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# The effects of mergers with dynamic capacity accumulation

Jiawei Chen

*Department of Economics, University of California-Irvine, 3151 Social Science Plaza, Irvine, CA 92697-5100, United States*

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ABSTRACT

The U.S. antitrust law enforcement agencies often base their assessment of mergers on a model with asymmetric costs. However, in many near-homogeneous product industries there is evidence that cost differences are minor and capacity differences seem a more reasonable explanation of firm heterogeneity. Based on simulations from a dynamic model of capacity accumulation, I find that mergers are welfare-reducing and that their long-run effects are worse than their short-run effects. If instead the simulated data is fit to an asymmetric costs model, the long-run welfare-reducing effects of mergers will be systematically underestimated, which can give rise to misguided antitrust policies.



## 1. Introduction

The U.S. antitrust law enforcement agencies (the U.S. Department of Justice and the Federal Trade Commission) often base their assessment of horizontal merger effects on a model with asymmetric costs. For example, in a number of merger cases the agencies take into account the hypothetical cost savings that could be achieved if a merged firm would combine the production from two facilities, one from each of the merging firms, at one facility that has lower marginal costs (U.S. DOJ and FTC, 1992, Section 4, and 2006, Section 4).

More generally, in the literature the asymmetric costs model has been a common approach to explaining asymmetries in market shares (for example, Hopenhayn, 1992; Werden and Froeb, 1994). Those asymmetries are observed in most industries and are often persistent, implying that for an empirical model to fit the data it must be able to allow firms to maintain noticeably different market shares for a long time[1]. For industries in which products have different perceived qualities, the persistent asymmetries in market shares can, at least in part, be explained by differences in perceived qualities, but for industries with near-homogeneous products, those differences are insignificant and so the assumption of asymmetric costs seems even more relevant.

Many merger cases investigated by the U.S. antitrust law enforcement agencies involve near-homogeneous product industries, such as cement, industrial gas, aluminum, "away-from-home" tissue products, and rock salt, and the asymmetric costs model is often applied to them (U.S. DOJ and FTC, 2006). However, in some of those industries, there are good reasons to believe that cost differences are minor and that capacity differences seem a more reasonable explanation of heterogeneity among firms. A case in point is the U.S. aluminum industry, in which there are large and persistent differences in firms' market shares (see, for example, Yang, 2002). Primary aluminum ingots are highly homogeneous and firms in the industry have similar technology and roughly the same marginal costs (Froeb and Geweke, 1987; Rosenbaum, 1989; Yang, 2002). On the other hand, there is evidence that capacity constraints are important for the aluminum industry and that they shape the nature of firms' competition. Reynolds (1986) documents that over the period 1951–1970 the industry operated near full capacity utilization and that utilization rates above 100% were possible (though rare) because firms had high-cost stand-by capacity. This shows signs of "soft" capacity constraints, that is, firms can produce beyond their capacity, albeit at much higher costs. Peck (1961, pp. 144-165) describes the capacity investment behavior of primary aluminum producers and shows that rivalry for a share of the market led to an "investment race" to build capacities in the post-1954 period.

*E-mail address:* jiaweic@uci.edu.

[1] See, for example, Gort (1963), Mueller (1986), Baldwin (1995), and Geroski and Toker (1996) for empirical evidence that there are substantial and persistent differences in firms' sizes in most industries.

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The purpose of this paper is to see how much the assessment of merger effects would change when the industry is more aptly described by a dynamic model of capacity accumulation, which is capable of explaining persistent asymmetries in market shares without resorting to the assumption of asymmetric costs. We extend the Besanko and Doraszelski (2004) duopoly model of dynamic capacity accumulation to more than two firms, and use it to predict both the short-run and the long-run effects of hypothetical mergers in near-homogeneous products industries. The Markov-perfect-equilibrium (MPE) framework described in Ericson and Pakes (1995) is adapted to study the industry evolution. In the model firms are *ex ante* identical and face the same cost structure. They tend to produce near full capacity utilization and thus have little difference in their marginal costs, but they develop substantial and persistent differences in their capacities and market shares due to idiosyncratic shocks to their investments and depreciation.

Simulations based on the model show that mergers are welfare-reducing and that their long-run effects are worse than their short-run effects: in the long run average price increases further while total surplus and consumer surplus decrease further. The worsening of the merger effects in the long run results from the fact that certain firms in the postmerger industry optimally choose to let their capacities shrink, resulting in higher prices, lower total surplus, and lower consumer surplus.

These predictions are then compared to the ones obtained when we instead fit the simulated data with an asymmetric costs model (firms are *ex ante* asymmetric by having different but constant marginal costs). The comparison reveals substantial bias: with the asymmetric costs model we will systematically underestimate the long-run welfare-reducing effects of mergers, which can give rise to misguided antitrust policies. In particular, a merger that would result in a substantial reduction in total welfare may actually be approved based on total welfare considerations.

The bias in merger evaluations revealed in this paper results from two differences between the specifications. The first difference is between the asymmetric costs assumption and the asymmetric capacities assumption. The former suggests that a merger could result in substantial cost savings, while the latter means that there would be little cost savings because firms have little difference in their marginal costs.

The second difference is between a static model and a dynamic model. In the asymmetric costs model, everything is stationary after the merger and the long-run dynamics are not captured. However, in the dynamic model of capacity accumulation, capacities are endogenous and firms will adjust their capacities after the merger, so the long-run effects of a merger can be very different from the short-run effects [2].

The effects of mergers are studied in dynamic settings in prior studies. A key observation that is shared by this paper is that long-run reactions of merging and non-merging firms play an important role in shaping the industry. For example, Compte, Jenny, and Rey (2002) study the effects of horizontal mergers in a repeated Bertrand model with capacity constraints and asymmetrically-positioned firms, and show that when capacity constraints are severe any merger involving the largest firm hurts tacit collusion. With dynamics introduced by the durability of goods, Carlton and Gertner (1989) show that if goods depreciate slowly and entry is likely then even a merger to monopoly may have small welfare effects in a durable-good industry. Werden and Froeb (1998) and Pesendorfer (2005) study mergers and entry. Werden and Froeb observe that a presumably profitable merger cannot be expected to induce entry if it does not generate significant efficiencies, and Pesendorfer find that a merger for monopoly may not be profitable and that a merger in a nonconcentrated industry can be profitable.

Some prior studies on the effects of mergers take a computational approach. See, for example, Werden and Froeb (1994) on mergers of U.S. long distance carriers, Dalkir, Logan, and Masson (2000) on hospital mergers, and Richard (2003) on airline mergers. Berry and Pakes (1993) use simulations to study mergers in a dynamic oligopoly model with capacity investment. They find that the presence of investment as an additional strategic variable in the dynamic model may overturn the result of the simple static framework.

The organization of this paper is as follows. The next section presents the model. Section 3 examines the price and welfare effects of hypothetical mergers and computes the bias due to the misspecification. Section 4 presents robustness checks and some antitrust implications. Section 5 then concludes.

## 2. Model

We extend the Besanko and Doraszelski (2004) duopoly model of dynamic capacity accumulation with price competition and product differentiation to more than two firms producing near-homogeneous products. The product market game assumes Bertrand competition in which a firm commits to supply all of its demand at the set price. That assumption avoids the need to specify a rationing rule and leads to a Nash equilibrium in pure strategies, making the estimation and analysis simpler [3].

There are $J$ ($J \geq 3$) firms competing in prices in a discrete-time infinite-horizon setting. We need $J \geq 3$ in order to have an oligopolistic rather than monopolistic industry after hypothetical mergers. In the following development of the model we have $J=3$, and the analysis can be easily extended to models with $J>3$ firms.

### 2.1. Demand

The representative consumer has the following utility function,

$$u = q_0 + a_1 q_1 + a_2 q_2 + a_3 q_3 - \frac{b_1}{2} q_1^2 - \frac{b_2}{2} q_2^2 - \frac{b_3}{2} q_3^2 \\ -\gamma_1 q_2 q_3 - \gamma_2 q_1 q_3 - \gamma_3 q_1 q_2, \tag{1}$$

where $q_0 \geq 0$ is consumption of the numeraire good, $q_j \geq 0$, $j=1, 2, 3$, are consumptions of the products of the competing firms, and $a_j$ , $b_j > 0$ and $\gamma_j \geq 0$, $j=1, 2, 3$, are parameters of the model. Since we are interested in the case in which firms are *ex ante* identical, we focus on the specification with $a_1 = a_2 = a_3 \equiv a$, $b_1 = b_2 = b_3 \equiv b$, and $\gamma_1 = \gamma_2 = \gamma_3 \equiv \gamma$ (so that the products are symmetrically differentiated). Furthermore, let $\theta \equiv \frac{\gamma}{b}$, where $\theta \in [0, 1)$ measures the degree of product differentiation, ranging from 0 for independent goods to 1 for homogeneous goods. The values of $\theta$ examined in this paper are greater than or equal to 0.9, representing near-homogeneous goods industries. Eq. (1) becomes

$$u = q_0 + aq_1 + aq_2 + aq_3 - \frac{b}{2} q_1^2 - \frac{b}{2} q_2^2 - \frac{b}{2} q_3^2 \\ -\theta b q_2 q_3 - \theta b q_1 q_3 - \theta b q_1 q_2. \tag{2}$$

Maximizing Eq. (2) with respect to $q_0$, $q_1$, $q_2$, and $q_3$ subject to the budget constraint $q_0 + p_1 q_1 + p_2 q_2 + p_3 q_3 = y$ yields the following linear inverse demand functions:

$$p_j(q_j, q_{j-1}) = a - bq_j - \theta b \sum q_{-j}, j = 1, 2, 3, \tag{3}$$

[2] One way to incorporate long-run effects in the asymmetric costs model would be to model firms as investing to reduce their marginal costs. Thus firms' marginal costs are still constant with respect to quantity, but can vary over time. Mergers will then have long run impact by altering firms' incentives to invest in cost reduction. While such a model is interesting and seems to be a reasonable approximation for some industries, it will not be appropriate for industries in which capacity constraints are important.

[3] See, for example, Maggi (1996).

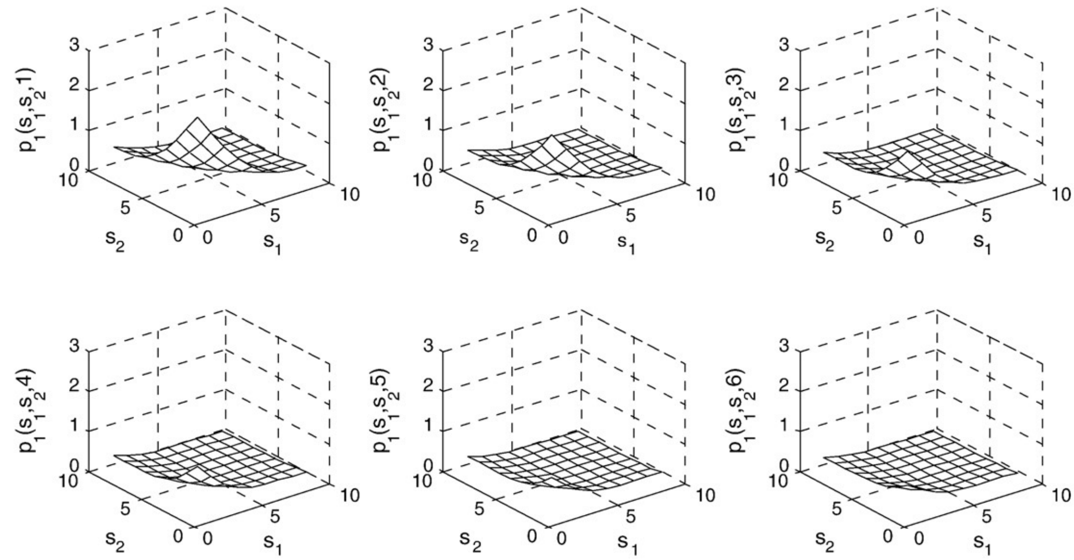


**Fig. 1.** Equilibrium price function in states with $s_3 \le 6$ (baseline model).

which give us a demand system:

$$q_j(p_j, p_{-j}) = \frac{1}{b\left(1+\theta-2\theta^2\right)}\left[a(1-\theta)-(1+\theta)p_j+\theta\sum p_{-j}\right], \quad j=1,2,3, \tag{4}$$

where $q_{-j}$ and $p_{-j}$ denote the demands and the prices of firm $j$'s rivals, respectively.

