we conclude that for $s = \tilde{c}^{NI} - \tilde{m}^{NI}$, the analysis in the main text apply to the case of no price discrimination.

We now turn to the Hotelling model in order to show the robustness of our results even when $s \neq \tilde{c}^{NI} - \tilde{m}^{NI}$. In the Hotelling model, (b-1) yields the equilibrium input prices under non-integration: $\tilde{c}_i(m_1, m_2) = 3t + [2m_1 + m_2]/3$ so that $\tilde{c}^{NI} - \tilde{m}^{NI} = 3t$. (Recall that $\tilde{c}_i(m_1, m_2)$ is derived under the assumption that $c_2 - s < c_1 < c_2 + s$. For $\tilde{c}^{NI}$ to be a Nash equilibrium, we need $s \geq (3/2)t$. Otherwise, an upstream firm can earn higher profits by cutting its price slightly below $\tilde{c}^{NI} - s$.) The Hotelling model actually *requires* that $s < 3t$. (Otherwise, the non-integrated downstream firm $D2$'s equilibrium output under partial integration is equal to 0. Then, vertical integration by $U1$ and $D1$ necessarily triggers a counter-merger by $U2$ and $D2$.) The following proposition establishes conditions under which an anticompetitive vertical integration arises in equilibrium.

Proposition B-7 Consider the Hotelling model with $I(K) = \gamma K^2/2$, $\gamma > 0$, for $K \leq 2/[3\gamma]$ and $I(K) = \infty$, for $K > 2/[3\gamma]$. Suppose that $3[\sqrt{3} - 1] < \alpha < 3$ and that $2/9 \leq \beta < \min \{ \dfrac{2}{[9 + \alpha][3 - \alpha]}$, $\dfrac{\alpha^2 - 6\alpha - 13}{2\alpha[2\alpha - 3]}$, $\dfrac{2}{9 - \alpha} \}$, where $\alpha \equiv s/t$ and $\beta \equiv t\gamma$. Then, a profitable but anticompetitive (both for consumers and for aggregate efficiency) vertical integration without price discrimination arises

in equilibrium without triggering the counter-integration by the remaining firms or causing hold-out problems among the upstream firms.

Proof. From (b-3), $\tilde{K}^{NI} = 2/[3\gamma]$. Substituting $\tilde{K}^{NI}$ into (b-2) yields $\tilde{\pi}_{U1}^{NI} = \tilde{\pi}_{U2}^{NI} = 3t - 2/[9\gamma]$. Output prices are $\tilde{p}_1^{NI} = \tilde{p}_2^{NI} = \overline{m} + 4t - 2/[3\gamma]$. A downstream firm's profit under non-integration does not change from the case of price discrimination: $\tilde{\pi}_{D1}^{NI} = \tilde{\pi}_{D2}^{NI} = t$. Under partial integration, we obtain the same equilibrium outcome as in the case of price discrimination: $\tilde{K}_1^{PI} = 0$, $\tilde{K}_2^{PI} = [1 - \alpha/3]/\gamma$, $\tilde{p}_1^{PI} = \overline{m} + t + s/3$, $\tilde{p}_2^{PI} = \overline{m} + t + (2/3)s$, $\tilde{\pi}_{U1}^{PI} + \tilde{\pi}_{D1}^{PI} = t[1 + \alpha/3]^2$, $\tilde{\pi}_{U2}^{PI} = s[1 - \alpha/3] + [1 - \alpha/3]^2/[2\gamma]$, and $\tilde{\pi}_{D2}^{PI} = t[1 + \alpha/3]^2$. Hence, vertical integration is profitable if and only if $\beta < \dfrac{2}{[9 + \alpha][3 - \alpha]}$. Both output prices rises if and only if $\beta < \dfrac{2}{9 - \alpha}$.

