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Horizontal Mergers With One Capacity Constrained Firm Increase Prices?

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Abstract

It is often claimed that horizontal mergers cannot cause price increases if one of the merging firms is capacity constrained. The argument is that the constraint prohibits the post-merger recapture of lost sales, and thereby disables the mechanism by which merger-induced price increases occur. In this paper we show that this claim is incorrect. We show that mergers between substitutes in which one of the merging firms faces a binding pre-merger capacity constraint unambiguously increase prices. The intuition is simple. Even if there is no recapture of lost sales, a merger causes the acquiring entity to take into account the effect of a change in the price of its good on the price of the acquired good. In a price setting context where the constraint continues to bind post-merger, this reduces to the simple fact that an increase in the price of the unconstrained good also increases the price at which the constrained good sells out its capacity, which is internalized post-merger. This result points to the danger of focusing only on lost sales, and ignoring the internalization of higher prices.

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1 Introduction

In recent years it has become common to explain the price effects of horizontal mergers by reference to the "recapture of lost sales" intuition. Before a merger, each firm chooses the price that equates the negative effect of an infinitesimal price increase (lost marginal sales) against the positive effect (higher price on all infra-marginal sales). Those lost marginal sales will be divided among competing firms, except for those that drop out of the market. After a merger with one of the competing firms, the fraction of total sales lost that go to that firm (equal to the diversion ratio), and the associated profits, will be recaptured and will no longer be lost by the merged entity. The negative effect of a price increase gets smaller after the merger, while the positive effect stays the same, which means that the pre-merger price can no longer be the profit-maximizing price; absent efficiencies, the new profit-maximizing price must be higher.¹

This familiar recapture intuition has been used to justify the claim that if one merging party faces a capacity constraint that binds in the pre-merger equilibrium, and continues to bind in the post-merger equilibrium, then the merger cannot increase prices.² The argument is that the pre-merger price of the constrained good is set so that the quantity demanded at that price equals the capacity constraint, given the prices of rival firms. After the merger, there is no incentive to raise the price of the unconstrained good because none of the customers lost as a result of that higher price can purchase the constrained good. Since the price of the unconstrained good will not change, there is no benefit to increasing the price of the constrained good, as that is the price at which profits are already maximized. Thus, the merger will have no effect.

¹This intuition has entered antitrust practice in the form of Upward Pricing Pressure (UPP) analysis. See the DOJ/FTC Horizontal Merger Guidelines (2010) and Farrell and Shapiro (2010). In its simplest form, UPP analysis involves comparing the recaptured profits from an infinitesimal price increase (equal to the diversion ratio times the profit margin on recaptured sales) against the marginal cost efficiencies in order to determine whether or not a merger will increase price. There are now a number of simulation methods that extend this idea to generate quantitative predictions on the magnitudes of the price increases, as well as research evaluating the accuracy of those methods. See Weyl and Jaffe (2013) and Miller et al. (2016, 2017). This idea is referred to as the "value of diverted sales" in Section 6.1 of the Horizontal Merger Guidelines.

²Neurohr (2016) makes this claim only with regard to the case where one of the merging firms faces a capacity constraint that binds in both the pre-and post-merger equilibria. He correctly points out that prices will increase when the constraint does not bind in the pre-merger equilibrium. Moreover, the authors of present paper have commonly heard this claim made in non-public correspondence in merger cases.
This paper explains why the above argument is incorrect. Our primary insight is that a merger causes the price setter of the unconstrained good to become the residual claimant of the constrained good. Before the merger, the unconstrained firm does not internalize the effect of its price on the price of the constrained firm, specifically the price at which the constrained firm continues to sell out its capacity. But after the merger, the merged entity does internalize this effect. We show that as long as the products are substitutes, this creates an incentive to raise both prices by at least a small amount.

This intuition applies in both a Cournot model where undifferentiated firms compete in quantities and in a Bertrand model where differentiated firms compete in prices. The Cournot results are less technically complicated and so can be proven with more generality. For this reason, we discuss the Cournot results first. However, the incorrect recapture argument discussed above is usually made in the context of price setting models.

Using a Cournot model with homogeneous goods, we provide a general proof that mergers increase the market price when one of the merging firms is capacity constrained before the merger. This price increase occurs whether or not the constraint continues to bind post-merger. The key intuition, again, is that the owner of the unconstrained plant becomes the residual claimant on the sales of the constrained plant. This makes demand for the merged entity more inelastic; the merged entity will reduce quantity relative to the pre-merger quantity level in response to this change in elasticity. The remaining firms will increase quantity, but by less than the quantity reduction by the merged entity, so total market quantity will decrease, which raises the market price of the good. This is true whether or not the constraint continues to bind in the post-merger equilibrium.

This intuition is very similar to the standard intuition for mergers in Cournot models: mergers increase prices because the merged entity internalizes the effect of a price increase on its merger partner. There is no recapture of lost sales in these models, so the confusion that has led to the incorrect argument discussed above is avoided. It is only in the Bertrand model that the issue arises.

General results are more difficult to prove in a Bertrand model. This is because of the well-known problem that pure strategy equilibria may not exist in price-setting games with upward-sloping marginal cost curves. This problem is certain to exist when the marginal cost curve is vertical at the capacity constraint, as we assume. Rather than attempt to model a mixed strategy equilibria, we instead consider two special cases.
In the first Bertrand example, we make a restrictive assumption about consumer behavior that ensures that a pure strategy equilibrium does exist. Under this assumption, we show that mergers unambiguously raise both prices when one of the merging firms faces a capacity constraint that binds in the pre-merger equilibrium. Our primary insight is that, as in the case of Cournot competition, the merger causes the price setter of the unconstrained good to become the residual claimant of the constrained good. Specifically, before the merger, the unconstrained firm does not internalize the effect of its price on the price at which the constrained good sells out its capacity. After the merger, the merged entity internalizes this effect, which holds even if there are no recaptured sales.