The above specification first appeared in Bowley (1924), and has been picked up by Spence (1976) and Dixit (1979).

### 2.2. States and Transitions

A firm's capacity $\bar{q}$ takes on one of $M$ positive values, and we set $\bar{q}_1 < \bar{q}_2 < \ldots < \bar{q}_M$ . Firms compete in a dynamic process. In period $t$, the state of the industry is $S_t = (s_{1t}, s_{2t}, s_{3t}) \in \{1, 2, \ldots, M\}^3$ , where $s_{jt}$ denotes firm $j$'s capacity level and firm $j$'s capacity is $\bar{q}_{s_{jt}}$. In what follows, the time subscript is sometimes dropped to make the notation concise.

Given that a firm holds $\bar{q}$ units of capacity, the total cost of producing $q$ units of output is

$$C(q|\bar{q}) = \frac{1}{1+\eta}\left(\frac{q}{\bar{q}}\right)^{\eta} q. \tag{5}$$

Eq. (5) poses a "soft" capacity constraint in the following sense: if $\eta$ is large, then as long as $q$ is below or near $\bar{q}$, marginal cost $c(q|\bar{q}) = \left(\frac{q}{\bar{q}}\right)^{\eta}$ is relatively small; but once $q$ becomes noticeably greater than $\bar{q}$, marginal cost increases rapidly [4]. Note that $c(.)$ does not have firm subscript, that is, different firms have the same cost structure; this preserves the condition that firms are *ex ante* identical [5]. It is against this identical cost structure across firms that we later assume firms have different but constant marginal costs, and calculate the bias in merger evaluation due to this misspecification [6].

Firms also invest to increase their capacities, and the success of their investment is stochastic. The probability that firm j's investment is successful is increasing in $x_j \ge 0$, the amount spent on investment by firm $j$. Formally, if in the current period firm $j$ has capacity $\bar{q}_s$, $s = 1, 2, \ldots, M$, and invests $x_j$, and there is no depreciation in capacity, then the probability that firm j's capacity becomes $\bar{q}_{s+1}$ in the next period is $\frac{\alpha x_1}{1+\alpha x_1}$, where $\alpha > 0$ indexes how likely investments are to be successful. Firms can only increase their capacities "step by step", that is, a firm's capacity can not jump from $\bar{q}_s$ in the current period to $\bar{q}_{s+2}$ in the next period.

Unless a firm is operating at the lowest capacity level, its capacity is subject to stochastic depreciation, indexed by the depreciation rate $\delta \ge 0$. Specifically, if there is no investment, then a firm with $\bar{q}_s$ in the current period will have $\bar{q}_{s-1}$ in the next period with probability $\delta$. A firm's capacity can not jump from $\bar{q}_s$ in the current period to $\bar{q}_{s-2}$ in the next period.

Taking into account both the investment process and the depreciation process, the transition probabilities for firm $j$ are:

$$prob(s_j+1|s_j, x_j) = \begin{cases} \dfrac{\alpha x_j}{1+\alpha x_j} & \text{if} \quad s_j = 1, \\ \dfrac{(1-\delta)\alpha x_j}{1+\alpha x_j} & \text{if} \quad 2 \le s_j \le M-1, \end{cases} \tag{6}$$

$$prob(s_j|s_j, x_j) = \begin{cases} \dfrac{1}{1+\alpha x_j} & \text{if} \quad s_j = 1 \\ \dfrac{1+\delta\alpha x_j-\delta}{1+\alpha x_j} & \text{if} \quad 2 \le s_j \le M-1, \\ \dfrac{1+\alpha x_j-\delta}{1+\alpha x_j} & \text{if} \quad s_j = M, \end{cases} \tag{7}$$

and

$$prob(s_j-1|s_j, x_j) = \frac{\delta}{1+\alpha x_j} \text{ if } 2 \le s_j \le M, \tag{8}$$

[4] The cost specification in Perry and Porter (1985) corresponds to a special case of the soft capacity constraint with $\eta = 1$. The specification was later used in some studies on merger effects, e.g., McAfee and Williams (1992) on the welfare implications of Cournot mergers.

[5] Robustness checks in Section 4 show that allowing firms to have slight differences in their cost structures in the capacity model has little impact on our analysis.

[6] The soft capacity constraint in our model allows firms that produce vastly different quantities to have little difference in their marginal costs, as long as they have similar rates of capacity utilization (for example, if they all produce near full utilization). In fact, in the simulations using the baseline model of the current paper, firms' capacity utilization rates fall within (0.9, 1.1) for 94% of the time, according to the limiting distribution.

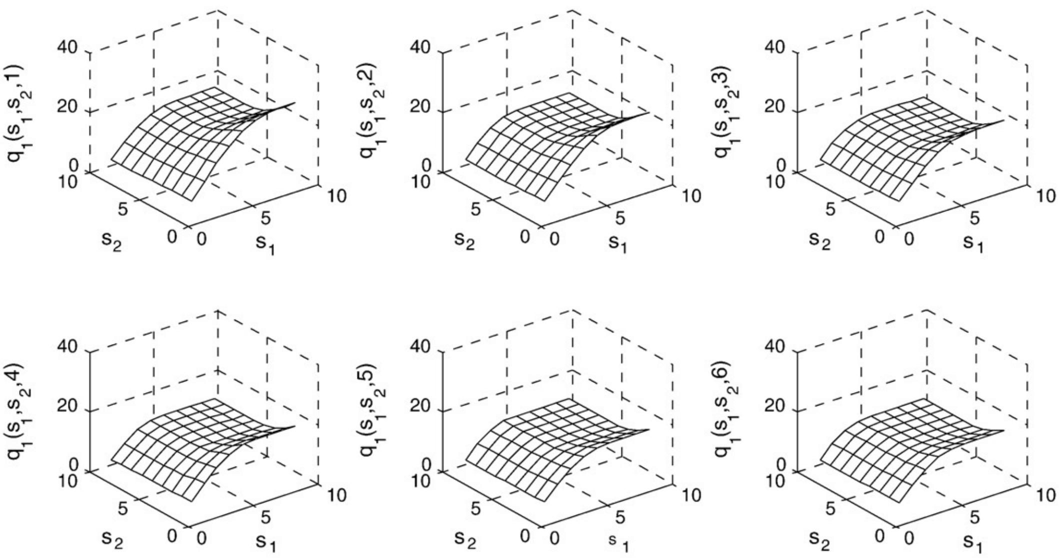


**Fig. 2.** Equilibrium quantity function in states with $s_3 \le 6$ (baseline model).

where $prob(s_j+1|s_j, x_j)$ denotes the probability that a firm has a capacity level of $s_j+1$ in the next period, if its current capacity level is $s_j$ and it invests $x_j$ . $prob(s_j|s_j, x_j)$ and $prob(s_j-1|s_j, x_j)$ are defined analogously.

### 2.3. Price competition

In single-period competition, each firm sets price simultaneously and then produces to satisfy demand generated according to the demand system in Eq. (4). Firm $j$'s profit maximization problem is given by:

$$\max_{p_j \ge 0} p_j q_j(p_j, p_{-j}) - C\left(q_j(p_j, p_{-j}) | \bar{q}_{s_j}\right). \tag{9}$$

Solving the first order conditions gives the equilibrium prices $p_j^*(\bar{q}_{s_j}, \bar{q}_{s_{-j}})$, where $\bar{q}_{s_{-j}}$ denotes the capacities of firm $j$'s rivals. We solve for the $p_j^*$'s numerically and compute the equilibrium profits for firm $j$ according to

$$\pi_j^*(s_j, s_{-j}) = q_j\left(p_j^*, p_{-j}^*\right) p_j^* - C\left(q_j\left(p_j^*, p_{-j}^*\right) | \bar{q}_{s_j}\right). \tag{10}$$

### 2.4. Policy function and value function

Let $V_j$ denote the expected net present value of firm $j$ (henceforth the "value" of firm $j$), and let $x_j$ denote the amount firm $j$ invests in the current period given the state. $V_j(s_1, s_2, s_3)$ and $x_j(s_1, s_2, s_3)$ are firm $j$'s value function and policy function, respectively. We will restrict ourselves to symmetric Markov perfect equilibria (MPE). See Doraszelski and Satterthwaite (2005) for arguments that show the existence of a symmetric MPE in pure investment strategies provided there is an upper bound on investment. While in general uniqueness cannot be guaranteed, our computations show that different starting points and different convergence routes always lead to the same value functions and policy functions. We will focus our attention on firm 1, knowing that because of symmetry, $V_2(s_1, s_2, s_3)=V_1(s_2, s_1, s_3)$, $V_3(s_1, s_2, s_3)=V_1(s_3, s_1, s_2)$, $x_2(s_1, s_2, s_3)=x_1(s_2, s_1, s_3)$, and $x_3(s_1, s_2, s_3)=x_1(s_3, s_1, s_2)$.

### 2.5. Solving the Bellman equation

The Bellman equation for this problem is

$$V_1(s_1, s_2, s_3) = \max_{x_1 \ge 0} \pi_1^*(s_1, s_2, s_3) - x_1 + \beta \sum_{s_1'=1}^{M} W_1(s_1') prob(s_1'|s_1, x_1), \tag{11}$$

where $0<\beta<1$ is the time discount rate, $s_1'$ is the capacity level of firm 1 in the next period, and

$$W_1(s_1') = \sum_{s_2'=1}^{M} \sum_{s_3'=1}^{M} V_1(s_1', s_2', s_3')\, prob\,(s_2'|s_2, x_2(s_1, s_2, s_3))\, prob\,(s_3'|s_3, x_3(s_1, s_2, s_3)).\ ^{7} \tag{12}$$

The first order condition (FOC) for an interior solution to Eq. (11) is

$$-1 + \beta \sum_{s_1'=1}^{M} W_1(s_1') \frac{\partial prob\,(s_1'|s_1, x_1)}{\partial x_1} = 0. \tag{13}$$

Let

$$\Delta \equiv \begin{cases} \beta\alpha[W_1(s_1+1) - W_1(s_1)] & \text{if} \quad s_1 = 1 \\ \beta\alpha[(1-\delta)(W_1(s_1+1) - W_1(s_1)) + \delta(W_1(s_1) - W_1(s_1-1))] & \text{if} \quad 2 \le s_1 \le M-1, \\ \beta\sigma\delta[W_1(s_1) - W_1(s_1-1)] & \text{if} \quad s_1 = M. \end{cases} \tag{14}$$

The investment strategy of firm 1 is obtained by solving the above FOC:

$$x_1(s_1, s_2, s_3) = \begin{cases} 0 & \text{if} \quad \Delta < 0, \\ \max\left\{0, \frac{-1+\sqrt{\Delta}}{\alpha}\right\} & \text{if} \quad \Delta \ge 0. \end{cases} \tag{15}$$

We use a variant of the Pakes and McGuire (1994) algorithm to compute the MPE [8].

