Diagnosing Anticompetitive Effects of Vertical Integration by Multiproduct Firms*

Fernando Luco[†] Guillermo Marshall[‡]

Abstract

The 2020 Vertical Merger Guidelines assume that the elimination of double marginalization caused by vertical integration is procompetitive. A body of research shows that this assumption may fail to hold in multiproduct industries. In this paper, we present a model of a vertical supply chain to analyze equilibrium effects of vertical integration, which we use to shed light on when an elimination of double marginalization may fail to be procompetitive in multiproduct industries. In particular, we discuss diversion ratios as a tool for diagnosing anticompetitive effects.

Keywords: vertical integration, multiproduct firms, elimination of double marginalization, diversion ratios

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[†]Texas A&M University, Department of Economics; fluco@tamu.edu

[‡]University of British Columbia, Sauder School of Business; guillermo.marshall@sauder.ubc.ca

1 Introduction

The 2020 Vertical Merger Guidelines characterize vertical mergers as transactions that "often benefit consumers through the elimination of double marginalization, which tends to lessen the risks of competitive harm".[1] While this assumption seems intuitive, a small body of research suggests that it may fail to hold when the integrated firm is a multiproduct firm (Salinger, 1991, Luco and Marshall, 2020). Given that vertical mergers in multiproduct industries are common, we complement existing work and investigate when such an assumption can be made in vertical transactions that involve multiproduct firms.[2]

Why can we not generally assume an elimination of double margins to be procompetitive in multiproduct industries? Consider the case when a subset of the products that are sold by a firm is exposed to an elimination of double margins. This has two effects on pricing incentives (Salinger, 1991): First, it reduces the downstream firm's perceived cost of selling the products with eliminated double margins (integrated products, henceforth), which thereby induces the firm to set lower prices for these goods (efficiency effect). Second, it makes integrated products more profitable to sell, which creates an incentive to increase the prices of unintegrated substitute products so as to sell more units of the integrated ones (anticompetitive effect). Salinger (1991) shows examples where the anticompetitive effect may dominate the efficiency effect and lead to a loss in consumer welfare caused by vertical integration. Empirical evidence in Luco and Marshall (2020) from vertical transactions in the US carbonated-beverage industry suggest that the anticompetitive effect can be as large as the efficiency effect (in absolute value). Combined, these works suggest that the elimination of double margins that can accompany vertical integration cannot be blindly assumed to be procompetitive in multiproduct industries.

[1] Vertical Merger Guidelines, 2020, pp. 2.

[2] Vertical transactions that involve multiproduct firms include, for example, mergers in the carbonated-soda industry (e.g., The Coca-Cola Company's acquisition of Coca-Cola Enterprises in 2010); mergers in the eyeware industry (e.g., the merger between Luxottica and Essilor in 2018); mergers between retailers and one of their suppliers (e.g., McKesson Canada Corporation's acquisition of Rexall Pharmacy Group Ltd. (2016) and Uniprix (2017), Brown Shoe Co., Inc.'s acquisitions of Wohl Shoe Company and Wetherby-Kayser in 1951 and 1953, respectively); mergers between health insurance companies and hospitals and clinics (e.g., Humana's acquisition of Concentra in 2010, WellPoint Inc.'s acquisition of CareMore Health Group in 2011); mergers in the media industry (e.g., AT&T's acquisition of Time Warner and Disney's acquisition of 21st Century Fox, both in 2019); mergers between drug manufacturers and pharmacy benefit managers (e.g., Merck & Co., Inc.'s acquisition of Medco Managed Care, L.L.C. in 1993, Eli Lilly and Company's acquisition of McKesson Corporation in 1995); and joint ventures in network industries (e.g., MCI Communications Corporation's joint venture with British Telecommunications PLC in 1994); among others.