The pre-merger price of the constrained good is the price at which its quantity demanded just equals the capacity constraint, given the prices of rivals. If the two goods are substitutes, then an increase in the price of the unconstrained good diverts some demand to (i.e., shifts out demand for) the constrained good, which creates excess demand for that good. This means that the price of the constrained good can be increased by some amount while continuing to sell out at the constraint. This higher capacity-clearing price increases the profits of the constrained good, as the same quantity is sold at a higher price. And since the unconstrained firm’s pre-merger profit-maximizing price has the property that the firm is indifferent between increasing it by an infinitesimal amount and not, internalizing this effect is sufficient for the merged entity to increase both prices post-merger. Therefore, the result is just like the standard Bertrand result in the unconstrained case: absent efficiencies, mergers between firms with positive diversion ratios unambiguously increase the price of both goods by at least a small amount. For closely related reason, this is also true in the case where the constraint does not bind in the post-merger equilibrium.

In the second Bertrand example, we consider a market with only two firms. We observe that while the lack of a pure strategy equilibrium is a problem in the pre-merger environment, it is not a problem in the post-merger environment. The merged entity simply chooses the joint profit maximizing prices of the two goods, and all strategic considerations are removed. We show that starting at the post-merger equilibrium and "unmerging" the two firms, there is downward pricing pressure on both prices. This is true whether or not the constraint continues to bind in the post-merger equilibrium. We also discuss the relationship between the support of the prices in the mixed strategy "post-unmerger" (i.e., pre-merger) equilibrium and the post-merger prices.
The remainder of the paper proceeds as follows. Section 2 contains a review of relevant literature. Section 3 contains the Cournot results, including numerical examples. Section 4 contains the Bertrand Results. Section 5 concludes.

2 RELATED LITERATURE

A substantial theoretical literature has explored the effect of capacity constraints on competition in oligopolistic markets (e.g. Levitan and Shubik (1972), Bresnahan and Suslow (1989), and Compte, Jenny, and Rey (2002)). Only a few papers in this literature deal with the specific question that we address, namely the effect of capacity constraints on unilateral price effects of mergers.

Perhaps the best known of these papers is Froeb et al. (2003), who use a Bertrand-based computational oligopoly model to simulate the effects of hypothetical mergers of parking garages. They show that the presence of a capacity constraint that is binding on one of the pre-merger firms reduces the price effect of a merger by about half. Unlike our paper, Froeb et al. (2003) do not show that merger effects are necessarily positive even in the presence of a binding capacity constraint on one of the merging firms, nor do they articulate a reason why this must be so. However, their finding that a binding pre-merger capacity constraint on one of the merging firms mitigates the magnitude of the price effect is consistent with the results of our own parametric examples, and with the findings of prior literature including Hosken et al. (2002) and Higgins et al. (2004).

Another related paper is Neurohr (2016), which adjusts the UPP framework used by competition authorities in merger investigations to account for pre-merger capacity constraints. That paper, like ours, finds that a capacity constraint that binds one of the firms pre-merger mitigates merger effects. However, it deals exclusively with the case where the merged entity chooses not to sell out the constrained good post-merger. The paper does contain a brief mention of the case in which the constraint continues to bind post-merger. Neurohr says that, “If the constraint still holds post merger, the merger has no effect.” As we show in the present paper, this claim is incorrect.

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Froeb et al. (2003) do not distinguish between the case where the constrained good continues to sell out post-merger vs. the case where post-merger quantity of the constrained good is reduced. Therefore, it is not clear to which of these cases their results apply. Moreover, despite their finding of a positive merger effect when one of the merging firms is capacity constrained pre-merger, the paper contains language that suggests the opposite: “In the case where the merged firm is capacity-constrained, there is no merger price effect.” This comment may have contributed to the confusion surrounding this subject.
Greenfield and Sandford (2017) independently discovered some of the same results as the present paper, though their description of the underlying intuition is somewhat different from ours. Their paper also develops simulation methods for predicting merger effects quantitatively, allowing for differences in capacity, cost, and demand across firms.

As discussed in Section 4 below, introducing a capacity constraint into a Bertrand model means that the unconstrained firm faces a convex kink in its demand curve, which eliminates the possibility that a pure strategy pre-merger equilibrium exists. This well-known problem is discussed by Shapley and Shubik (1969) and by Levitan and Shubik (1972), who characterized a mixed strategy equilibrium for Bertrand games with capacity constraints.

The papers already discussed in this review either implicitly ignore this problem or simply assume that the problem is quantitatively small enough that it can be ignored in their quantitative analysis. However, Chen and Li (2014) confront this problem directly in a Bertrand game (they do not model a quantity-setting game). They analyze mixed strategy equilibria in a symmetric firm, homogenous good Bertrand model with symmetric capacity constraints in order to determine merger price effects. In their model, a merger between two identically capacity constrained firms (where the rest of the firms in the market are also constrained) can produce a merger price effect. Unlike our paper, their model does not allow for differentiated goods or for one firm to be unconstrained pre-merger. Moreover, they do not develop a general intuition for why a merger in which one firm is capacity constrained pre-merger must increase prices.

3 COURNOT MODEL

In this section we analyze merger effects in a Cournot model where one of the merging firms faces a capacity constraint that binds in the pre-merger equilibrium. We show that for general demand, a merger between the constrained firm and one of any number of symmetric unconstrained firms with identical cost functions results in a higher post-merger price.\footnote{Relaxing the symmetry assumption would cause different firms to have different cost functions, which would cause asymmetric equilibrium quantities among non-constrained firms. The proof method that we use below can be extended to accommodate this. But doing so would require defining a sequential mapping firm by firm, which is an algebra intensive process that adds no additional intuition, so we omit it for brevity. However, later in this section we present an intuitive discussion of the results of relaxing the symmetry assumption.} This is true whether or not...
the constrained good remains constrained after the merger. We also discuss how this result can be extended to a model of firms with non-identical cost functions.

The intuition behind this result is straightforward. Consider a standard symmetric Cournot model with no capacity constraints and marginal cost functions that have the necessary properties for a merger between two of the firms to be profitable. In the pre-merger equilibrium, each firm’s quantity is the one at which the loss from a small quantity reduction (fewer sales) is equal to the benefit (higher market price, which the firm will enjoy for all infra-marginal sales, as well as movement down the marginal cost curve). After the merger, each firm takes into account the fact that the price increase resulting from a quantity reduction will also benefit the merger partner, so these pre-merger equilibrium quantities cannot be the post-merger equilibrium quantities, which must be lower. This reduction in quantity by the merging firms results in an expansion by the non-merging firms, because the price is higher and sales are more profitable, but not by enough to fully restore the pre-merger equilibrium quantity.