### 2.6. Industry dynamics and structure

We use the following parameter values in our baseline model: $a=4$, $b=0.1$, $\alpha=0.0625$, $\beta=\frac{1}{1.05} \simeq 0.952$, $\delta=0.1$, $\eta=10$, $\theta=0.9$, and $M=9$ with $\bar{q}_1=5$, $\bar{q}_2=10$ up to $\bar{q}_9=45$. That is, if the industry is in state $(s_1, s_2, s_3)$, then $(\bar{q}_{s_1}, \bar{q}_{s_2}, \bar{q}_{s_3})=(5s_1, 5s_2, 5s_3)$. Note that the choice of $\alpha$ corresponds to a 0.5 success probability for an investment in the amount of 20, given the value of $\delta\left(\frac{(1-\delta)\alpha \cdot 20}{1+\alpha \cdot 20} = 0.5\right)$. The choice of $\beta$ corresponds to a yearly interest rate of 5%.

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[7] In the Bellman equation the firm always stays in the industry, so the salvage value of capital is not included even though it contributes to the firm's producer surplus.

[8] We thank Ulrich Doraszelski for providing the duopoly programs used in Besanko and Doraszelski (2004).

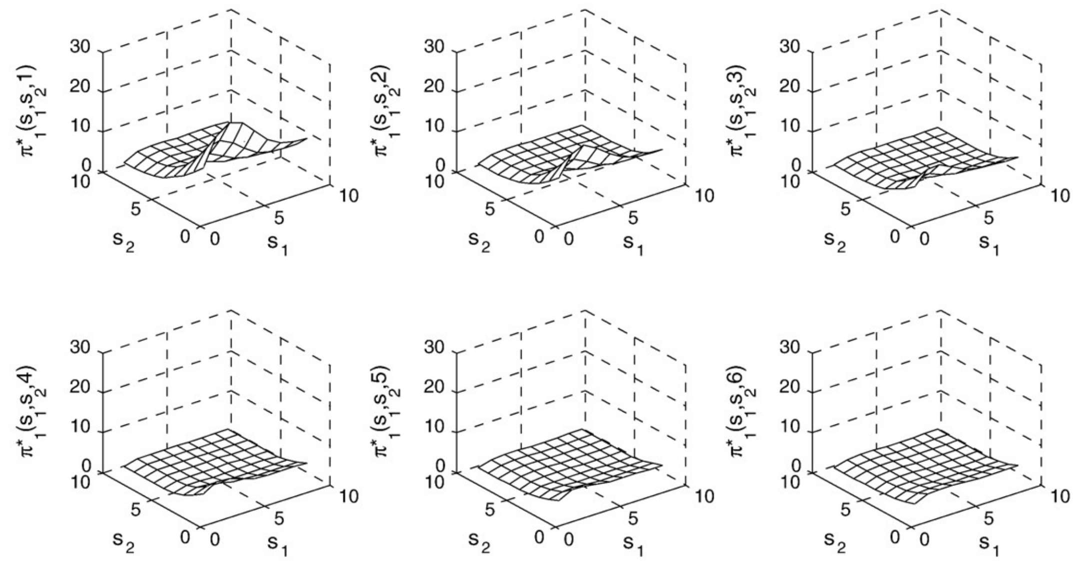


**Fig. 3.** Single-period profit function in states with $s_3 \leq 6$ (baseline model).

Figs. 1–3 present the equilibrium price function, the equilibrium quantity function, and the single-period profit function, respectively. Each function is illustrated by six panels with each panel corresponding to one level of the third firm's capacity. States with $s_3 > 6$ are outside of the single closed communicating class (see below), and are not included in the figures.

Roughly speaking, the farther away is the industry structure from (1, 1, 1), the lower the prices are, and prices decrease at a decreasing rate as the structure moves away from this minimal state.

Figs. 4 and 5 then present the value function and the policy function, respectively. Notice that firms have no incentive to invest once either of their rivals reaches a capacity level of 5. In fact, firms engage in a preemption race that is similar to the one in Besanko and Doraszelski (2004): they invest heavily when there is no large firm in the industry, hoping to be the first one to have a high capacity and deter their rivals from investing; but once a rival becomes large, the smaller firms simply give up by investing nothing.

There is a single closed communicating class (recurrent set) in the state space:

$$\left\{(s_1, s_2, s_3) \in \{1, 2, \dots M\}^3 : s_1, s_2, s_3 \leq 5, s_1 + s_2 + s_3 \leq 13\right\}.$$

When the state of the industry is on the outer edge of this set, no firm invests. Since there is stochastic depreciation, the state of the industry can remain the same or move inward (that is, firms have less capacities), but can not move outward.

The limiting distribution (ergodic distribution) of the industry is depicted in Fig. 6, which shows the probability (fraction of time) that the industry is in each state. Notice that although firms are *ex ante* identical, in the limiting distribution asymmetric industry structures prevail. In fact, the modes are states (1, 1, 5), (1, 5, 1), and (5, 1, 1), each having a probability of 11%.

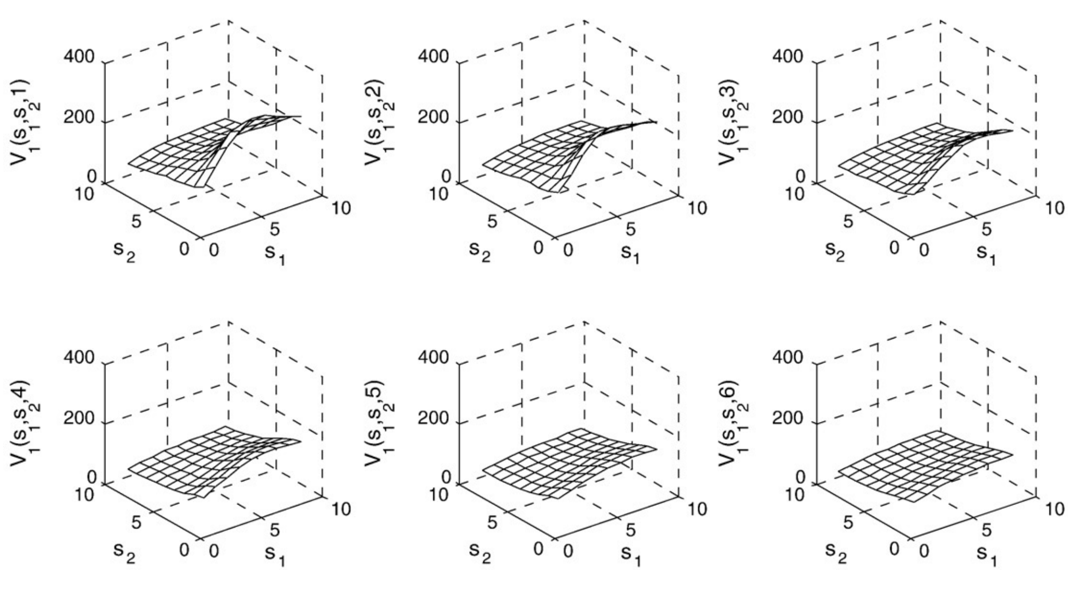


**Fig. 4.** Value function in states with $s_3 \leq 6$ (baseline model).

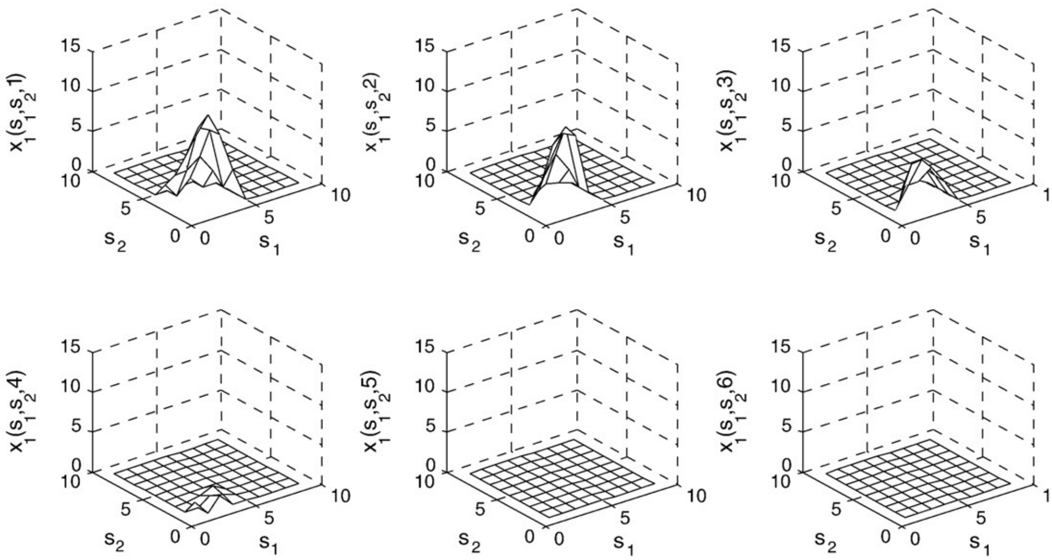


**Fig. 5.** Policy function in states with $s_3 \leq 6$ (baseline model).

Table 1 reports the probabilities of the most likely long-run industry structures, combining the probabilities of the states that differ only by the order of firms. For example, the probabilities of states (1, 2, 4), (1, 4, 2), (2, 1, 4), (2, 4, 1), (4, 1, 2), and (4, 2, 1) are combined and assigned to state (1, 2, 4), the one that has ascending capacities. The industry structures that have combined probabilities greater than 5% are reported. It is shown that most of the time the industry consists of one large firm and two (equally or unequally) small firms.

Also reported in Table 1 are the corresponding cross-price elasticities. Since firms' products are highly homogenous, one may expect the competition among them to be fierce. It is confirmed by the cross-price elasticities, which range from 1.01 to 8.00 and have a probability-weighted average of 4.07.

## 3. Merger evaluation

In this section, we examine the price and welfare effects of hypothetical mergers and compute the bias due to the misspecification described in Section 1. The two specifications used are: (a) firms are *ex ante* symmetric, and are subject to the same soft capacity constraints in a dynamic setting, and (b) firms are *ex ante* asymmetric with different but constant marginal costs. Both specifications assume price competition with differentiated products and have the same demand system in Eq. (4). As discussed above, both can give rise to persistent asymmetries in market shares.The procedures are as follows. We first simulate panel data of firms' prices and quantities by letting a triopoly evolve $T=100$ periods according to the first specification (the "true" specification). The purpose of letting the industry evolve $T$ periods before the mergers take place is to obtain premerger data of firms' prices and quantities, so that we can estimate firms' marginal costs under the asymmetric costs specification, and can compare merger predictions from the two specifications.