Our contributions are twofold: First, we provide a detailed discussion of the effect of an elimination of double margins on pricing incentives in multiproduct industries. Second, we present a model of a vertical supply chain to analyze equilibrium effects of vertical integration. We use our analysis to shed light on when the anticompetitive effects that are caused by an elimination of double margins are more likely to arise.

In particular, we discuss how diversion ratios – a tool that is commonly used in merger evaluation – can be used to diagnose whether vertical integration will cause an increase in the prices of unintegrated products.[3] Because computing diversion ratios requires only demand estimates (though other data such as customer surveys could be used), this approach to screening proposed transactions is particularly useful as it saves the researcher and relevant antitrust agencies from having to model the entire vertical chain to predict price changes that are caused by a vertical merger.[4]

The paper is organized as follows: Section 2 presents an economic discussion of the impact of vertical integration on the pricing incentives of a multiproduct firm. We introduce our model in Section 3, and Section 4 presents the equilibrium analysis of vertical integration as well as our discussion of diversion rates as a diagnostic tool. Section 5 concludes,

2 Multiproduct Pricing and Vertical Integration

In this section, we discuss the impact of vertical integration on the pricing incentives of a multiproduct firm. The focus of this section is to identify the various economic effects that are caused by vertical integration, and we postpone the discussion of how these effects interact in equilibrium until the next section.

We consider a downstream monopolist retailer that sells two substitute products – products 1 and 2 – which are produced by two separate upstream firms: U_1 and U_2, respectively.[5] The downstream firm purchases these products at wholesale (linear) prices w_1 and w_2 and then resells them at prices p_1 and p_2.[6] We assume that upstream

[3]Our proposal to use diversion ratios as a diagnosis tool is similar to the one in Moresi and Salop (2013), who propose using measures of vertical gross upward pricing pressure, vGUPPIs. The main differences are that we examine within-firm diversion in the context of multiproduct firms, and that our proposal requires no information about the vertical structure of the industry.

[4]See the current Horizontal Merger Guidelines, sections 4.1.3 and 6.1, and Conlon and Mortimer (2020) for a detailed discussion of diversion ratios and their estimation.

[5]Alternatively, we can think of the downstream firm as one that manufactures both products, with upstream firm U_j supplying all the necessary inputs for product j.

[6]See, for example, Luco and Marshall (2020) and Marshall (2020) for evidence on the use of linear prices along the vertical supply chain. More in general, the issues that we discuss in this article arise so long as the pricing scheme of the upstream firms exhibit a linear component with a

firms choose their wholesale prices: Upstream firms have all of the bargaining power. For simplicity, we assume here that upstream firms face no production costs and the retailer's marginal cost of selling product j is w_j: The retailer faces no costs other than the input costs but we relax these assumptions in the next section.

The multiproduct pricing problem of the downstream retailer is

$$\max_{p_1,p_2} q_1(p_1,p_2)(p_1-w_1)+q_2(p_1,p_2)(p_2-w_2),$$

where w_1 and w_2 are wholesale prices that the downstream firm takes as given. The demand for the goods are given by $q_1(p_1,p_2)$ and $q_2(p_1,p_2)$ and because the products are assumed substitutes, the cross-price effects of demand are positive: $\partial q_1/\partial p_2 > 0$.

The equilibrium prices – p_1^* and p_2^*– solve the first-order necessary conditions

$$\begin{aligned} q_1(p_1^*,p_2^*)+(p_1^*-w_1)\frac{\partial q_1}{\partial p_1}+(p_2^*-w_2)\frac{\partial q_2}{\partial p_1} &= 0 \\ q_2(p_1^*,p_2^*)+(p_2^*-w_2)\frac{\partial q_2}{\partial p_2}+(p_1^*-w_1)\frac{\partial q_1}{\partial p_2} &= 0. \end{aligned} \tag{1}$$

For ease of exposition, we will postpone our discussion about how upstream firms choose their prices until the next section.