The analysis when one firm has a capacity constraint \( k \) that binds in the pre-merger equilibrium is fundamentally similar. Pre-merger, the constrained firm produces quantity \( k \) by assumption. The unconstrained firm chooses the quantity that balances the marginal loss and the marginal benefit of reducing quantity. But the merged entity internalizes the fact that a quantity reduction for the unconstrained good benefits the constrained good, which will still sell \( k \) units but at a higher price. So it reduces its quantity by at least a small amount. If this reduction is not too large, then the constrained good will remain constrained in the post-merger equilibrium. If it is large enough, then the constraint will no longer bind. In either case, the merger reduces total quantity. Note that because

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5 In a well-known paper, Salant, Switzer, and Reynolds (1983) show that in a symmetric Cournot model with constant marginal costs and no capacity constraints, a merger of two firms is never jointly profitable for the merging firms if there are \( n > 2 \) firms in the pre-merger market. The intuition in their model is that the merging firms want to reduce quantity to raise price, but the other competitors increase quantity so much that the profits from selling \( 1/(n - 1) \) of the post-merger quantity at the higher price is less profitable than selling \( 2/n \) of the pre-merger quantity at the lower price. Perry and Porter (1985) show that this result is not robust to the case where Cournot competitors face upward-sloping marginal cost. The upward-sloping marginal cost curves of the non-merging firms make expanding quantity more costly relative to the case with constant marginal cost curves. Informally, the Perry and Porter insight is that a merger between two small firms creates a big firm, not a single firm that is no different than either of the pre-merger firms. For steep enough marginal cost, the effect of non-merging firm expansion is not great enough to completely offset the gains to the merged entity from reducing quantity, and so the merger can be profitable. The numerical examples that we present in Section 3.3 satisfy this condition.
this is a Cournot model of quantity competition with undifferentiated products, it is clear that our result does not depend on Bertrand-style diversion between the merging parties.

3.1 Setup

There are \( n \) firms indexed by \( i \in \{1, 2, ..., n\} \), each with a single plant with identical cost curves. Each plant \( j \) has a total cost curve, \( c(q_j) \) with \( c' > 0 \) and \( c'' \geq 0 \). Without loss of generality, the last \( n - 1 \) firms have no capacity constraint, while Firm 1 has a capacity constraint at \( q_1 = k \). Firm 1’s cost curve is given by \( c(q) \) for \( q_1 \leq k \) and is infinite for any units in excess of \( k \). The market demand curve is denoted by \( p = d(\sum_i q_i) \) with \( d' < 0 \). Each firm chooses a quantity and firm \( j \) earns a profit of \( \pi_j = d(\sum_i q_i) - c(q_j) \). The demand and cost functions \( d(\cdot) \) and \( c(\cdot) \) are such that for any \( \sum_{i \neq j} q_i \), \( \pi_j \) is concave in \( q_j \). In addition, the marginal revenue of firm \( j \) is decreasing in \( \sum_{i \neq j} q_i \). The equilibrium concept is the standard Cournot equilibrium in quantities.

3.2 Equilibrium

We first describe the premerger equilibrium in which Firm 1 produces at the constraint \( k \). This will occur whenever \( d(\cdot) \) and \( c(\cdot) \) are such that the \( n \)-firm unconstrained (symmetric) equilibrium firm quantity \( q^*_j \) is greater than \( k \). We let Firm 1 merge with (WLOG) Firm 2, and call the merged entity Firm 1,2. We consider only those \( d(\cdot), c(\cdot) \) and \( k \) combinations for which the new Firm 1,2 would continue to be capacity constrained at Plant 1 (the plant of the pre-merger Firm 1) post-merger. This would happen if and only if Firm 1,2’s optimal post-merger quantity exceeds \( 2k \). We now state and prove the proposition that any such merger would result in a price increase.

**Proposition 1** If Firms 1 and 2 merge, and if the merged entity’s profits are maximized by operating the constrained plant at its capacity post-merger, then equilibrium market quantity will be lower, and price will be higher, in the post-merger equilibrium than in the pre-merger equilibrium.

**Proof.** The proof proceeds through the following series of lemmas.

**Lemma 1** The optimal quantity of any firm \( j \) depends only on the sum of the quantity choices of the remaining firms and is independent of the distribution of quantity across firms.

**Proof.** This is a well-known property of Cournot equilibria and is stated without proof.

□
Lemma 2 Post merger, the merged Firm 1, 2 would produce a total quantity less than \( q_j^* + k \) if each of the other \( n - 2 \) firms produced \( q_j^* \). That is, the merged entity would choose to reduce its quantity if all non-merging rivals continued to produce their pre-merger quantities.

Proof. The pre-merger equilibrium quantity of Firms 2 through \( n \), \( q_j^* \), satisfies each unconstrained firm’s (identical) first-order condition \( \frac{\partial \pi_j}{\partial q_j} = d’((n - 1)q_j^* + k)q_j^* + d((n - 1)q_j^* + k) - c'(q_j^*) = 0 \). Firm 1, 2’s post-merger profit function is \( \pi_{1, 2} = d(\sum q_i)(k + q^*_2) - c(k) - c(q^*_2) \), where \( q^*_2 \) denotes the quantity produced in the plant owned by Firm 2 pre-merger. Since the post-merger quantity of Plant 1 is fixed at \( k \) by assumption, the FOC for Firm 1, 2 is \( \frac{\partial \pi_{1, 2}}{\partial q_2} = d’((n - 2)q_j^* + k + q^*_2)(k + q^*_2) + d((n - 2)q_j^* + k + q^*_2) - c'(q^*_2) = 0 \). Comparing to the pre-merger FOC, it is clear that the derivative \( \frac{\partial \pi_{1, 2}}{\partial q_2} \), evaluated at \( q^*_2 = q_j^* \), is negative, because \( d’ < 0 \) and because reducing quantity lowers marginal cost. Firm 1, 2 has a larger number of sales affected by a price change, so it will reduce its quantity; its best-response quantity for Plant 2 given the optimal pre-merger production of the other \( n - 2 \) firms is less than \( q_j^* \). We denote this best response quantity \( q^*_2 \).

Lemma 3 Each of the \( n - 2 \) non-merging rivals’ best responses to \( q^*_2 \) is: (i) greater than \( q_j^* \), and (ii) less than \( \frac{(n - 1)q_j^* - q^*_2}{n - 2} \). That is, each of the other \( n - 2 \) firms would increase its quantity in response to Firm 1, 2 reducing quantity at Plant 2 from \( q_j^* \) to \( q^*_2 \), but not by enough that total quantity of all \( n - 1 \) unconstrained firms would be as high as the total premerger quantity.