Call each evolution an experiment. In each experiment, the industry starts with the initial state (1, 1, 1). Given this state, firms set prices $p_j^*(\bar{q}_{s_j}, \bar{q}_{s_{-j}})$, satisfy their respective demands in Eq. (4), and obtain profits generated according to Eq. (10). They also invest according to the policy function, and the next industry state is determined stochastically based on the transition probabilities in Eqs. (6), (7) and (8), taking into account both the investments and the depreciation. A new period arrives with a new state, and the industry moves on. In each experiment after period $T$

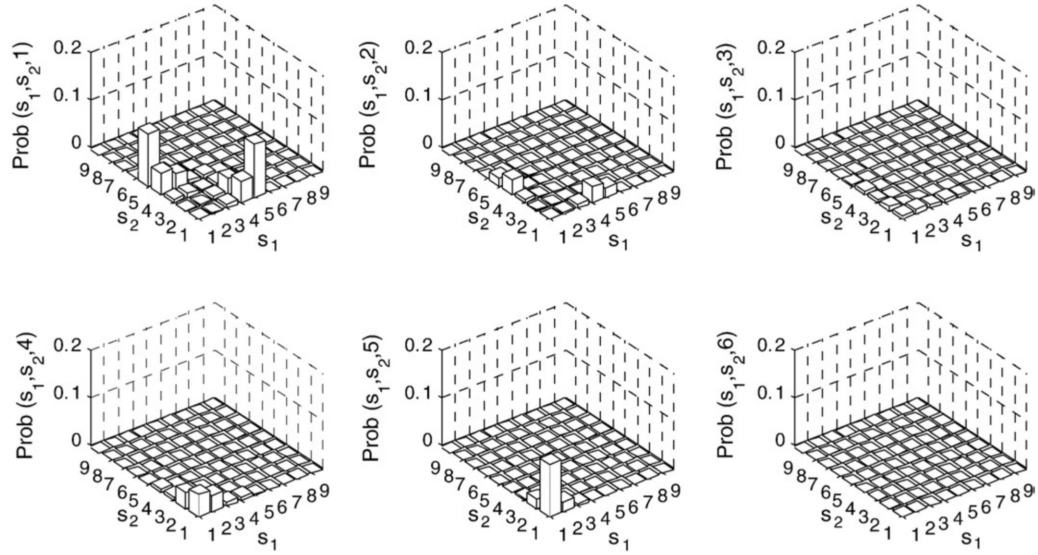


**Fig. 6.** Limiting distribution in states with $s_3 \leq 6$ (baseline model).

**Table 1**
Most likely industry structures and corresponding probabilities and cross-price elasticities

| Most likely industry structures[a] | Combined probabilities | Cross-price elasticities[b,c] | | | | | |
|---|---|---|---|---|---|---|---|
| | | $e_{i,j}$ | $e_{i,k}$ | $e_{j,i}$ | $e_{j,k}$ | $e_{k,i}$ | $e_{k,j}$ |
| (1,1,5) | 33.22% | 6.3557 | 5.1764 | 6.3557 | 5.1764 | 1.3613 | 1.3613 |
| (1,2,4) | 19.67% | 5.8368 | 5.2473 | 3.1198 | 2.6623 | 1.6159 | 1.5339 |
| (1,1,4) | 13.74% | 7.9985 | 7.0796 | 7.9985 | 7.0796 | 2.0728 | 2.0728 |
| (1,2,5) | 11.60% | 4.5562 | 3.7346 | 2.4797 | 1.9034 | 1.0769 | 1.0084 |
| (1,2,3) | 5.13% | 7.5780 | 7.2716 | 3.9901 | 3.6763 | 2.6925 | 2.5853 |

[a] The states that differ only by the order of firms are represented by the state that has ascending capacities. E.g., (1,2,4), (1,4,2), (2,1,4), (2,4,1), (4,1,2), and (4,2,1) are represented by (1,2,4). The industry structures that have combined probabilities greater than 5% are reported.
[b] i denotes the smallest firm in terms of capacity, j the medium, and k the largest.
[c] $e_{i,j}$ denotes the cross-price elasticity of firm i's demand with respect to firm j's price. Other cross-price elasticities are denoted analogously.

two out of the three firms merge, and we compute the price and welfare effects of these hypothetical mergers using both the true specification and the alternative specification.

We consider three types of exogenous mergers: the largest two firms in terms of output merge (type I mergers), the largest firm merges with the smallest firm (type II mergers), and the smallest two firms merge (type III mergers). Dividing mergers into three types allows us to examine the possible differences in merger effects due to the merging firms having different size positions in the industry.

In the current model mergers are exogenous and unanticipated. This scenario corresponds to an unexpected easing of merger rules by antitrust law enforcement agencies, such as the lifting of a merger ban. In a more general model, mergers would arise endogenously, such as in Gowrisankaran (1999). However, there are modeling difficulties that haven't been overcome in the literature. In particular, which mergers would arise endogenously depends crucially on how the merger game is specified, and as Gowrisankaran notes, designing the merger process is the most problematic part in analyzing endogenous mergers in a dynamic setting, because of two broad problems: multiple equilibria and no equilibrium. Currently, to abate those problems requires making strong assumptions on when and how firms move in the merger game. Moreover, as long as mergers in a duopoly industry are not allowed, modeling mergers as arising endogenously would only affect our premerger data. Therefore, our analysis of merger effects under the asymmetric capacity specification would remain valid, since the premerger data is primarily used for the estimation of firms' marginal costs under the asymmetric costs specification. We leave the more general model with endogenous mergers for future investigation.

86% of the mergers analyzed in this paper are profitable, in the sense that the merged firm would have a value higher than the values of the merging firms combined. Profitability is not a necessary condition for a merger to arise endogenously. For example, if a merger between two rivals of a firm would have a large negative impact on the firm's value, then the firm may have an incentive to merge with one of those rivals—even if such a merger would be unprofitable and the firm would be made worse off—in order to prevent a merger between those rivals from happening. Such behavior is called “spoiling” in merger and acquisition terminology. In reality, firms often try to spoil a merger if that merger would give its major rival a strategic advantage. For instance, in 2001, Microsoft sought to compete against AOL Time Warner to acquire AT&T Broadband. Microsoft's motive was to prevent archrival AOL Time Warner from merging with AT&T Broadband, which would create a major roadblock to Microsoft's own campaign to gain high-speed Internet subscribers (Gallivan, 2001) [9]. More recently in 2006, British Sky Broadcasting (BSkyB) bought a stake in ITV to become its biggest shareholder. The move was a spoiling tactic designed to prevent ITV from falling into the hands of BSkyB's largest competitor NTL (Dixon et al., 2006). In both examples, the spoilers' moves were seen as unprofitable by themselves but strategically important. Appendix A provides an example of a merger game that rationalizes such behavior.

Because firms' incentives to merge are diverse and the antitrust law enforcement agencies' responsibility is to assess the possible anticompetitive effects of every merger proposed, we include all possible mergers in the analysis (to exclude a merger we would have to show that it would not arise endogenously in any plausible merger process). The issue of whether different merger incentives have different implications on merger effects is left for future research.

### *3.1. The effects of mergers with dynamic capacity accumulation*

In our dynamic model of capacity accumulation, premerger output-weighted average price is

$$\bar{p} = \frac{\sum_{j=1}^{3} q_j p_j}{\sum_{j=1}^{3} q_j}. \tag{16}$$

Following Spence (1976), we use the following formula for our welfare analysis:

$$\begin{aligned} TS = & \int_0^{q_1} p_1(z_1, 0, 0) dz_1 + \int_0^{q_2} p_2(q_1, z_2, 0) dz_2 \\ & + \int_0^{q_3} p_3(q_1, q_2, z_3) dz_3 - TC, \end{aligned} \tag{17}$$

where TS denotes total surplus, TC denotes total costs, and $p_j(.)$ is given in Eq. (3). Note that the measure of total surplus is not affected by the order of firms in Eq. (17). Under the true specification,

$$TC = \sum_{j=1}^{3} \left[ \frac{1}{1+\eta} \left( \frac{q_j}{\bar{q}_{s_j}} \right)^{\eta} q_j \right]. \tag{18}$$

We then compute

$$PS = \sum_{j=1}^{3} q_j p_j - TC, \tag{19}$$

and

$$CS = TS - PS, \tag{20}$$

where *PS* denotes producer surplus and *CS* denotes consumer surplus. $\bar{p}$, TS, TC, PS, and CS are all computed based on prices, quantities and capacities in period *T*.

Note that investment cost and salvage value of capital are not included in the expressions of TS or PS, to make the capacity model comparable to the cost model. Here we are considering the case in which the discounted salvage value of the expected increment in capital due to an investment is equal to the cost of the investment, so they offset each other[10]. Robustness checks in Section 4 show that our results are robust to alternative treatments.

[9] Eventually Comcast, with significant help of Microsoft, beat out AOL Time Warner in bidding for AT&T Broadband.

[10] In Reynolds' (1986) welfare analysis of the American aluminum industry using a dynamic capacity model, the salvage value of capital is assumed to equal the cost of its acquisition.

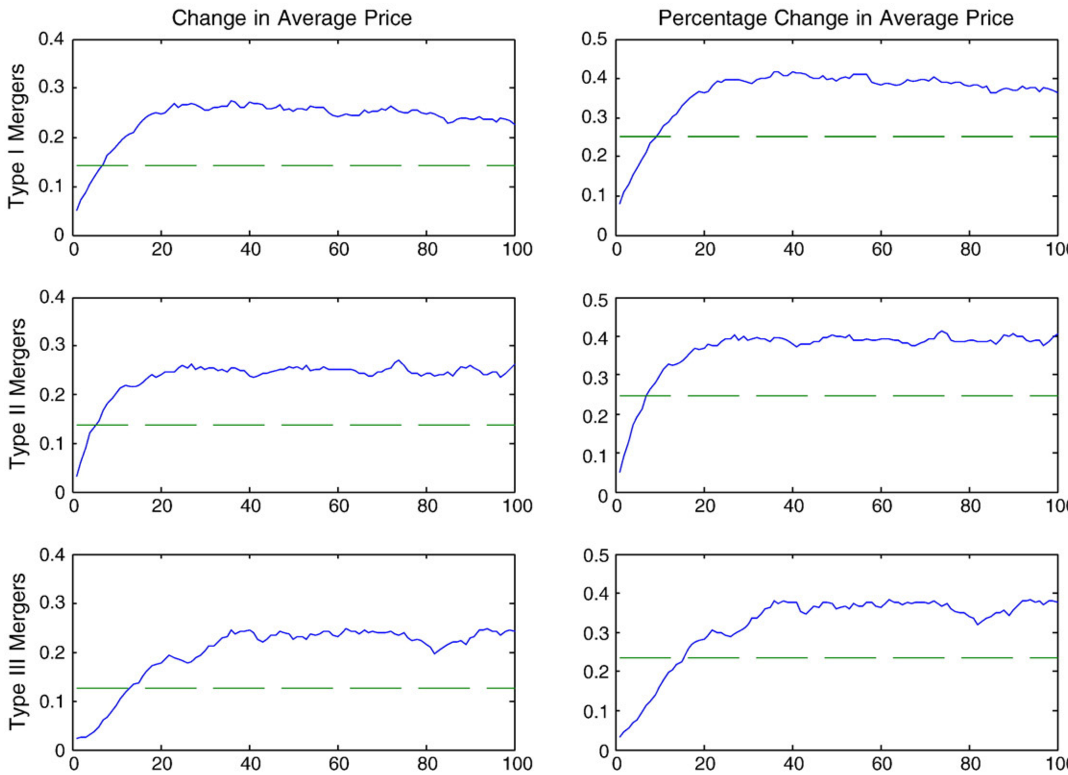


**Fig. 7.** Change and percentage change in average price. Percentage change equals change divided by premerger average price. For example, 0.2 in the right panels means a 20% increase in average price. Solid lines indicate soft capacity constraints specification, while dashed lines indicate asymmetric costs specification. The horizontal axis shows the number of periods since the merger. There are three types of mergers: the largest two firms in terms of output merge (type I mergers), the largest firm merges with the smallest firm (type II mergers), and the smallest two firms merge (type III mergers).