Consider now a vertical merger between the downstream retailer and upstream firm U_1. Vertical integration eliminates double marginalization, which causes the wholesale price of product 1 to drop to zero, as we have assumed that U_1 faces no production costs. We assume that w_2 remains at its pre-merger value for ease of exposition, but we relax this assumption in the rest of the paper.

Then, at the premerger prices p_1^* and p_2^*, we can establish the following inequalities that capture the change in pricing incentives of the multiproduct firm,

$$\begin{aligned} q_1(p_1^*,p_2^*)+p_1^*\frac{\partial q_1}{\partial p_1}+(p_2^*-w_2)\frac{\partial q_2}{\partial p_1} &< 0 \\ q_2(p_1^*,p_2^*)+(p_2^*-w_2)\frac{\partial q_2}{\partial p_2}+p_1^*\frac{\partial q_1}{\partial p_2} &> 0. \end{aligned}$$

We establish the signs of these inequalities with the use of the assumptions that demand is downward sloping – $\partial q_1/\partial p_1 < 0$) – and products are substitutes: $\partial q_1/\partial p_2 > 0$). We also note that vertical integration eliminates the terms $-w_1\partial q_1/\partial p_1$ (positive) and $-w_1\partial q_1/\partial p_2$ (negative) from the left-hand side of the first-order conditions of products 1 and 2 in equation (1), respectively.

non-zero markup.

These inequalities isolate the two effects of vertical integration on pricing incentives: First, the elimination of double marginalization makes product 1 cheaper to sell – w_1 drops to zero – which creates an incentive to decrease the price of product 1. This is the efficiency effect of the elimination of double marginalization. Second, the eliminated double margin in product 1 makes product 1 more profitable to sell – at the pre-merger prices, its margin increases from $p_1^* - w_1$ to p_1^* – which creates an incentive to increase the price of product 2 (a substitute for product 1), so as to incentivize consumers to choose (the now more-profitable-to-sell) product 1.[7] In our prior work, we call this anticompetitive effect the Edgeworth-Salinger effect (Luco and Marshall, 2020) .

As argued in Salinger (1991) and Luco and Marshall (2020), the Edgeworth-Salinger effect is an anticompetitive effect that counteracts the efficiency effect and may cause price increases. The Edgeworth-Salinger effect is a form of customer foreclosure, as vertical integration changes the downstream firm's incentives to sell the unintegrated product.[8] Luco and Marshall (2020) provide evidence that the magnitude of the anticompetitive effect can be as large as the efficiency effect (in absolute value), which suggests that the elimination of double marginalization cannot be blindly assumed as procompetitive in multiproduct industries.

We finish this section by noting that the impact of vertical integration on equilibrium prices will depend on the interplay of both the efficiency and Edgeworth-Salinger effects. The efficiency effect may well overwhelm the Edgeworth-Salinger effect but the evidence in Luco and Marshall (2020) and the examples in Salinger (1991) that feature price increases in unintegrated (and even integrated) products show that this is not generally true.

3 Equilibrium Effects of Vertical Integration

To examine how vertical integration affects market outcomes, we use a model that is similar to the ones that are commonly used for merger evaluations. The model allows us to assess when the anticompetitive effects of vertical integration in multiproduct industries are likely to cause harm.

[7]Naturally, upstream firm U_2 will have incentives to decrease w_2 to counteract the Edgeworth-Salinger effect. We incorporate this response into our analysis in the next section.

[8]See Salop (2018) for a discussion of the various forms of foreclosure that are caused by vertical integration.

3.1 Demand

In our model, each consumer decides whether to purchase one of the inside goods or the outside option: $j \in 0, 1, \ldots, J$, with the outside option labeled $j = 0$. The indirect utility function of consumer i for purchasing the inside good j is

$$u_{ij} = -\alpha p_j + \xi_j + \varepsilon_{ij}, \tag{2}$$

where: p_j is the price of good j; ξ_j is an unobserved (from the perspective of the econometrician) product attribute, such as quality; and ε_{ij} is an idiosyncratic shock. As is standard, we normalize the utility of the outside option to be $u_{i0} = \varepsilon_{i0}$.