Hold-out problems do not arise if and only if $\beta > \dfrac{[3 - \alpha]^2}{6\alpha[1 + \alpha]}$, which is implied by $\beta \geq 2/9$.[32]

Under full integration, again, we obtain the same equilibrium outcome as in the case of price discrimination: $\tilde{K}^{FI} = 2/[3\gamma]$ and $\tilde{\pi}_{U1}^{FI} + \tilde{\pi}_{D1}^{FI} = \tilde{\pi}_{U2}^{FI} + \tilde{\pi}_{D2}^{FI} = t - 2/[9\gamma]$. Thus, counter-integration is not profitable if and only if $\beta < \dfrac{\alpha^2 - 6\alpha - 13}{2\alpha[2\alpha - 3]}$. (The second-order conditions require that $\beta \geq 2/9$.) A straightforward derivation shows that there exists a non-empty interval of values of β which satisfies all the conditions for $3[\sqrt{3} - 1] < \alpha < 3$.　　　　　　　*Q.E.D.*

Notice that the investment cost function in Proposition B-7 has a kink at $K = 2/[3\gamma]$. As in Proposition 7, without the kink, $U2$ may find it profitable to increase its investment from $[1 - \alpha/3]/\gamma$ to $2/\gamma$ and supply both downstream firms by cut its price to slightly below $\overline{m} - s$. Again, this cannot happen if vertical integration is a commitment to internal supply by the integrating firms. As in Proposition 7, one can avoid this sudden increase in the investment cost function by examining an exponential cost function.

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[32] Recall that the above derivation assumes that $U2$ sells only to $D2$ (at $\overline{m} + s$). $U2$ can sell to both $D1$ and $D2$ by cutting its price to $\overline{m} - s$. In that case, $U2$'s optimal investment is $2/[3\gamma]$, the maximum feasible investment. (Without the kink in the investment cost function, $U2$ would invest $2/\gamma$.) It is not difficult to show that this deviation is not profitable for $U2$ if and only if $\beta > [11 + 6\alpha - \alpha^2]/[6\alpha(9 - \alpha)]$, which is implied by $\beta \geq 2/9$ and $3[\sqrt{3} - 1] < \alpha < 3$.

Appendix C. Cournot downstream competition

For simplicity, we assume that the final outputs are perfect substitutes. Let $Q = q_1 + q_2$ be the industry output and let $P(Q)$ be the inverse demand function, with $P'(Q) < 0$ when $P(Q) > 0$. The first-order condition for Di is $P(Q) + P'(Q)q_i - c_i = 0$. We make repeated use of this first-order condition in the proofs. Assumptions 1 - 4 are modified as follows:

Assumption C-1 $0 < \dfrac{\partial q_i(c_1, c_2)}{\partial c_j} \leq -\dfrac{\partial q_i(c_1, c_2)}{\partial c_i} \leq Z$, where $j \neq i$, and Z is finite.

Assumption C-2 (1) $\dfrac{\partial}{\partial c_i}\left[\dfrac{\partial q_i}{\partial c_i}\right] \geq 0$, $\dfrac{\partial}{\partial c_j}\left[\dfrac{\partial q_i}{\partial c_i}\right] \leq 0$ and $\dfrac{\partial}{\partial c_j}\left[\dfrac{\partial q_i}{\partial c_j}\right] \leq 0$, $j \neq i$.

(2) $P''(Q) \geq 0$ and $\dfrac{\partial}{\partial c_j}\left[\dfrac{\partial q_j}{\partial c_i} + \dfrac{\partial q_j}{\partial c_j}\right] \geq 0$, $j \neq i$.