Now we turn to postmerger predictions. For each experiment, we predict price and welfare effects for all three types of mergers.

After each hypothetical merger, there are only two firms remaining in the industry. In period $T+1$, the merged firm's capacity is the sum of the capacities of the two merging firms or $\bar{q}_M$, whichever is smaller, while the non-merging firm's capacity remains the same[11]. From then on, the industry evolves according to the policy function and the transition probabilities for duopoly. For each period after the merger,

$$TS^{pm}=\int_0^{q_1^{pm}} p_1(z_1,0)dz_1+\int_0^{q_2^{pm}} p_2(q_1^{pm},z_2)dz_2-TC^{pm}, \tag{21}$$

where the superscript pm denotes "postmerger", and $p_j(q_j,q_{-j})=a-bq_j-\theta bq_{-j}$ is the duopoly inverse demand function. We compute $\bar{p}^{pm}$, $TS^{pm}$, and $CS^{pm}$ in ways analogous to their premerger counterparts, and calculate their changes ($\Delta\bar{p}$, $\Delta TS$, and $\Delta CS$) and percentage changes ($\Delta\bar{p}\%$, $\Delta TS\%$, and $\Delta CS\%$) from the premerger values[12].

Figs. 7–9 show the predicted changes and percentage changes in average price, total surplus, and consumer surplus, respectively, using the baseline model. All results are averages of 1000 experiments. The solid lines indicate the soft capacity constraints specification (SCC), while the dashed lines indicate the asymmetric costs specification (AC), which will be discussed in the next subsection. In each figure, the left panels depict changes, and the right panels depict percentage changes. From top to bottom, the panels depict changes and percentage changes after type I mergers, type II mergers, and type III mergers, respectively. It is shown that mergers are welfare-reducing and that their long-run effects are worse than their short-run effects.

### 3.1.1. Short run vs. long run

A feature of the predicted changes and percentage changes under SCC is that they gradually increase in absolute values during the first twenty or thirty periods after the merger, and then relatively stabilize. For example, average price is predicted to increase by about 10% right after type I mergers, but this number steadily climbs, reaches about 40% after 25 periods, and then remains there. So under SCC the long-run effects are worse than the short-run effects: average price increases further, while total surplus and consumer surplus decrease further.

The reason lies in the fact that the long-run industry structure is governed by the duopoly limiting distribution (the upper left panel in Fig. 10), whereas the short-run structure is merely a result of the merger, and can be a rarity in the limiting distribution. Fig. 10 shows that the limiting distribution is bimodal, with the modes being states (1, 5) and (5, 1). The two modal states combined has a probability of 0.32. On the other hand, states in which at least one firm has a capacity level greater than or equal to 6 have very small probabilities—those states combined has a probability of 0.02.

In the period immediately after a type I or type II merger, the industry structure is often "overly asymmetric" in the sense that the merged firm has too large a capacity that the corresponding state $(s_1,s_2)$ is extremely unstable, that is, it has a very small probability in the limiting distribution. The merged firm optimally chooses to have zero

[11] The additive property of capacity is used in Perry and Porter (1985), Gowrisankaran (1999), and Pesendorfer (2003), among others. In the only closed communicating class of the current model, the constraint of $\bar{q}_M$ is binding only for type I mergers with the following premerger states: (1, 5, 5), (2, 5, 5), (3, 5, 5), (5, 1, 5), (5, 2, 5), (5, 3, 5), (5, 5, 1), (5, 5, 2), (5, 5, 3). These states have a small combined probability of $4.1072\times10^{-6}$.

[12] When products are close substitutes and cross elasticities are high, the welfare loss due to the removal of a product from consumers' choice set is small (see, for example, Spence, 1976). That is the case for the near-homogeneous product industries studied in this paper. When analyzing mergers in these "relatively undifferentiated" product industries, the antitrust law enforcement agencies do not assume that the merged firm would continue to produce both brands—after all, brand names are not important in such industries (U.S. DOJ and FTC, 1992, Section 2.22).

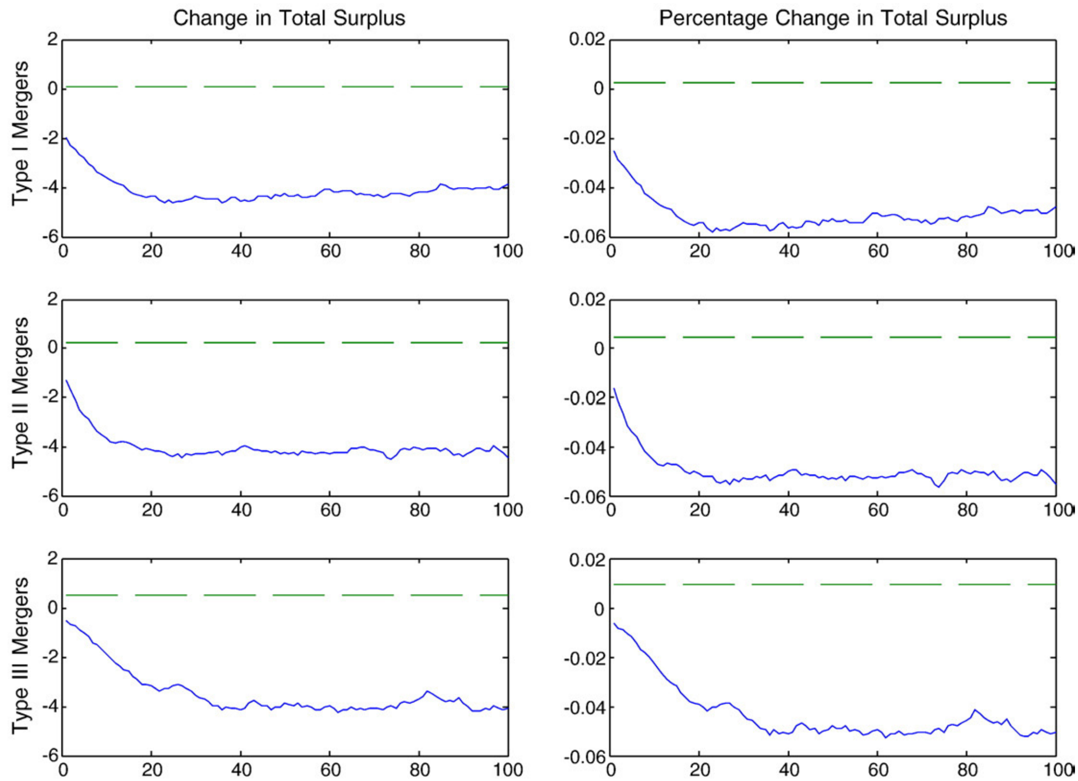


**Fig. 8.** Change and percentage change in total surplus. Percentage change equals change divided by premerger total surplus. For example, −0.02 in the right panels means a 2% decrease in total surplus. Solid lines indicate soft capacity constraints specification, while dashed lines indicate asymmetric costs specification. The horizontal axis shows the number of periods since the merger. There are three types of mergers: the largest two firms in terms of output merge (type I mergers), the largest firm merges with the smallest firm (type II mergers), and the smallest two firms merge (type III mergers).

investment and let its capacity shrink, and the industry moves towards states that are less asymmetric[13]. In the long run, the industry structure evolves according to the limiting distribution, and "overly asymmetric" industry structures rarely appear. For example, in our baseline triopoly model, the modal industry structure is (1, 1, 5), so if the industry is in this mode and either a type I merger or a type II merger occurs, the resulting industry structure is (1, 6) in the short run. But (1, 6) and (6, 1) combined has a low probability of 0.0016 and there is a strong tendency for the industry to move towards states that are less asymmetric.

There are two reasons why the large merged firm may want to let its capacity shrink. First, it is costly for a firm to maintain its capacity because of stochastic depreciation. Moreover, firms' price best response curves are upward sloping, and a reduction in the merged firm's capacity increases its marginal cost and shifts its curve up, resulting in higher equilibrium prices. Fig. 11 provides an illustration for the case in which the small unmerged firm has capacity level $s_1=1$, and the large merged firm reduces its capacity level from $s_2=6$ to $s_2=5$. By reducing its capacity, the merged firm causes the equilibrium prices to increase from (1.07, 0.86) to (1.33, 1.14), and raises its own profits from 22.21 to 25.83. More generally, when the merged firm has a large capacity, its equilibrium price is low and demand tends to be inelastic, so such price increases may result in higher profits for the merged firm. Let *i* and *j* denote the two firms in the postmerger industry. For any given level of $s_j$, firm *i*'s single-period profits always first increase and then decrease in its own capacity, peaking at either $s_i=3$ or $s_i=4$ (upper right panel in Fig. 10). Because of this relationship between a firm's profits and its own capacity, it is possible for a firm's value to be decreasing in its own capacity when it has a substantial capacity advantage over its rival. Examination of the value function (lower left panel in Fig. 10) shows that when facing a rival that is not too large ($s_j \le 5$), the value of firm i first increases and then decreases in its own capacity, peaking at $s_i=6$ (when $s_j \le 3$), $s_i=7$ (when $s_j=4$), or $s_i=8$ (when $s_j=5$)[14]. Note that because it is costly to maintain capacity, in the modal postmerger industry structure in which the smaller firm has a capacity level of 1, the larger firm has its capacity level at 5 instead of 6.

After many real-world mergers, the merged firm prunes some of its plants to reduce its capacity. For example, in the two years following the 2002 combination of the two forest-products giants Weyerhaeuser and Willamette, the merged firm closed more than 20 plants in its postmerger adjustment (Grund, 2004). The above analysis provides a possible explanation for such behavior.

The gradual extinction of the "overly asymmetric" industry structures is key in understanding the worsening of average price, TS, and CS as time passes. As discussed above, roughly speaking the farther away is the industry structure from the minimal state (1, 1, 1), the lower the prices are. That is true not only for triopoly markets, but also for duopoly markets (see the lower right panel in Fig. 10 for the equilibrium price function in a duopoly market). In the long run, the industry structure is less asymmetric and closer to the minimal state, so the firms charge higher prices.