We assume that the idiosyncratic taste shocks have a nest structure: Specifically, we define two groups of products. The first group – $g = 0$– contains the outside option only; while the second group – $g = 1$– contains the inside goods. The vector of idiosyncratic taste shocks – $\varepsilon_i = (\varepsilon_{i0}, \varepsilon_{i1}, \ldots, \varepsilon_{iJ})$ – has the following joint cumulative distribution function

$$G(\varepsilon) = \exp\left\{ -\exp\{-\varepsilon_0\} - \left(\sum_{j\in\{1,\ldots,J\}} \exp\{-\varepsilon_j\} \right)^{\sigma} \right\}, \quad \sigma \in (0, 1],$$

which allows for correlation between the taste shocks of the inside goods, $(\varepsilon_{i1}, \ldots, \varepsilon_{iJ})$ approximately given by $1 - \sigma$, while keeping ε_{i0} independent from the idiosyncratic taste shocks of the inside goods. This specification is commonly known as the "nested logit" model, which accommodates the special case of the logit model when $\sigma = 1$ when all taste shocks are independent.[9]

3.2 Supply

We consider a market with U upstream firms, each producing a single product that they sell to a downstream retailer. We assume that linear prices are used in all transactions along the vertical chain, and that upstream firms have all the bargaining power when setting wholesale prices. The wholesale price of product j that is set by upstream firm U_j is given by w_j, while the retail price that is set by the retailer for product j is p_j. We assume that the upstream firm U_j's marginal cost of producing product j is c_j^u, and the retailer's marginal cost of selling a unit of product j is $w_j + c_j^r$. The market share of product j, given a vector of retail prices p, is given by $s_j(\mathbf{p})$.

[9] See, for example, Miller and Weinberg (2017) for an empirical implementation of this demand system.

We describe the pricing problem of each type of firm in reverse order, as we solve the game by backward induction. We start by considering the case without vertical integration. In this case, the downstream firm sets its prices taking as given the vector of wholesale prices that have been set by the upstream firms, $\mathbf{w}$, and solves the problem

$$\max_{\{p_j\}} \sum_{j \in J} (p_j - w_j - c^r_j) s_j(\mathbf{p}).$$

The equilibrium retail prices solve the first-order conditions of the multiproduct monopolist,

$$0 = s_j + \sum_{k \in J} \frac{\partial s_k(\mathbf{p})}{\partial p_j} (p_k - w_k - c^r_k), \quad \forall j \in J. \tag{3}$$

We define $\mathbf{p}(\mathbf{w})$ to be the vector of best-response retail prices when the wholesale prices are given by $\mathbf{w}$.

Every upstream firm U_j chooses its wholesale price w_j given the vector of input costs $\mathbf{c^u}$ and taking into consideration how their wholesale prices affect the vector of equilibrium retail prices, $\mathbf{p}(\mathbf{w})$. Upstream firm U_j solves the problem

$$\max_{w_j} \; (w_j - c^u_j) s_j(\mathbf{p}(\mathbf{w})),$$

and the equilibrium wholesale prices solve the first-order necessary conditions

$$0 = s_j(p(w)) + \sum_{h \in J} \frac{\partial s_j(\mathbf{p}(\mathbf{w}))}{\partial p_h} \frac{\partial p_h(\mathbf{w})}{\partial w_j} (w_j - c^u_j), \quad \forall j \in J. \tag{4}$$

Equilibrium strategies are given by the wholesale price vector $\mathbf{w}$ and the correspondence $\mathbf{p}(\mathbf{w})$ that simultaneously solve equations (3) and (4).

We next consider the case where the downstream firm vertically integrates with upstream firm U_1. The problem of the downstream firm and upstream firms remain the same except for the elimination of double margins in product 1, as was described in the previous section: The integrated firm's cost of selling the integrated product equals the upstream marginal cost – $w_1 = c^u_1$ – after vertical integration.