Proof. Suppose that each non-merging firm were to produce \( q_j^* \) in response to \( q^*_2 = q^*_2 \). The total quantity of firms \( i \neq j \) would then be lower than under the pre-merger equilibrium. Since the marginal revenue of \( j \) is decreasing in \( \sum_{i \neq j} q_j \), \( j \)'s first-order condition is positive and it would want to produce more than \( q_j^* \). That is, the fact that quantities are strategic substitutes is sufficient to prove (i).

To prove (ii), let \( \Delta \) denote the difference between \( q_j^* \) and \( q^*_2 \) and assume that each unconstrained firm increases its quantity to \( q_j^* + \frac{\Delta}{n - 2} \) in response to \( q^*_2 = q^*_2 \), so that total post-merger quantity equals total pre-merger quantity. In that case, the first-order condition for each non-merging firm would be \( \frac{\partial \pi_j}{\partial q_j} = d’((n - 1)q_j^* + k)(q_j^* + \frac{\Delta}{n - 2}) + d((n - 1)q_j^* + k) - c'(q_j^* + \frac{\Delta}{n - 2}) < 0 \). Comparing the two FOCs, and recalling that total quantity is, by assumption, equal to the pre-merger quantity, the market price must be unchanged (i.e., the second term in the two FOCs are identical). Comparing the first term in the two FOCs, we see that the effect on the market price of an additional unit of quantity is the same, but each non-merging firm now has a larger quantity that is affected by that price change. Finally, comparing the third term in the two FOCs, we see that each non-merging firm now has a
higher marginal cost compared to the pre-merger equilibrium. For these reasons, each non-merging firm would want to produce a quantity lower than the level that would fully replace the post-merger reduction in quantity at Plant 2 from $q_j^*$ to $q_2^\#$. By continuity and symmetry, this implies there is a $q_j^* \in (q_j^*, q_j^* + \frac{\Delta}{n-2})$ at which $\frac{\partial \pi_j}{\partial q_j} = 0$. □

Lemma 4  Given quantities of $q_j^\#$ by each non-merging firm, Firm 1,2’s best response quantity for Plant 2 is less than $q_2^\#$.

Proof. Since $q_j^# > q_j^*$, and marginal revenue for Firm 1,2 is decreasing in the total quantity of the non-merging firms, Firm 1,2’s first-order condition evaluated at $q_j = q_j^#$ for each $j \neq 1, 2$ and at $q_2^{post} = q_2^#$ is negative. Thus, Firm 1,2’s best response quantity for Plant 2 is less than $q_2^#$. □

Lemma 5  There exists a post-merger Nash equilibrium in which total quantity is less than the pre-merger quantity level.

Proof. Define an iterative mapping process beginning with Lemmas 2 through 4. Denote the round of the process with superscript $r$. In round $r$, Firm 1,2’s best-response quantity given the $n-2$ rivals’ previous best-response quantities is $q_2^{#(r)}(q_j^{#(r-1)})$. In round $r+1$, each of the $n-2$ rivals’ best-response quantity given Firm 1,2’s previous best-response quantity is $q_j^{#(r+1)}(q_2^{#(r)})$. This mapping is a contraction mapping. That is, for each $q_2^{#(r)}$, $q_2^{#(r+1)}$ is mapped into the interior of the interval $[k, q_2^{#(r)}]$. Similarly, for each $q_j^{#(r)}$, $q_j^{#(r+1)}$ is mapped into the interior of the interval $[q_j^{#(r)}, \frac{(n-1)q_j^{#(r)} - q_2^{#(r)}}{n-2}]$. Because $q_2^{#(r)}$ is bounded by $k$ and $q_j^{*}$, the intervals are compact. It is well known that such a mapping has a fixed point and that fixed point is the Nash equilibrium of the post-merger game. □

QED

Lemma 2 contains the key result. When Firm 2 purchases Firm 1, it becomes larger without changing the slope of its residual demand curve. Thus, its demand becomes more inelastic at the pre-merger quantity levels, so it wants to reduce quantity to raise price. This is the main effect of the merger. The rest of the proof simply says that, in response to a reduction in quantity by the merged firm, the remaining firms will increase their quantity, but by less than the merged firm’s reduction. While the formal proof only shows the existence of equilibrium, under relatively weak conditions, the equilibrium will be unique (Gaudet and Salant, 1991).

The above proof considered the case where the constraint continues to bind post-merger. But the intuition from Proposition 1 is also easily applied to the case where it does not. To see this, start by
observing that if the pre-merger constrained firm is not constrained post-merger, its quantity must be lower post-merger than it was pre-merger. Because cost curves are symmetric, the quantity of the unconstrained plant of the merged entity must also be lower (since symmetry and cost-minimization imply identical quantity in the two unconstrained plants post-merger). One need only then apply the result that the other firms will not increase quantity by enough to completely offset the merging firms quantity reduction to obtain the result.

None of this analysis involves the recapture of lost sales. Recapture as a mechanism by which mergers increase prices is not present in the Cournot model. Therefore, the argument that a merger cannot increase prices in the presence of a capacity constraint because a constrained firm cannot recapture lost sales does not even arise; in the Cournot model mergers with capacity constraints raise prices for the same reason as they raise prices without capacity constraints, with only slight additional complication. The issue only arises in the Bertrand model discussed in Section 4 below.

3.3 Numerical Example

In the previous sub-section, we showed that a merger among Cournot-competing firms where one firm faces a capacity constraint that binds both before and after the merger must reduce quantity and increase price. It remains to be shown that such a merger is both possible and profitable. We do this by means of a numerical example. It is easy to construct such an example; we simply use the Perry and Porter (1985) model, introduce a capacity constraint, assume symmetric costs and linear demand, and choose parameter values such that the merger is profitable.