Assumption C-3 (1) $[P(m, m+s) - m]\dfrac{\left[\partial q_2(m, m+s)/\partial c_2 + \partial q_2(m, m+s)/\partial c_1\right]}{\left[\partial q_1(m, m+s)/\partial c_1 - \partial q_1(m, m+s)/\partial c_2\right]} > s.$

(2) $-[P(m, m) - m]\dfrac{\partial q_2(m, m)/\partial c_2}{\left[\partial q_1(m, m)/\partial c_2\right]\left[1 - P'(Q)\{(\partial q_1(m, m)/\partial c_2) + (\partial q_2(m, m)/\partial c_2)\}\right]} \geq s.$

Assumptions C-1 and C-2 are almost the same as Assumptions 1 and 2, respectively. These two assumptions are satisfied by the linear demand functions $[P(Q) = a - Q]$. Assumption C-3 combines Assumptions 3 and 4. It requires that the "adjusted" downstream profit margin is higher than the switching cost (i.e., upstream profit margin under non-integration). For the linear demand function, $q_i(c_i, c_j) = [P(c_i, c_j) - c_i] = [a - 2c_i + c_j]/3$. Hence, Assumption C-3 is satisfied if and only if $[P(m, m) - m] > 3s$: the downstream profit margin under full integration is greater than three times the switching cost.

Under non-integration, equation (3) still characterizes equilibrium investments K^{NI}. Under partial integration, the first-order condition of the integrated firm $U1$-$D1$ is given by

$$\frac{\partial(\pi_{U1}^{PI} + \pi_{D1}^{PI})}{\partial K_1} = q_1(\overline{m} - K_1^{PI}, \overline{m} - K_1^{PI} + s) + [P(Q) - m_1]\left\{\frac{\partial q_2}{\partial c_1} + \frac{\partial q_2}{\partial c_2}\right\} - I'(K_1^{PI}) \leq 0, \quad \text{(c-7)}$$

and the unintegrated upstream firm $U2$'s optimal investment K_2^{PI} is still characterized by equation (10). Under full integration, the equilibrium investment K^{FI} is implicitly defined by

$$\frac{\partial(\pi_{U1}^{FI} + \pi_{D1}^{FI})}{\partial K_1} = q_1(\overline{m} - K^{FI}, \overline{m} - K^{FI})\left\{1 - P'(Q)\frac{\partial q_2}{\partial c_1}\right\} - I'(K^{FI}) \leq 0, \qquad (\text{c-14})$$

with equality holding for $K^{FI} > 0$. A comparison of equation (3), (c-7) and (10) yields a result that parallels Proposition 1:

Proposition C-1 Under Assumptions C1 - C3, $K_1^{PI} < K^{NI}$ and $K_2^{PI} \leq K^{NI}$.

Proof. $\left.\dfrac{\partial[\pi_{U1}^{PI} + \pi_{D1}^{PI}]}{\partial K_1}\right|_{K_1 = K^{NI}}$

$$= q_1(m^{NI}, m^{NI} + s) + [P(m^{NI}, m^{NI} + s) - m^{NI}]\left\{\frac{\partial q_2}{\partial c_1} + \frac{\partial q_2}{\partial c_2}\right\} - q_1(m^{NI} + s, m^{NI} + s) +$$

$$s\frac{\partial q_1(m^{NI} + s, m^{NI} + s)}{\partial c_2}$$

$$\leq -s\left\{\frac{\partial q_1}{\partial c_1} - \frac{\partial q_1}{\partial c_2}\right\} + [P(m^{NI}, m^{NI} + s) - m^{NI}]\left\{\frac{\partial q_2}{\partial c_1} + \frac{\partial q_2}{\partial c_2}\right\} < 0.$$

The first equality follows from equations (3) and (c-7). The first inequality follows from the first-order Taylor expansion to q_1 and the first two parts of Assumption 2.1 (all terms in the third and fourth lines are evaluated at $(m^{NI}, m^{NI} + s)$). The second inequality follows from Assumption C-3.1. The proof for $K_2^{PI} \leq K^{NI}$ is exactly the same as in Proposition 1.   *Q.E.D.*

From (c-7) and (c-14), we obtain a result analogous to Proposition 3:

Proposition C-3 Under Assumptions C1 - C3, $K_1^{PI} < K^{FI}$.