The elimination of double marginalization affects the pricing decisions of the downstream firm, but the best-response function $\mathbf{p}(\mathbf{w})$ does not change. Unintegrated upstream firms still choose their prices by solving equation 4, but their price choices change as their equilibrium beliefs about w_1 are updated to $w_1 = c^u_1$.

3.2.1 An extension

A variation of our model follows Miller and Weinberg (2017) in assuming that the retail prices are determined by the system of equations

$$0 = \lambda s_j + \sum_{k \in J} \frac{\partial s_k(p)}{\partial p_j}(p_k - w_k), \quad \forall j \in J, \tag{5}$$

where $\lambda \in [0, 1]$. This system of equations is identical to the system in equation (3) except for the presence of the retail scaling parameter λ. The parameter λ scales the retail markups between zero ($\lambda = 0$) and the monopoly markups ($\lambda = 1$), and allows us to capture the competitive pressure that is faced by the retailer in a simple way.

3.3 Implementation

The parameters of the model include the demand parameters $(\alpha, \{\xi_j\}_{j \in J}, \sigma)$, the marginal costs of production of upstream firms $\{c_j^u\}_{j \in J}$, the marginal costs of the retailer $\{c_j^r\}_{j \in J}$, and the retail scaling parameter λ. Given a set of parameter values, we solve for the equilibrium before and after vertical integration. Throughout our analysis, we assume that the downstream retailer vertically integrates with the upstream producer U_1: the maker of product 1. Our baseline analysis assumes $J = 2$ – two inside goods and an outside option – though we also present results for markets with more goods. We solve the game numerically using a MATLAB code that we make available to the public.

4 Equilibrium analysis

In this section, we present the impact of vertical integration on the retail prices of both the integrated product – the efficiency effect of vertical integration – and the unintegrated product – the Edgeworth-Salinger effect – as well as other equilibrium objects of interest. As was previously mentioned, we assume that the downstream retailer vertically integrates with the upstream producer U_1: Product 1 becomes the integrated product and product 2 remains the unintegrated product after vertical integration.

Figure 1 presents the first set of results. Panel (a) shows that the efficiency effect of vertical integration leads to price decreases in the integrated product of up to 32 percent, with substantial variation that depends on the particular choice of parameters. In addition, Panel (a) shows that the magnitude of the efficiency effect of vertical integration is increasing in σ (recall that the correlation in the idiosyncratic taste shocks of both products is approximately given by $1-\sigma$). That is, the efficiency effect is largest when the taste shocks are independent and is smallest in the case of perfect substitutes – no product differentiation – all else equal. We explain these findings in detail below.

Panel (b)) shows that the Edgeworth-Salinger effect of vertical integration can cause increases in the price of unintegrated products of up to 2.5 percent; but the effect may also be overwhelmed by the efficiency effect of vertical integration due to the strategic complementarity of prices, which can result in the price of the unintegrated product to decrease as a consequence of vertical integration – despite the upward pricing pressure that is exerted by the Edgeworth-Salinger effect. The figure shows that price increases in the unintegrated products arise for large values of σ: when products are more horizontally differentiated.

Panel (c) shows that the price of the unintegrated product becomes greater relative to the price of the integrated product as σ increases. We explain this relationship with the use of diversion ratios – $-(\partial s_2/\partial p_1)/(\partial s_1/\partial p_1)$ – which measure how much of a quantity decrease in product 1 caused by an increase in p_1 is captured by product 2.

Panel (d) shows the diversion ratio before vertical integration as a function of σ and shows that the diversion ratio decreases in σ. To understand this relationship in Panel (c), recall that vertical integration makes product 1 more profitable to sell, which motivates the downstream retailer to divert demand away from product 2 to boost the sales of product 1. The downstream firm has two ways of doing this: decreasing p_1; and increasing p_2. When products are perceived as close substitutes (small σ), the diversion ratio is high, in which case a small decrease in p_1 is sufficient to divert demand towards product 1. When products are perceived as more differentiated (large σ), the diversion ratio is low, in which case a small decrease in p_1 has a limited effect in diverting demand towards product 1. Hence, the downstream firm must complement a decrease in p_1 with an increase in p_2 to boost the sales of product 1.