Let there be a linear market demand curve with intercept \(a\) and slope \(b\). There are \(n\) firms with identical linear marginal cost curves that intersect the origin and have slope \(d\), except that Firm 1 has a capacity constraint at \(q_1 = k\). Firms compete as Cournot competitors pre- and post-merger. For \(a = 25\), \(b = -1\), \(n = 4\), \(d = 6\), and \(k = 2\), pre-merger equilibrium quantity for each of the three (unconstrained) firms is 2.3 units. Firm 1 produces 2 units (its capacity constraint \(k\)), so the total pre-merger quantity is 8.9. The pre-merger price is $16.10. The pre-merger profit of Firm 1 is $20.20, and the pre-merger profits of the unconstrained firms are $21.16 each. Following the merger, quantity in the constrained plant of the merged entity remains at \(k = 2\), quantity in the unconstrained plant of the merged entity falls to 2.04, and quantity at each of the rivals increases to 2.33, for a total quantity of 8.7, which is 2.2% below the pre-merger quantity. The price increases by 1.2% to $16.30.
It is easy to obtain larger price effects if we let the marginal cost curve be strictly convex instead of linear. This assumption allows us make the non-merging firms larger while making the marginal cost curve steeper at the equilibrium quantity levels, both of which reduce the non-merging firms’ incentives to increase quantity in response to the merged firm’s quantity reduction. This convexity is most easily accomplished by assuming a piecewise linear cost curve where marginal cost is constant up to some point $z$ and then has a positive constant slope for units beyond $z$. Alter the example above by letting $k = 3.8$, and letting marginal cost be 0 up to $z = 4$, beyond which point marginal cost has slope $d = 6$. With these parameters, the merger keeps the quantity of the constrained plant constant at 3.8, reduces the quantity of the unconstrained plant from 4.5 to just over 4, and increases the quantity at the rivals from 4.5 to 4.58. The quantity reduction is 2.2%, and the price increase is 5%, from $7.62$ to $8.01$.

One could also induce asymmetries among the firms to obtain larger price effects. For example, one could allow the acquiring and the acquired firms to both have flatter marginal cost curves than the non-merging firms. This would again reduce the incentives of the non-merging firms to increase quantity in response to a quantity reduction by the merged firm. This result should not be surprising when one notes that the merging firm with the flatter marginal cost curve would have a larger premerger market share, and mergers among firms with larger shares typically result in larger price effects.

It is also easy to construct a numerical example to show that there are conditions under which the constraint ceases to bind post-merger, but the merger is still profitable and prices still increase. In fact if we take the example from above with $a = 25$, $b = -1$, $n = 4$, $d = 6$, and increase $k$ from 2 to 2.2, we find that the post-merger quantity in each of the two merged plants fall to 2.035 (which is less than the constraint of 2.2) and the price effect of the merger is about 2%.

4 Bertrand Model

We now consider how capacity constraints influence merger effects in a Bertrand model of price competition. As above, Firm 1 faces a binding capacity constraint pre-merger, Firm 2 is the merger partner, and the merged entity is Firm 1,2. The key intuition is very similar to that in the Cournot case above: the merged entity (which now owns the plants of each pre-merger firm) takes into account the

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\[6\text{If the MC curve began at the origin, then making it steeper would increase merger effects, but it would also reduce the size of each firm, making it more difficult for the capacity constraint to bind in equilibrium. The piecewise MC function eliminates this problem, because it combines a steeper MC curve with larger firms.} \]
effect of the actions of the unconstrained plant on the prices of the constrained plant. In Cournot, the merged entity takes into account the fact that a lower quantity by the unconstrained plant increases the market price, which increases the profits at the constrained plant. In Bertrand, the merged entity takes into account the fact that a higher price for the unconstrained good increases the price at which the constrained plant sells out its capacity. So while there is no net recapture of lost sales following a merger (which is often cited as the source of merger effects in models of price competition), there is an internalization of higher prices, which is sufficient for a merger effect. This is true whether or not the capacity constraint continues to bind in the post-merger equilibrium.

While the intuition is straightforward, introducing a capacity constraint into a Bertrand model creates a technical problem, namely that it causes the unconstrained firm to face a convex kink in the demand curve, which in turn causes there not to exist any pure strategy pre-merger equilibrium. The reason is as follows. Consider a price pair under which Firm 1 just sells out at its capacity constraint. At this price pair, Firm 2 faces an asymmetry in the effect of slightly increasing its price vs. slightly decreasing it. Slightly increasing $p_2$ would cause some customers to want to switch from Good 2 to Good 1. But since Firm 1 is constrained when $p_1$ is held constant (per the Bertrand assumption) this would cause excess demand at Firm 1; not every customer who wishes to purchase Good 1 at $p_1$ can be accommodated. Some of these excess Firm 1 customers will return to Firm 2, which makes Firm 2’s demand curve steeper relative to the case where Firm 1 is not constrained. However, decreasing $p_2$ does not have a symmetric effect, because at a lower $p_2$ Firm 1 will not cause excess demand. The slope of the demand curve for price reductions by Firm 2 will therefore have a flatter slope resulting from Firm 1 not being constrained.

To see this, consider the price pair $(p_1^{pre}, p_2^{pre})$, which is the equilibrium price pair under the assumption that Firm 2 ignores this effect of recapture of unserved Firm 1 customers. This pair cannot be an equilibrium when Firm 2 does take the effect into account, because at that price pair Firm 2 would want to increase $p_2$. Now consider a different price pair $(\tilde{p}_1^{pre}, \tilde{p}_2^{pre})$ that would prevail if Firm 2 did take this effect into account. This also cannot be an equilibrium because Firm 2 would then want to reduce its price. This means that there is no equilibrium in pure strategies.\[7\]

An alternative way to model Firm 1’s capacity constraint would be to assume that its MC curve is arbitrarily close to, but not quite, vertical. In that case, $(p_1^{pre}, p_2^{pre})$ would be an equilibrium price pair. For an arbitrarily steep MC curve, there will be an increase in $p_2$ small enough that Firm 1 can fully accommodate the resulting increase in quantity demanded. However, this is only a local equilibrium, not necessarily a global one. Though a sufficiently small increase in $p_2$ will not lead to excess demand at Firm 1, a larger increase in $p_2$ might do so. The recapture by Firm 2 of some
One way to address this problem would be to model a mixed strategy equilibrium and examine how that equilibrium is affected by the merger. In this paper, we do not attempt to do this. Instead, we do two simpler analyses to demonstrate our main result, without a claim to full generality. (Recall, however, that our Cournot results described above face no such difficulties and are general.) These analyses are as follows.