To see that, again consider the modal industry structure in our baseline model. Prior to any merger, the industry structure (1, 1, 5) results in prices (0.98, 0.98, 0.80) and quantities (4.95, 4.95, 23.12), so the output-weighted average price is 0.85. After a type I merger or a type II merger, the industry structure becomes (1, 6), which gives rise to prices (1.07, 0.86) and quantities (4.99, 26.96), so the short-run average price is 0.89, representing a 4.44% price increase. In the long run, however, the industry structure will be governed by the limiting distribution. If the

[13] As noted above, profitability is not a necessary condition for a merger to arise endogenously. However, that the merged firm optimally chooses to let its capacity shrink after the merger does not necessarily mean that the merger is unprofitable—it merely means that the industry structure immediately after the merger is not ideal for the merged firm (when investment costs needed to maintain the capacity are taken into account), yet the merged firm may still prefer it to the premerger structure.

[14] When the larger firm's capacity advantage over its rival is small, the increase in the probability of a role reversal resulting from a reduction in its own capacity more than offsets any possible profit gains, so its value is always increasing in its own capacity.

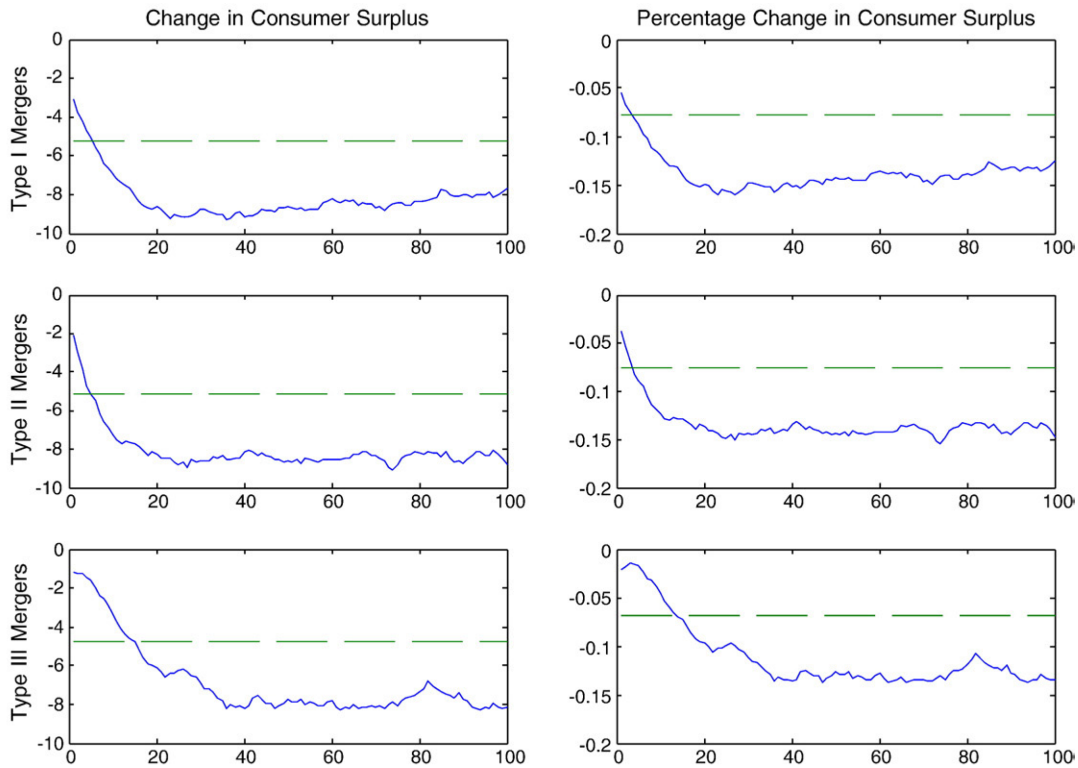


**Fig. 9.** Change and percentage change in consumer surplus. Percentage change equals change divided by premerger consumer surplus. For example, −0.05 in the right panels means a 5% decrease in consumer surplus. Solid lines indicate soft capacity constraints specification, while dashed lines indicate asymmetric costs specification. The horizontal axis shows the number of periods since the merger. There are three types of mergers: the largest two firms in terms of output merge (type I mergers), the largest firm merges with the smallest firm (type II mergers), and the smallest two firms merge (type III mergers).

market has the duopoly modal structure (1, 5) in the long run, prices will be (1.33, 1.14) and quantities will be (5.10, 24.05), so the average price is further increased to 1.17, representing a far larger 37.23% price increase. In the long run, both the small firm and the large firm charge higher prices than in the short run because the industry structure is less asymmetric and closer to the minimal state, resulting in a larger price increase.

On the other hand, if there is a type III merger, the industry structure immediately after the merger will have no firm with the minimal capacity level. Such an industry structure is "unstable" because of the preemption race that characterizes the industry dynamics: the smaller firm or the firm that becomes smaller due to bad shocks will give up by having little or no investment, and will shrink towards having the minimal capacity

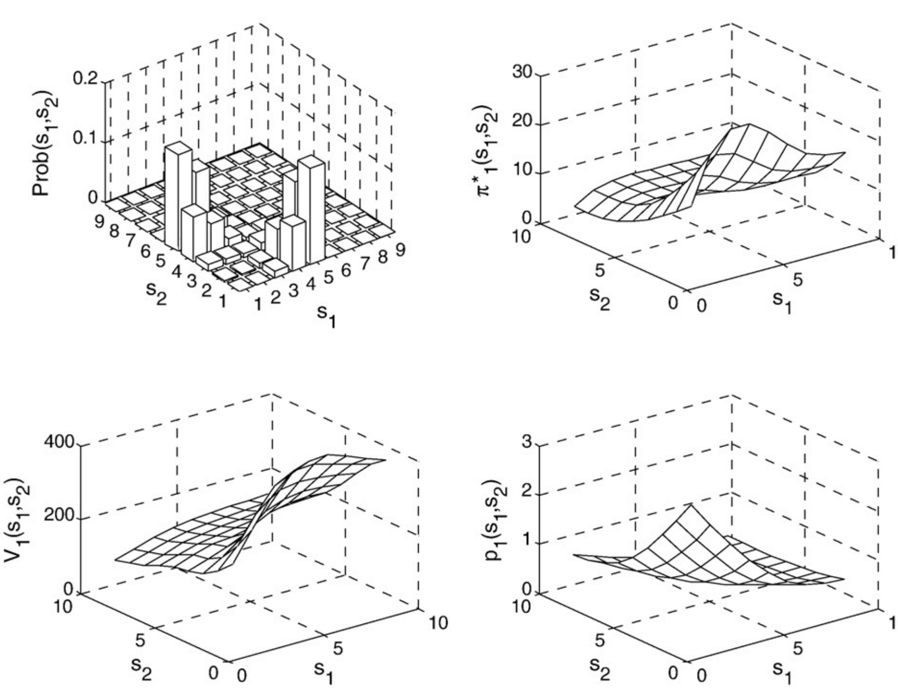


**Fig. 10.** Limiting distribution (upper left), single-period profit function (upper right), value function (lower left), and equilibrium price function (lower right) for the duopoly case.

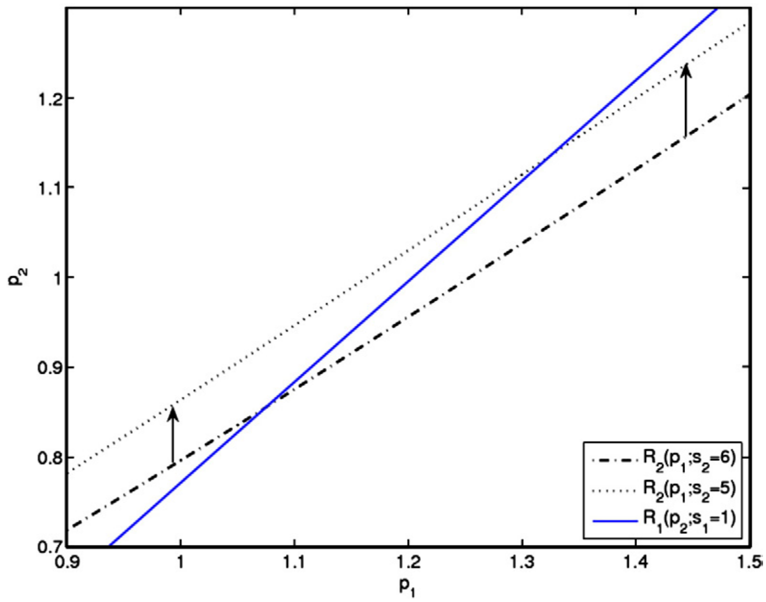


**Fig. 11.** Duopoly price best response curves: $s_1 = 1$, $s_2$ reduced from 6 to 5. $R_i(p_j;\, s_i)$ denotes firm $i$'s price best response when it has capacity level $s_i$ and its rival charges $p_j$.

level. As a result, average price becomes higher in the long run since the industry structure becomes closer to the minimal state.

The differences between the short-run and the long-run SCC predictions of TS and CS changes can be explained analogously. To summarize, after a merger of any type certain firms in the industry optimally choose to let their capacities shrink, resulting in higher prices, lower total surplus, and lower consumer surplus, which explains the worsening of the merger effects in the long run.

*3.1.2. Differences across types of mergers*

The above analysis also sheds light on the differences across types of mergers. Under SCC different types of mergers result in different short-run predicted changes in average price, TS, and CS, but those differences diminish as time passes: in the long run, the predicted changes are almost the same for different types of mergers. That is again due to the fact that in the long run, industry structure, and consequently prices and quantities, are governed by the limiting distribution. So in the long run, different types of mergers end up with the same distribution of industry structure, and the short-run differences in the predicted changes disappear.

*3.2. Bias in merger evaluation due to the misspecification*

Here we compare the predictions of merger effects in the previous subsection to the ones obtained when we instead fit the simulated data with an asymmetric costs model.

*3.2.1. Premerger estimates*

Under the asymmetric costs specification (that is, assuming firms have different but constant marginal costs), premerger output-weighted average price is computed according to Eq. (16), same as under the true specification.

To carry out the welfare analysis, we need to estimate $a$, $b$, $\theta$, $c_1$, $c_2$ and $c_3$, where $c_j$ is firm $j$'s marginal cost, $j = 1, 2, 3$, so we allow the model to have two error terms unobserved by the econometrician:

1. Let $\xi_{jt}$ be the error term on the demand side, so the demand system becomes:

$$q_{jt}(p_{jt}, p_{-jt}) = \frac{1}{b\left(1+\theta-2\theta^2\right)}\left[a(1-\theta)-(1+\theta)p_{jt}+\theta\sum p_{-jt}\right]+\xi_{jt},\quad j = 1, 2, 3, \tag{22}$$

where $\xi_{jt}$ is *i.i.d.* and $E[\xi_{jt} \mid p_1, p_2, \ldots, p_T] = 0$ with $p_t = (p_{1t}, p_{2t}, p_{3t})$. $\xi_{jt}$ is unknown to firm $j$ in period $t$.

2. On the cost side, we have

$$c_{jt} = \bar{c}_j + 2\varepsilon_{jt}, \tag{23}$$

where $\varepsilon_{jt}$ is *i.i.d.* and $E[\varepsilon_{jt} | p_{-j1}, p_{-j2}, \ldots, p_{-jT}] = 0$. That is, firm $j$'s marginal cost in period $t$ has two components, a firm-specific component $\bar{c}_j$ (firm $j$'s permanent marginal cost) and a time-varying error term. $\varepsilon_{jt}$ is known to firm $j$ in period $t$, but unknown to other firms.