As products become more differentiated (large σ), the firm has to become more aggressive in both decreasing p_1 and increasing p_2 to divert demand towards product 1, which explains the patterns in Panels (a)-(c).

Figure 2 is similar to Figure 1, but presents the impact of a demand shifter that is common to both inside options – $\xi = \xi_1 = \xi_2$ – on the equilibrium objects. Crucially, Panel (c) shows that an increase in the demand shifter makes the unintegrated product relatively cheaper than the integrated product. This again can be explained by the effect of the demand shifter on diversion ratios: An increase in ξ leads to an increase in the diversion ratio because the inside goods become more attractive relative to the outside option – which implies that consumers are more likely to substitute towards an inside good than to the outside option. For this reason, an increase in ξ requires the downstream firm to be less aggressive in both decreasing p_1 and increasing p_2 to divert demand towards product 1.

Our numerical examples suggest that vertical integration increases consumer welfare on average. The welfare gains are driven by the efficiency effect of the elimination of double marginalization, which in our examples are larger in magnitude than the Edgeworth-Salinger effect (in absolute value). Hotelling (1932) and Salinger (1988), however, provide examples where welfare unambiguously decreases with vertical integration. In these examples, the Edgeworth-Salinger effect overwhelms the efficiency effect and causes all equilibrium prices to increase. These examples are special in that they feature asymmetric Slutsky matrices – $\partial q_j/\partial p_i \neq \partial q_i/\partial p_j$ – which are often viewed as a departure from consumer rationality (Aguiar and Serrano, 2017).

Though one may be tempted to consider these cases to be exceptions rather than the norm, the range of industries in which consumer behavior is consistent with limits on consideration set formation is large enough so as to warrant the attention of practitioners and researchers. Examples that have been studied in the literature include: consideration sets that arise from consumer search's being costly or consumers facing information asymmetries (Goeree, 2008 and Pires, 2016); settings in which consumers consider only the highest ranked products according to some measure (Honka, 2014, Honka et al., 2017); settings in which default options play an important role (Hortaçsu et al., 2017, Abaluck and Adams-Prassl, 2021, and Dressler and Weiergraeber, 2019); and settings in which incumbency status may be relevant (Gugler et al., 2018), among others.[10] This evidence offers plausibility to the examples in Hotelling (1932) and Salinger (1988) and suggest that measuring diversion ratios without ex-ante imposing Slutzky matrix symmetry may be a good practice (Hendel et al., 2017). Further, this may explain why the anticompetitive effect estimates in Luco and Marshall (2020) – which were computed without imposing demand function restrictions – are so large relative to the efficiency effect estimates.

4.1 Extensions

4.1.1 Downstream competition

In Sections 3 and 4, we have thus far examined the effect of vertical integration on pricing incentives in the context of a downstream monopolist. Our findings, however,

[10] When consumers form consideration sets, consumers are choosing to consider only a subset of the full set of products that are available to them.

do not depend on this assumption. As we explained in subsubsection 3.2.1, we follow Miller and Weinberg (2017) in incorporating downstream competition in the analysis with the use of a scaling parameter $\lambda \in [0, 1]$ that scales retail markups between those of a monopolist ($\lambda = 1$, our baseline) and zero ($\lambda = 0$) (see equation (5)).

We find that our economic analysis is robust to values of λ that are smaller than one. The exception is when the value of λ is so small that double marginalization does not arise in equilibrium – when λ is less than 0.35 in our simulations – in which case vertical integration has a small effect on the pricing incentives of the downstream retailer.[11]

4.1.2 Upstream competition

Our baseline specification considers the case with $J = 2$ inside goods. We explore whether the Edgeworth-Salinger effect can also arise in markets with more goods. To this end, we compute the equilibrium of our model allowing for up to 15 products in the particular case when $\sigma = 1$: the logit model. Across all these specifications, we see that vertical integration affects pricing incentives as described above, although the effects vary in magnitude with the number of products.