First, we proceed with the admittedly unrealistic assumption that Firm 2 does not recapture any of the customers who are not accommodated by Firm 1 when it faces excess demand at its posted price. Under this assumption, the first of the two candidate pure strategy equilibria mentioned above, \((p_{1\text{pre}}, p_{2\text{pre}})\), is in fact a pure strategy equilibrium. We characterize this equilibrium, and show that a merger unambiguously increases both prices.

Second, we consider the special case of duopoly. In a duopoly, the post-merger equilibrium is free of any strategic considerations, and so the kinked demand issue does not arise. The equilibrium price pair is simply the pair that maximizes the profits of the merged entity. We show that if one begins at the post-merger equilibrium and then "unmerges" the two firms, there is downward pricing pressure. This is true whether or not Good 1 operates at the constraint in the post-merger equilibrium. This downward pricing pressure exists regardless of the pre-merger equilibrium, even if there is no pre-merger equilibrium in pure strategies in which Firm 1 operates on the constraint.

### 4.1 Bertrand Model With No Recapture of Unserved Customers

#### 4.1.1 Setup

We use as our baseline case a standard price-setting demand model in which neither firm faces a capacity constraint. Two competing firms produce substitute goods. Both goods have continuously of these unserved customers would reintroduce the kink in demand, which might make a larger price increase profitable. The flatter the MC curve, the less likely this is to occur, but for a MC curve steep enough to be considered a capacity constraint, it remains a concern.

To be correct, this assumption would require either a non-standard demand specification or that one or more market participants makes systematic mistakes.

The model in this sub-section could easily accommodate incorporating non-merging rivals. Doing so would not reverse our results. In fact, the strategic complementarity of prices means that the effects would become larger. We assume a duopoly market structure merely for simplicity. This is in contrast to the model in Section 4.2 below, where incorporating non-merging firms significantly complicates the analysis.
differentiable demand functions with respect to own prices and rival prices, which are strictly decreasing in own prices and strictly increasing in rival prices, and prices are strategic complements. The firms produce differentiated goods at the same constant marginal cost $c$. Profits of Firm 1 are $(p_1 - c)q_1(p_1, p_2)$, and profits of Firm 2 are $(p_2 - c)q_2(p_1, p_2)$. The firms compete in prices, and the first-order conditions for the unconstrained pre-merger equilibrium prices $p_1^{pre}$ and $p_2^{pre}$ are:

$$q_1(p_1, p_2) + (p_1 - c)\frac{\partial q_1(p_1, p_2)}{\partial p_1} = 0$$
$$q_2(p_1, p_2) + (p_2 - c)\frac{\partial q_2(p_1, p_2)}{\partial p_2} = 0. \tag{1}$$

After Firm 1 and Firm 2 merge, the profits of the merged entity are $(p_1 - c)q_1(p_1, p_2) + (p_2 - c)q_2(p_1, p_2)$. We assume that variable cost efficiencies are zero, so marginal costs remain at $c$. The first-order conditions for the non-constrained post-merger equilibrium prices $p_1^{post}$ and $p_2^{post}$ are:

$$q_1(p_1, p_2) + (p_1 - c)\frac{\partial q_1(p_1, p_2)}{\partial p_1} + (p_2 - c)\frac{\partial q_2(p_1, p_2)}{\partial p_1} = 0$$
$$q_2(p_1, p_2) + (p_2 - c)\frac{\partial q_2(p_1, p_2)}{\partial p_2} + (p_1 - c)\frac{\partial q_1(p_1, p_2)}{\partial p_2} = 0. \tag{2}$$

Inspection of (1) and (2) makes clear that the post-merger prices are higher than the pre-merger prices as long as the cross-partial derivatives are positive. This can be explained by the standard "recapture" intuition: the merged entity internalizes the fact that some of the lost sales resulting from a price increase will go to the merger partner, and those sales, and the associated profits, are no longer lost by the merged entity.

Now let Firm 1 face a capacity constraint at $q_1^{\text{constr}}$, such that the marginal cost of producing above the constraint is infinity. Assume that the constraint binds in the pre-merger equilibrium (Firm 2 remains unconstrained). We assume that the constraint strictly binds. That is, we ignore the knife-edge case where the unconstrained pre-merger equilibrium quantity is exactly equal to $q_1^{\text{constr}}$. The condition for the constraint to bind pre-merger is that the unconstrained equilibrium quantity $q_1^{\text{pre}}(q_2^{\text{pre}})$ is exactly equal to $q_1^{\text{constr}}$. In this case, the equilibrium conditions become:

$$q_1(p_1, p_2) = q_1^{\text{constr}}$$
$$q_2(p_1, p_2) + (p_2 - c)\frac{\partial q_2(p_1, p_2)}{\partial p_2} = 0. \tag{3}$$

The possibility that Firm 1’s non-constrained pre-merger profit-maximizing quantity $q_1(p_1^{\text{pre}}, p_2^{\text{pre}}) > q_1^{\text{constr}}$, but that its constrained profit-maximizing quantity is less than $q_1^{\text{constr}}$, is ruled out as long as its profit function is concave in prices.
Firm 2’s first-order condition is unchanged from (1) above. Firm 1 no longer has a first-order condition; its equilibrium condition is to charge the $p_1$ for which quantity demand equals $q_1$, given $p_2$. Because the quantity constraint binds, downward-sloping demand for Firm 1’s product is sufficient for Firm 1’s constrained pre-merger price, $p_{1\text{pre}}$, to exceed its pre-merger unconstrained price $p_{1\text{pre}}$. Strategic complementarity in prices is sufficient for Firm 2’s constrained pre-merger price $p_{2\text{pre}} > p_{2\text{pre}}$. Thus, both pre-merger prices are higher when Firm 1 faces a binding capacity constraint.

4.1.2 Profit Effect of a Small Increase in Both Prices

We begin the analysis of the merger effect by showing that a very small increase in $p_2$, accompanied by whatever increase in $p_1$ is necessary for the quantity demanded of Good 1 to equal $q_1$, increases the profits of the merged entity. This is the subject of the following proposition.

**Proposition 2** Suppose Goods 1 and 2 have positive diversions to each other in the constrained pre-merger equilibrium, Good 1 sells out its capacity $\overline{q_1}$ in equilibrium before the merger, and Good 2 is unconstrained in equilibrium both before and after the merger. In that case, increasing $p_2$ above its pre-merger equilibrium value by a very small amount $\epsilon > 0$, and also increasing $p_1$ so that the quantity demanded of Good 1 equals $\overline{q_1}$, will increase profits to the merged entity.