Proof. Suppose that $K_1^{PI} > 0$. $\left.\dfrac{\partial[\pi_{U1}^{PI} + \pi_{D1}^{PI}]}{\partial K_1}\right|_{K_1 = K^{FI}}$

$$= q_1(m^{FI}, m^{FI} + s)\left\{1 - P'(Q)\left\{\frac{\partial q_2}{\partial c_1} + \frac{\partial q_2}{\partial c_2}\right\}\Big|_{(m^{FI}, m^{FI} + s)}\right\} - q_1(m^{FI}, m^{FI})\left\{1 - P'(Q)\left\{\frac{\partial q_2}{\partial c_1}\right\}\Big|_{(m^{FI}, m^{FI})}\right\}$$

50

$$\leq s\frac{\partial q_1}{\partial c_2}\left\{1 - P'(Q)\left\{\frac{\partial q_2}{\partial c_1} + \frac{\partial q_2}{\partial c_2}\right\}\right\} - [P(Q) - m^{FI}]\frac{\partial q_2}{\partial c_1} < 0.$$

The first equality follows from equations (c-7) and (c-14). The first inequality follows from the first-order Taylor expansion to q_1 and the last part of Assumption 2.1 (all terms are now evaluated at (m^{FI}, m^{FI})). The second inequality follows from Assumption C-3.2.   Q.E.D.

In the homogeneous-good Cournot oligopoly with constant marginal costs of production, vertical integration raises the output price if and only if the sum of marginal costs increases. As in Section 4, this occurs when the vertically integrated firm reduces its investments sufficiently:

Assumption C-5   If $K^{NI} - K_1^{PI} > s/2$.

The effects of vertical integration on final consumers and overall social surplus are similar to those in Section 4:

Proposition C-6   Under Assumptions C-1 - C-3 and C-5, vertical integration by $U1$ and $D1$ reduces both consumer surplus and overall social surplus.

Proof. $2c^{NI} = 2[\bar{m} - K^{NI} + s] > c_1^{PI} + c_2^{PI} = 2[\bar{m} - K_1^{PI}] + s$ if and only if $K^{NI} - K_1^{PI} > s/2$. The negative effect on social surplus can be proved along the lines in Proposition 6.   Q.E.D.

The above results show that the effects of vertical merger on investments, output prices and social surplus under Cournot downstream competition are analogous to those under Bertrand downstream competition. The *profitability* of vertical integration (and counter-integration), however, can be quite different under different modes of downstream competition. Unlike under Bertrand downstream competition, the initial vertical merger under Cournot downstream competition is *always* profitable in our model. (Both the elimination of the double markup and the adjustment of investments by the integrating firms raise their joint profits.) Since the counter-merger with fixed investments is also always profitable under Cournot downstream

51

competition, the already-integrated upstream firm must raise its cost-reducing investments substantially to make counter-merger unprofitable. In Proposition 8, we stated the conditions under which counter-merger is unprofitable for linear demand functions and quadratic investment cost functions. The proof of this claim follows.

Proof of Proposition 8. From equations (3), (c-7), (10), and (c-14), we obtain $K^{NI} = [\alpha - 2s]/[3\gamma - 1]$, $K_1^{PI} = 2[\alpha + s]/[9\gamma - 2]$, $K_2^{PI} = [3\gamma\alpha - 2(3\gamma - 1)s]/\gamma[9\gamma - 2]$, and $K^{FI} = 4\alpha/[9\gamma - 4]$. (Second-order conditions are satisfied if $\gamma > 8/9$.) The equilibrium outputs are $q^{NI} = [\alpha - s + K^{NI}]/3 = [3\gamma\alpha - (3\gamma + 1)s]/3[3\gamma - 1]$, $q_1^{PI} = [\alpha + s + K_1^{PI}]/3 = 3\gamma[\alpha + s]/[9\gamma - 2]$, $q_2^{PI} = [\alpha - 2s + K_1^{PI}]/3 = [3\gamma\alpha + (6\gamma - 2)s]/[9\gamma - 2]$, and $q^{FI} = [\alpha + K^{FI}]/3 = 3\gamma\alpha/[9\gamma - 4]$. The equilibrium profits are $\pi_{U1}^{NI} = \pi_{D1}^{NI} = sq^{NI} - \frac{\gamma}{2}[K^{NI}]^2$, $\pi_{D1}^{NI} = \pi_{D2}^{NI} = [q^{NI}]^2$, $\pi_{U1}^{PI} + \pi_{D1}^{PI} = [q_1^{PI}]^2 - \frac{\gamma}{2}[K_1^{PI}]^2$, $\pi_{U2}^{PI} = [K_2^{PI} - K_1^{PI} + s]q_2^{PI} - \frac{\gamma}{2}[K_2^{PI}]^2$, $\pi_{D2}^{PI} = [q_2^{PI}]^2$, and $\pi_{U1}^{FI} + \pi_{D1}^{FI} = \pi_{U2}^{FI} + \pi_{D2}^{FI} = [q^{FI}]^2 - \frac{\gamma}{2}[K^{FI}]^2$.