5 Discussion

In contrast to the assumption in the 2020 Vertical Merger Guidelines, our findings suggest that an elimination of double margins may cause anticompetitive price increases in multiproduct industries. Our equilibrium analysis shows that these anticompetitive price effects are more likely to arise when the diversion ratio between products is low – when products are more distant substitutes– which renders diversion ratios a useful tool in diagnosing whether vertical integration will cause price increases in the unintegrated product.

Diversion ratios are already commonly used when screening horizontal mergers (see, for example, the 2010 Horizontal Merger Guidelines, Farrell and Shapiro, 2010, Conlon and Mortimer, 2020). Using them to screen vertical mergers has the added benefit that it saves the researcher from having to specify a model of the vertical supply chain to make predictions about price changes that are caused by vertical integration. In fact, computing diversion ratios requires only demand estimates as well less data and fewer assumptions than what would be needed to estimate a model of the vertical supply chain.

[11] Double marginalization does not arise when λ is small because competition is so intense that the retailer must absorb the entirety of the (perceived) cost increase.

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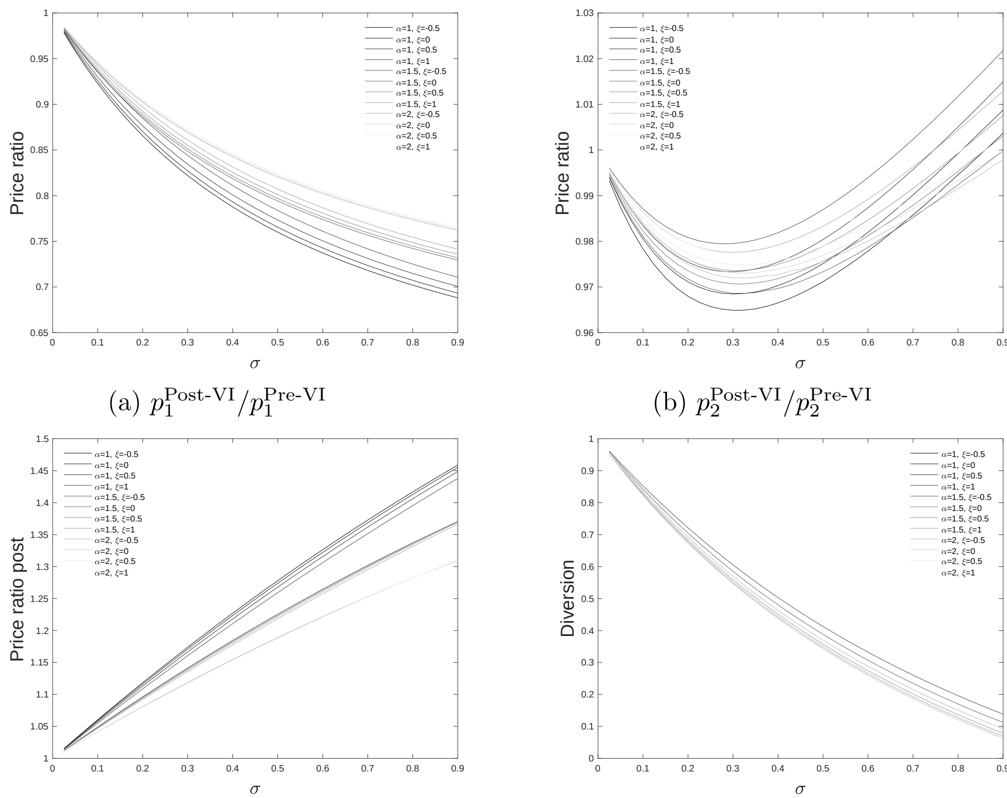