**Proof.** Suppose the merged entity increases the price of Good 2 above $p_{2\text{pre}}$ (its pre-merger level) by a small amount $\epsilon > 0$. Since $p_{2\text{pre}}$ is the pre-merger profit-maximizing price for Good 2, the first-order effect on $\frac{\partial \pi_2}{\partial p_2}$ (the profits of Good 2) is arbitrarily close to zero for a sufficiently small value of $\epsilon$. But positive diversion from Good 2 to Good 1 means that $\frac{\partial q_1}{\partial p_2}$ is bounded away from zero. Good 1 now has excess demand at its pre-merger price: $q_1(p_{1\text{pre}}, p_{2\text{pre}} + \epsilon) > q_1(p_{1\text{pre}}, p_{2\text{pre}}) = \overline{q_1}$, so the merged entity will want to increase its price. By the assumptions on $q_1$, there exists a $\delta > 0$ such that $q_1(p_{1\text{pre}} + \delta, p_{2\text{pre}} + \epsilon) = q_1(p_{1\text{pre}}, p_{2\text{pre}}) = \overline{q_1}$. The higher price of Good 1, at the same quantity $\overline{q_1}$, unambiguously increases the profits of the merged entity, while the increase in the price of Good 2 has a negligible effect on its profits. Therefore, total profits increase. □

Proposition 2 makes a key point of the paper. While the merger does not lead to increased sales for the merged entity to internalize, it does internalize higher prices, which has essentially the same effect. That is, a small positive deviation from the pre-merger prices is profitable. Now consider alternative deviations from the pre-merger equilibrium prices. One alternative deviation would be a small increase in $p_2$ accompanied by an increase in $p_1$ large enough that Good 1 no longer sells out
at $\bar{q_1}$. This cannot be profitable unless the constraint was just exactly binding pre-merger, which we have assumed away. No change in one price, holding the other constant, can be profitable because at the pre-merger equilibrium each price is already optimal given the other. There are two other possible deviations to consider. The first is a small increase in $p_2$ and a decrease in $p_1$. This cannot be profitable because Good 1 would be capacity constrained after an increase in $p_2$, and it would be unprofitable to reduce the price of Good 1 when its quantity cannot expand. The second is a small decrease in $p_2$. This cannot be profitable. While it would have infinitesimal effect on the profits of Good 2, it would lower the profits of Good 1, because both its price and its quantity would fall.

4.1.3 Post-Merger Equilibrium

Proposition 2 shows that the merged entity can increase profits by raising both prices by a very small amount, choosing $p_1$ so that the quantity demanded for Good 1 remains at $\bar{q_1}$. Because prices are strategic complements, the post-merger equilibrium must be characterized by higher prices for all firms (DeGraba, 1995). At the post-merger equilibrium, Good 1 may or may not continue to sell out at $\bar{q_1}$. That is, there are two possible post-merger equilibrium price pairs. We denote one possible pair as $p_{1}^{\text{post}}$ and $p_{2}^{\text{post}}$, which produces the highest total profits conditional on Good 1 continuing to sell out at $\bar{q_1}$. The condition for this to be the post-merger equilibrium is that the unconstrained post-merger equilibrium quantity $q_{1}^{\text{post}} > \bar{q_1}$. This is what we mean when we say that the constraint continues to bind post-merger. We denote the other possible price pair as $p_{1}^{\text{post}}$ and $p_{2}^{\text{post}}$, which are the unconstrained post-merger equilibrium prices. The condition for this to happen is that $q_{1}^{\text{post}} < \bar{q_1}$; the constraint does not bind even though it did bind in the pre-merger equilibrium. These are the only two possibilities; either the constraint will bind post-merger or it will not, and these are the profit-maximizing price pairs in each case.\(^\text{11}\)

\(^{11}\)For any given value of $p_2$, there is one and only one value of $p_1$ that causes Good 1’s quantity to sell out at $\bar{q_1}$. This necessary functional relationship between $p_2$ and $p_1$ means that the merged entity’s problem reduces to choosing the profit-maximizing value of $p_2$ given that relationship. For an explicit functional form, this would mean substituting the expression for Good 1’s capacity constraint into Firm 2’s profit function before differentiating with respect to $P_2$.

\(^{12}\)Whether the constraint continues to bind in the post-merger equilibrium will depend on the difference between the constrained and the unconstrained equilibrium quantities. All else equal, the smaller this difference, the more likely the constraint will cease to bind.
4.2 "Unmerging" a Two-Firm Monopoly

Another way to address the problem of no pure strategy equilibrium is to consider the special case where there are two firms. This is useful because when the two firms are merged, there is no strategic interaction between them, so the problem does not arise (though it is still present in the pre-merger duopoly equilibrium). The merged entity simply sets both prices at the joint profit-maximizing level. Starting at this post-merger equilibrium, it is straightforward to show that "unmerging" the two firms always generates downward pricing pressure. Since this is true for any post-merger equilibrium, it must be true in cases where the constraint binds in the pre-merger (i.e., post-unmerger) equilibrium.

This result holds regardless of whether the constraint binds in the post-merger equilibrium. If the constraint does not bind post-merger, un-merging the two firms must cause both prices to decrease for the reverse of the standard argument for why a merger between substitutes with no capacity constraint must make prices increase. At the post-merger equilibrium, the merged entity chooses a price for each product such that it would not want to change that price taking into account the fact that if it lowered that price by a small amount, some of the increased quantity that it would sell would be at the expense of its merger partner. If the two firms unmerge, that effect disappears, so each of the unmerged firms would lower its price. If the constraint does bind post-merger, un-merging the two firms must also cause both prices to decrease, for the reverse of the argument laid out in Proposition 2 above. At the post-merger equilibrium, the equilibrium price of unconstrained good is chosen taking into account the fact that cutting that price would reduce the price at which the constrained good can fully sell out at its constraint. If the two firms unmerge, this effect disappears, so each of the unmerged firms would lower its price.