Output price rises (that is, Assumption C-5 is satisfied) if and only if $A > \frac{27\gamma^2 + 33\gamma - 10}{6\gamma}$, where $A \equiv [a - \overline{m}]/s$. (It is not difficult to show that Assumptions C-5 imply Assumptions C-1 - C-3 in this example.) Counter-merger is not profitable (that is, $\pi_{U2}^{PI} + \pi_{D2}^{PI} \le \pi_{U2}^{FI} + \pi_{D2}^{FI}$ if and only if

$$\frac{2\gamma^2[9\gamma - 8][9\gamma - 2]^2 A^2}{[9\gamma - 4]^2} \le [3\gamma A - (6\gamma - 2)][\gamma(6\gamma - 1)A + 2(3\gamma^2 - 5\gamma + 1)]$$

and hold-out problems do not arise (that is, $\pi_{U1}^{PI} + \pi_{D1}^{PI} \ge \pi_{U2}^{PI} + \pi_{D2}^{PI}$) if and only if

$$2\gamma^2[9\gamma - 2]A^2 \ge [3\gamma A - (6\gamma - 2)][\gamma(6\gamma - 1)A + 2(3\gamma^2 - 5\gamma + 1)].$$

For K^{NI} to be a Nash equilibrium under non-integration, a deviation by $U1$ to $K_1 > K^{NI} + s$ must not yield a higher profit than $\pi_{U1}^{NI} = \frac{[-A^2 + (6\gamma + 2)A - (6\gamma + 4 - 2/3\gamma)]}{6[3\gamma - 1]^2}$. It is not difficult to show that, $U1$'s optimal deviation is to $\hat{K}^{NI} = \frac{2q^{NI}}{\gamma}$, with the resulting profit $\hat{\pi}_{U1}^{NI} =$

$\dfrac{2sq^{NI}}{3\gamma}$. A straightforward derivation shows that $\pi_{U1}^{NI} > \hat{\pi}_{U1}^{NI}$ if and only if $A < \dfrac{18\gamma^2 - 15\gamma + 5}{3\gamma}$.

(Rising output price and $\pi_{U1}^{NI} > \hat{\pi}_{U1}^{NI}$ guarantees that $\pi_{U1}^{NI} > 0$.)

Similarly, we need to confirm that deviations to very high or very low investment levels are not profitable under partial integration and full integration. Tedious derivations show that none of these deviations are profitable for $\dfrac{27\gamma^2 + 33\gamma - 10}{6\gamma} < A < \dfrac{18\gamma^2 - 15\gamma + 5}{3\gamma}$ and $\gamma \geq 20/3$.

($\gamma \geq 20/3$ guarantees that this interval is not empty.)

Finally, it is not difficult to show that rising prices ensures that counter-merger is not profitable (for $\gamma \geq 20/3$). Similarly, $\pi_{U1}^{NI} > \hat{\pi}_{U1}^{NI}$ guarantees that no hold-out problems arise. *Q.E.D.*

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