(a) $p_1^{\text{Post-VI}}/p_1^{\text{Pre-VI}}$

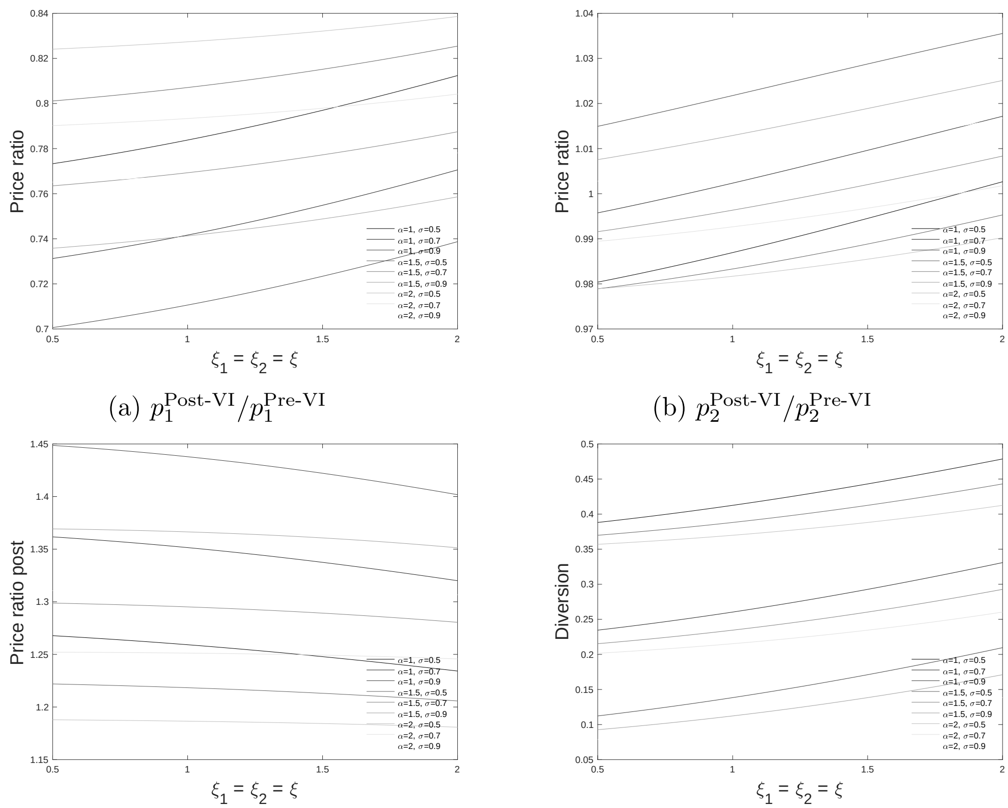
(b) $p_2^{\text{Post-VI}}/p_2^{\text{Pre-VI}}$

(c) $p_2^{\text{Post-VI}}/p_1^{\text{Post-VI}}$

(d) Diversion ratio before VI

FIGURE 1: Impact of vertical integration on retail prices, as a function of σ

Notes: The parameters α and $\xi = \xi_1 = \xi_2$ are reported in the legend. The parameter σ is reported on the x-axis. c_j^r and c_j^u are set at 0.5 for $j = 1, 2$.



(a) $p_1^{\text{Post-VI}}/p_1^{\text{Pre-VI}}$

(b) $p_2^{\text{Post-VI}}/p_2^{\text{Pre-VI}}$

(c) $p_2^{\text{Post-VI}}/p_1^{\text{Post-VI}}$

(d) Diversion ratio before VI

FIGURE 2: Impact of vertical integration on retail prices, as a function of ξ

Notes: The parameters α and σ are reported in the legend. The parameter $\xi = \xi_1 = \xi_2$ is reported on the x-axis. c_j^r and c_j^u are set at 0.5 for $j = 1, 2$.