We then solve the FOCs of the firms' profit maximization problems to obtain

$$p^*_{jt}(p_{-jt}, c_{jt}) = \frac{(1-\theta)a+\theta\sum p_{-jt}}{2(1+\theta)}+\frac{\bar{c}_j}{2}+\varepsilon_{jt}, j = 1, 2, 3. \tag{24}$$

Combining Eqs. (22) and (24), we have a system of six equations, each containing an *i.i.d.* error term with zero mean. That gives us a system nonlinear panel data model[15]. We estimate the six parameters in the system ($a$, $b$, $\theta$, $\bar{c}_1$, $\bar{c}_2$ and $\bar{c}_3$) in Matlab using PNLS (Pooled Nonlinear Least Squares)[16].

$$\min_{a,b,\theta,\bar{c}_1,\bar{c}_2\bar{c}_3} \sum_{t=1}^{T}\left(\xi_{1t}^2+\xi_{2t}^2+\xi_{3t}^2+\varepsilon_{1t}^2+\varepsilon_{2t}^2+\varepsilon_{3t}^2\right) \tag{25}$$
$$s.t.\ a > 0, b > 0, 0 \le \theta < 1, \bar{c}_1 \ge 0, \bar{c}_2 \ge 0, \text{ and } \bar{c}_3 \ge 0.$$

After obtaining $\hat{a}, \hat{b}, \hat{\theta}, \hat{\bar{c}}_1, \hat{\bar{c}}_2$ and $\hat{\bar{c}}_3$ as the solution to the above minimization problem, we compute premerger total surplus ($\widehat{\mathrm{TS}}$) and premerger consumer surplus ($\widehat{\mathrm{CS}}$) using the price and quantity data from period $T$, where the hats in $\widehat{\mathrm{TS}}$ and $\widehat{CS}$ indicate that they are computed under the asymmetric costs specification. Note that in this case the premerger total cost are

$$\widehat{\mathrm{TC}} = \sum_{j=1}^{3} \bar{c}_j q_j, \tag{26}$$

ignoring the mean zero error term.

[15] See Wooldridge (2002) for discussions on nonlinear panel data models.

[16] Under our orthogonality conditions and a mild rank condition the PNLS estimates are consistent. PGLS (Pooled Generalized Least Squares), which uses optimal weighting matrices when computing the sum of squared residuals, gives consistent and efficient estimates. In our case, the differences between PNLS and PGLS estimates are minor.

**Table 2**
Short-run* bias in evaluations of type I mergers

| δ | θ | Change in average price | | | Change in total surplus | | | Change in consumer surplus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] |
| 0.1 | 0.9 | 0.0487 | 0.1322 | 172% | −1.9723 | 0.1122 | 106% | −3.0669 | −5.0097 | −63% |
| | 0.95 | 0.0080 | 0.0824 | 936% | −0.7615 | 0.4549 | 160% | −0.9539 | −3.1132 | −226% |
| | 0.99 | 0.0007 | 0.0162 | 2356% | −0.1289 | 0.4288 | 433% | −0.1536 | −0.8862 | −477% |
| 0.2 | 0.9 | 0.0239 | 0.1316 | 450% | −1.5617 | 0.5425 | 135% | −1.9922 | −4.7485 | −138% |
| | 0.95 | 0.0082 | 0.0950 | 1065% | −0.6899 | 0.7064 | 202% | −0.9068 | −3.5876 | −296% |
| | 0.99 | 0.0003 | 0.0368 | 11194% | −0.1222 | 0.6569 | 638% | −0.1405 | −1.6957 | −1107% |
| 0.3 | 0.9 | 0.0289 | 0.1401 | 385% | −1.6020 | 0.7063 | 144% | −2.2021 | −5.1414 | −133% |
| | 0.95 | 0.0118 | 0.1054 | 792% | −0.7113 | 0.7497 | 205% | −1.0474 | −3.9531 | −277% |
| | 0.99 | 0.0014 | 0.0363 | 2494% | −0.1239 | 0.7357 | 694% | −0.1775 | −1.8158 | −923% |

*: Immediately after merger.
[a] Assuming soft capacity constraints and using true parameter values.
[b] Assuming asymmetric costs and using estimated parameter values.
[c] Bias%=(AC−SCC)/|SCC|*100%.

*3.2.2. Postmerger predictions*

After each merger, the merged firm's permanent marginal cost is the minimum of the two merging firms', while the non-merging firm's permanent marginal cost remains the same.[17] Since we have a static model under the asymmetric costs specification and there is no industry evolution, the predictions of merger effects are the same regardless of how many periods have passed since the merger.

Let the postmerger permanent marginal costs be $\hat{\hat{c}}_1$ and $\hat{\hat{c}}_2$. We will take these two as postmerger marginal costs since the $\varepsilon_{jt}$'s are unobserved and mean zero. The demand system is

$$\hat{q}_j(p_j, p_{-j}) = \frac{1}{\hat{b}\left(1-\hat{\theta}^2\right)}\left[\hat{a}\left(1-\hat{\theta}\right)-p_j+\hat{\theta}p_{-j}\right], j=1,2. \tag{27}$$

Solving the FOCs of the firms' profit maximization problems, we have the following postmerger prices:

$$\hat{p}_j^{pm} = \frac{\left(-2+\hat{\theta}+\hat{\theta}^2\right)\hat{a}-2\hat{\hat{c}}_j-\hat{\theta}\hat{\hat{c}}_{-j}}{\hat{\theta}^2-4}, j=1,2. \tag{28}$$

We drop the time subscripts since these predicted postmerger prices are time-invariant.

Substituting Eq. (28) into Eq. (27) gives us $\hat{q}_1^{pm}$ and $\hat{q}_2^{pm}$. We then compute postmerger total surplus according to

$$\widehat{TS}^{pm} = \int_0^{\hat{q}_1^{pm}} \hat{p}_1(z_1, 0)dz_1 + \int_0^{\hat{q}_2^{pm}} \hat{p}_2\left(\hat{q}_1^{pm}, z_2\right)dz_2 - \widehat{TC}^{pm}, \tag{29}$$

where $\hat{p}_j(q_j, q_{-j}) = \hat{a} - \hat{b}q_j - \hat{\theta}\hat{b}q_{-j}$ is the duopoly inverse demand function and $\widehat{TC}^{pm} = \sum_{j=1}^{2}\hat{\hat{c}}_j\hat{q}_j^{pm}$.

Finally we compute $\hat{\bar{p}}^{pm}$, $\widehat{CS}^{pm}$, $\Delta\hat{\bar{p}}$, $\Delta\hat{\bar{p}}\%$, $\Delta\widehat{TS}$, $\Delta\widehat{TS}\%$, $\Delta\widehat{CS}$ and $\Delta\widehat{CS}\%$ in ways analogous to their counterparts above. Here we are essentially computing *expected* average price, *expected* consumer surplus, etc., due to the existence of the mean zero error terms.

*3.2.3. Bias*

The dashed lines in Figs. 7–9 indicate the asymmetric costs specification (AC). It is shown that under AC, average price is predicted to increase after the mergers, and consumer surplus is predicted to decrease, same as under SCC. The predictions differ in sign when it comes to total surplus, with decreases predicted under SCC and slight increases predicted under AC.

A comparison between the solid lines and the dashed lines in Figs. 7–9 reveals that the predictions under AC are substantially biased. Some have a wrong sign, and those with a right sign often miss by a large percentage.

In particular, while under SCC the long-run effects of mergers are worse than the short-run effects, under AC the effects are time-invariant. In the cases of average price and consumer surplus, this difference causes the bias to be of opposite signs in the short run versus in the long run. For instance, under SCC consumer surplus is predicted to decrease by 5% right after a type I merger, and by 15% after 20 periods. Consequently, the prediction of a 7.5% decrease under AC constitutes a 50% upward bias (in absolute value) right after the merger, but a 50% downward bias in the long run. In the case of total surplus, the predictions under AC miss the point because they are of the wrong sign: after any type of mergers, total surplus is predicted to decrease (by about 1% to 2% right after the merger, and about 5% in the long run) under SCC, but under AC it is predicted to increase (by less than 1%).

The above bias in merger evaluations results from two differences between the specifications. The first difference is between the asymmetric costs assumption and the asymmetric capacities assumption. The former suggests that a merger could result in substantial cost savings, while the latter means that there would be little cost savings because firms have little difference in their marginal costs. That explains why the AC specification tends to underestimate the welfare-reducing effects of mergers.

The second difference is between a static model and a dynamic model. In the asymmetric costs model, everything is stationary after the merger and the long-run dynamics are not captured. However, in the dynamic model of capacity accumulation, capacities are endogenous and firms will adjust their capacities after the merger, so the long-run effects of a merger can be very different from the short-run effects. That is the reason why the magnitudes and even the signs of the bias change in the long run.

## 4. Robustness checks and antitrust implications

In this section, we conduct a set of robustness checks by varying the depreciation rate and/or the degree of product differentiation. We also compare the results from several alternative specifications. We then discuss the antitrust implications of our findings.

*4.1. Different parameter values*

In order to check whether the results obtained in the previous section are specific to the parameter values we use, we perform a set of robustness checks. Tables 2–7 report the results for a range of parameter values. Tables 2–4 report short-run bias (immediately after merger), while Tables 5–7 report long-run bias (50 periods after

[17] The assumption that the merged firm's marginal cost is the minimum of the two merging firms' is consistent with many of the antitrust law enforcement agencies' merger analyses (U.S. DOJ and FTC, 1992, Section 4, and 2006, Section 4). In Section 4 we consider an alternative case in which the merged firm's permanent marginal cost is the average of the two merging firms', as a robustness check.

**Table 3**
Short-run* bias in evaluations of type II mergers

| δ | θ | Change in average price | | | Change in total surplus | | | Change in consumer surplus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] |
| 0.1 | 0.9 | 0.0323 | 0.1253 | 288% | −1.2917 | 0.3138 | 124% | −2.0513 | −4.7632 | −132% |
| | 0.95 | 0.0043 | 0.0811 | 1775% | −0.5116 | 0.4833 | 194% | −0.6195 | −3.0705 | −396% |
| | 0.99 | 0.0004 | 0.0157 | 4158% | −0.0940 | 0.4386 | 567% | −0.1089 | −0.8722 | −701% |
| 0.2 | 0.9 | 0.0174 | 0.1308 | 651% | −1.2432 | 0.5672 | 146% | −1.5496 | −4.7186 | −205% |
| | 0.95 | 0.0052 | 0.0940 | 1713% | −0.5298 | 0.7317 | 238% | −0.6678 | −3.5563 | −433% |
| | 0.99 | 0.0001 | 0.0368 | 53929% | −0.0908 | 0.6570 | 823% | −0.0995 | −1.6948 | −1603% |
| 0.3 | 0.9 | 0.0203 | 0.1395 | 589% | −1.2514 | 0.7239 | 158% | −1.6660 | −5.1212 | −207% |
| | 0.95 | 0.0080 | 0.1044 | 1197% | −0.5463 | 0.7739 | 242% | −0.7746 | −3.9228 | −406% |
| | 0.99 | 0.0009 | 0.0363 | 3883% | −0.0963 | 0.7358 | 864% | −0.1318 | −1.8152 | −1277% |

*: Immediately after merger.
[a] Assuming soft capacity constraints and using true parameter values.
[b] Assuming asymmetric costs and using estimated parameter values.
[c] Bias%=(AC−SCC)/|SCC|*100%.

merger). Tables 2 and 5 report type I mergers, Tables 3 and 6 report type II mergers, and Tables 4 and 7 report type III mergers. Each table contains nine sets of parameter values, with δ being .1, .2 or .3 and θ being .9, .95 or .99. What we want to examine is how different depreciation rates and/or different degrees of product differentiation affect the results. The tables show that changes in parameter values leave our findings unchanged regarding the price and welfare effects of mergers and the bias due to the misspecification.