The fact that the two unmerged firms would want to reduce their prices from the joint monopoly prices is not sufficient to show that those prices must with certainty, or even in expectation, be below the monopoly level in the post-unmerger (pre-merger) mixed strategy equilibrium (though it seems intuitive that this would be the case). To show this, we first consider the pre-merger equilibrium price pair \((p_{1}^{\text{pre}}, p_{2}^{\text{pre}})\) from sub-section 4.1 above. Recall that in that sub-section we assumed that Firm 2 ignores the fact that an increase in its price will induce excess demand for Firm 1’s product, and that Firm 2 will recapture some of those unserved customers and the associated profits. But if we relax this assumption, then this price pair can no longer be a pure strategy equilibrium, because Firm 2 would want to increase its price, and because prices are strategic complements, Firm 1 would want to increase \(p_1\) as well. That is, \((p_{1}^{\text{pre}}, p_{2}^{\text{pre}})\) is the lower bound of possible equilibrium prices. Now consider
another, higher price pair \((p_1^{\text{pre}}, p_2^{\text{pre}})\) at which Firm 1 also just sells out its capacity, but where \(p_2^{\text{pre}}\) is the price at which Firm 2 would not want to raise it any further when it fully takes into account this recapture of unserved customers. This also cannot be an equilibrium, because Firm 2 would want to cut its price; at \(p_2^{\text{pre}}\) there are no unserved customers for Firm 1 to recapture, so a price that takes those customers into account in deciding upon a further increase cannot be the profit-maximizing price when deciding upon a decrease, as there will be no recapture at a lower \(p_2\). Because prices are strategic complements, Firm 1 will want to lower \(p_1\) as well.

While we offer no formal proof, we expect that, for any mixed strategy equilibrium, all of the probability mass will lie between these lower and upper bounds, or at a minimum the expected price will lie within these bounds. If this is correct, it only remains to show that the upper bound pair \((p_1^{\text{pre}}, p_2^{\text{pre}})\) must lie below the monopoly prices. To see that this is the case, recall that \(p_2^{\text{pre}}\) was the price such that Firm 2 would not want to increase its price any further even taking into account the fact that a higher price would lead to excess capacity at Firm 1, some of which would likely be recaptured by Firm 2. The merged entity, in contrast, would want to raise the price at Plant 2 above \(p_2^{\text{pre}}\). This is because the merged entity would not want to merely recapture some of these lost sales. Rather, it will want to raise \(p_1\) high enough that there is no excess demand, which is more profitable.

Adding non-merging rivals to the model would re-introduce the kinked demand problem, so there would be no pure strategy equilibrium either pre-merger or post-merger. However, we conjecture that the same result would hold even in that case. Whatever the post-merger equilibrium, it would still be the case that unmerging the two firms would cause each of them to no longer internalize the effect of its pricing behavior on the other, which generates downward pricing pressure. Put differently, it would be surprising if going from monopoly to duopoly reduced prices, but going from tripoly to duopoly increased them.

These results demonstrate the same effect that we found in the Cournot analysis in Section 3, and in the Bertrand analysis in sub-section 4.1. Once again, an unconstrained firm that purchases a constrained firm raises its price because doing so increases the price at the constrained firm.

5 Discussion and Concluding Remarks

Standard merger theory says that mergers between competitors increase prices (absent efficiencies). The purpose of this paper is to answer a very simple question: does that standard result continue
to hold when one of the merging firms faces a capacity constraint that binds both before and after
the merger? We find that the answer is yes.\footnote{This paper addresses the most basic version of the question. It ignores interesting complications such as whether capacity truly binds pre-merger (in our model production beyond the constraint is impossible), or whether and how quickly capacity could be adjusted (in our model capacity is exogenous and constant).} While some previous work has found results along
these lines, to our knowledge the literature has not provided a general statement or articulated the
mechanism by which this must be true (but see Greenfield and Sandford, 2017, for an independent
development of related ideas). Moreover, it has been mistakenly suggested that the answer is in fact
the opposite, namely that a capacity constraint that binds both pre- and post-merger makes merger
effects impossible (see footnote 2 above).

This confusion is a result of the fact that it has become common to think of merger effects in
price-setting games in terms of recapture of lost sales. That is, the price effect of a merger between
substitutes is often described by reference to the merged entity internalizing the fact that some of the
lost sales following a price increase will be recaptured by the merger partner. For example, this framing
is at the heart of Upward Pricing Pressure analysis, which has become common in merger evaluation.
But if the merger partner faces a binding capacity constraint, then no sales can be recaptured, which
might appear to mean that no merger effect is possible.

This way of describing merger effects, while correct, is incomplete even in the standard case, and
is misleading in the presence of capacity constraints. It misses the fact that recapture of lost sales
is not the only benefit of a post-merger price increase. Another benefit, which accrues even if the
capacity constraint prevents recapture, is that by acquiring a competing good, a firm benefits from
any price increase that accrues to the acquired good. This also creates an incentive to increase the
price of the original good, because that price increase will allow the merged entity to increase the
price of the acquired good. Once it is understood that recapture is not the only mechanism by which
mergers cause price increases, it is easy to see that the claim that capacity constraints prevent merger
effects is incorrect. Note that no such confusion exists a Cournot model.

As discussed in Section 4, differentiated product Bertrand games in the presence of upward-sloping
marginal cost curves present problems involving a lack of pure strategy equilibria. For this reason, we
provide formal general results in a homogeneous product Cournot game and we confine our Bertrand
analysis to two special cases. We expect our results to hold for more general settings of Bertrand
competition in differentiated products, but we leave a more general treatment of capacity constraints in a Bertrand setting to future work.

Another topic for future work is to examine the extent to which capacity constraints mitigate the magnitude of merger effects. As discussed in Section 2 above, there is some literature suggesting that constraints do mitigate merger effects. For example, Froeb et al. (2003) find that merger effects are mitigated when one firm is capacity constrained, and are eliminated when both firms are constrained. Greenfield and Sandford (2017) also show that if both goods remain constrained post merger, then there are no price effects. Moreover, it is obvious that constraints must mitigate merger effects in settings where the capacity constraint does not bind in the post-merger equilibrium; the post-merger equilibrium is the same as in the unconstrained case, but the constraint causes higher pre-merger prices, so the effect must be smaller. This is true for both the Cournot and Bertrand models. We have not proven a general result for whether the constraint mitigates merger effects when it does continue to bind post-merger. We do know that it mitigates merger effects in the parametric Cournot example presented in Section 3 above, and more generally in any Cournot model with linear demand and piecewise linear marginal cost as described in Section 3. It also holds in a parametric Bertrand example based on Section 4.1 above (excluded but available upon request). This result may be more general, but proving this and also identifying the factors that increase or decrease the mitigation are questions for future research.

References