In particular, the following three conclusions are robust to different parameter values.

1. Under SCC mergers are welfare-reducing and their long-run effects are worse than their short-run effects: in the long run average price increases further, while total surplus and consumer surplus decrease further.
2. Compared to SCC, AC leads to overestimation of the increases in average price and the decreases in consumer surplus in the short run, and underestimation of them in the long run.
3. Contrary to the SCC prediction that total surplus decreases after a merger, total surplus is predicted to increase under AC.

### 4.2. Alternative specifications

As further robustness checks, we compare the long-run results in merger evaluations in four cases.

a. Our baseline case (SCC vs. AC). Each of the following three cases contains one modification to the baseline case.
b. Firms are allowed to have slight differences in their cost structures in the capacity model. To do that, let a firm's cost function in the SCC specification be given by

$$C(q|\bar{q}) = \left[\mathrm{mc} + \frac{1}{1+\eta}\left(\frac{q}{\bar{q}}\right)^{\eta}\right]q, \tag{30}$$

so that its marginal cost is $c(q|\bar{q}) = \mathrm{mc} + \left(\frac{q}{\bar{q}}\right)^{\eta}$, where mc is a firm-specific constant. The merged firm's mc is the minimum of the merging firms'. Note that in this case we no longer have symmetric and anonymous MPE.
c. Investment costs are deducted from TS and PS in the SCC specification, that is, the discounted salvage value of the expected increment in capital due to any investment is zero, implying that capital is industry-specific.
d. The merged firm's marginal cost is the average (instead of the minimum) of the merging firms' in the AC specification.

Our findings are robust to these alternative specifications. Table 8 reports the long-run results in merger evaluations in the above four cases for all three types of mergers. For (b), the premerger mc's used in the capacity model are (0.5, 0.5, 0), representing an industry in which one firm is more efficient than the other two. The results in Table 8 show that regardless of the case considered, in the long run the AC specification underestimates increases in average price, decreases in consumer surplus, and decreases in total surplus (or even predict in the opposite direction).

**Table 4**
Short-run* bias in evaluations of type III mergers

| δ | θ | Change in average price | | | Change in total surplus | | | Change in consumer surplus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] |
| 0.1 | 0.9 | 0.0223 | 0.1168 | 424% | −0.5106 | 0.5599 | 210% | −1.1602 | −4.4623 | −285% |
| | 0.95 | 0.0071 | 0.0756 | 960% | −0.2143 | 0.6282 | 393% | −0.4334 | −2.8875 | −566% |
| | 0.99 | 0.0014 | 0.0148 | 956% | −0.0354 | 0.4600 | 1399% | −0.0810 | −0.8406 | −937% |
| 0.2 | 0.9 | 0.0152 | 0.1223 | 704% | −0.4171 | 0.8029 | 292% | −0.8382 | −4.4408 | −430% |
| | 0.95 | 0.0074 | 0.0895 | 1113% | −0.1898 | 0.8467 | 546% | −0.4217 | −3.4106 | −709% |
| | 0.99 | 0.0011 | 0.0358 | 3019% | −0.0358 | 0.6803 | 1999% | −0.0749 | −1.6640 | −2122% |
| 0.3 | 0.9 | 0.0167 | 0.1297 | 678% | −0.4529 | 1.0090 | 323% | −0.9301 | −4.8013 | −416% |
| | 0.95 | 0.0088 | 0.0996 | 1027% | −0.1953 | 0.9010 | 561% | −0.4784 | −3.7668 | −687% |
| | 0.99 | 0.0016 | 0.0354 | 2105% | −0.0343 | 0.7587 | 2311% | −0.0893 | −1.7846 | −1899% |

*: Immediately after merger.
[a] Assuming soft capacity constraints and using true parameter values.
[b] Assuming asymmetric costs and using estimated parameter values.
[c] Bias%=(AC−SCC)/|SCC|*100%.

**Table 5**
Long-run* bias in evaluations of type I mergers

| $\delta$ | $\theta$ | Change in average price | | | Change in total surplus | | | Change in consumer surplus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] |
| 0.1 | 0.9 | 0.2503 | 0.1322 | −47% | −4.2489 | 0.1122 | 103% | −8.4506 | −5.0097 | 41% |
| | 0.95 | 0.1710 | 0.0824 | −52% | −2.7472 | 0.4549 | 117% | −5.6301 | −3.1132 | 45% |
| | 0.99 | 0.1158 | 0.0162 | −86% | −1.5624 | 0.4288 | 127% | −3.4650 | −0.8862 | 74% |
| 0.2 | 0.9 | 0.2275 | 0.1316 | −42% | −4.2398 | 0.5425 | 113% | −7.3877 | −4.7485 | 36% |
| | 0.95 | 0.2599 | 0.0950 | −63% | −4.0550 | 0.7064 | 117% | −7.9132 | −3.5876 | 55% |
| | 0.99 | 0.1965 | 0.0368 | −81% | −2.8146 | 0.6569 | 123% | −5.5548 | −1.6957 | 69% |
| 0.3 | 0.9 | 0.1590 | 0.1401 | −12% | −3.2859 | 0.7063 | 121% | −5.5300 | −5.1414 | 7% |
| | 0.95 | 0.2815 | 0.1054 | −63% | −4.2644 | 0.7497 | 118% | −8.5611 | −3.9531 | 54% |
| | 0.99 | 0.2901 | 0.0363 | −87% | −3.9017 | 0.7357 | 119% | −8.3896 | −1.8158 | 78% |

*: 50 periods after merger.
[a] Assuming soft capacity constraints and using true parameter values.
[b] Assuming asymmetric costs and using estimated parameter values.
[c] Bias%=(AC−SCC)/|SCC|*100%.

The differences between the results in (a) and (b) are minor, which shows that allowing firms to have slight differences in their cost structures in the capacity model has little impact on our analysis.

The results regarding average price and CS are the same in (a) and (c) since deducting investment costs from TS and PS does not affect average price and CS. The results regarding TS are different but very close, resulting from the fact that in the long run the industry has similar total investments whether there are two firms or three firms. Probability-weighted average of industry total investments is 3.13 in the triopoly model and 3.27 in the duopoly model, where the weights are the probabilities of industry states in the limiting distribution. The difference is only about 4%.

When the merged firm's marginal cost is the average (instead of the minimum) of the merging firms', the AC specification will predict less cost savings resulting from a merger and so the differences between the AC predictions and the SCC predictions are expected to be smaller. That is confirmed by Table 8. A comparison between (a) and (d) shows that the bias in merger evaluations is smaller in (d), but the directions of the bias are unchanged and the bias is still substantial. Unlike in the baseline case, the AC specification predicts decreases in TS according to (d), but the decreases predicted are noticeably smaller than those predicted in the SCC specification.

### 4.3. Anticipated mergers

In general, mergers should be modeled as arising endogenously (as in Gowrisankaran, 1999). Since it is difficult to model an endogenous merger process that determines both the timing of the merger and the identity of the merging firms (see the difficulties encountered by Gowrisankaran, 1999), this paper takes a simplified approach and considers a robustness check in which firms anticipate that a merger will take place in the future. Specifically, firms anticipate that at the beginning of each period, there is a probability of $\rho$ that the industry will switch forever to the postmerger duopoly MPE. Each of the three possible mergers happens with probability $\rho/3$. When two firms merge, their shares of the merged firm's value are proportional to their premerger capacities (below we also consider two alternative assumptions).

Let $V_1^T$ and $V_1^D$ denote firm 1's values in the premerger triopoly MPE and in the postmerger duopoly MPE, respectively. The Bellman equation in the premerger industry is

$$V_1^T(s_1,s_2,s_3)=\max_{x_1\geq 0}\pi_1^*(s_1,s_2,s_3)-x_1+\beta\sum_{s_1'=1}^{M}W_1(s_1')prob(s_1'|s_1,x_1),$$

where

$$W_1(s_1') = \sum_{s_2'=1}^{M}\sum_{s_3'=1}^{M}\phi_1(s_1',s_2',s_3')prob(s_2'|s_2,x_2(s_1,s_2,s_3))prob(s_3'|s_3,x_3(s_1,s_2,s_3)),$$

and

$$\begin{aligned}\phi_1(s_1',s_2',s_3') = {} & (1-\rho)V_1^T(s_1',s_2',s_3') \\ & +\frac{\rho}{3}V_1^D(s_1',\min(s_2'+s_3',M)) \\ & +\frac{\rho}{3}\frac{s_1'}{s_1'+s_3'}V_1^D(\min(s_1'+s_3',M),s_2') \\ & +\frac{\rho}{3}\frac{s_1'}{s_1'+s_2'}V_1^D(\min(s_1'+s_2',M),s_3').\end{aligned}$$

Four values of $\rho$ are considered, $\rho$=0, 0.01, 0.1, and 0.2. When $\rho$=0, we are back to the baseline case in which mergers are unanticipated. Corresponding to the three positive values of $\rho$, firms anticipate that a merger will take place, in expectation, in 100, 10, and 5 periods, respectively. Table 9 reports the long-run results in merger evaluations for these four cases. The results show that our findings are largely unaffected by modeling mergers as anticipated by the firms. The AC specification underestimates the long-run increases in average price by

**Table 6**
Long-run* bias in evaluations of type II mergers

| $\delta$ | $\theta$ | Change in average price | | | Change in total surplus | | | Change in consumer surplus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] |
| 0.1 | 0.9 | 0.2129 | 0.1253 | −41% | −3.6534 | 0.3138 | 109% | −7.3015 | −4.7632 | 35% |
| | 0.95 | 0.1374 | 0.0811 | −41% | −2.3138 | 0.4833 | 121% | −4.5720 | −3.0705 | 33% |
| | 0.99 | 0.1296 | 0.0157 | −88% | −1.7338 | 0.4386 | 125% | −3.8718 | −0.8722 | 77% |
| 0.2 | 0.9 | 0.2321 | 0.1308 | −44% | −4.3461 | 0.5672 | 113% | −7.4824 | −4.7186 | 37% |
| | 0.95 | 0.2507 | 0.0940 | −62% | −3.9178 | 0.7317 | 119% | −7.7145 | −3.5563 | 54% |
| | 0.99 | 0.1964 | 0.0368 | −81% | −2.7784 | 0.6570 | 124% | −5.6008 | −1.6948 | 70% |
| 0.3 | 0.9 | 0.1684 | 0.1395 | −17% | −3.4153 | 0.7239 | 121% | −5.8532 | −5.1212 | 13% |
| | 0.95 | 0.2878 | 0.1044 | −64% | −4.4074 | 0.7739 | 118% | −8.6858 | −3.9228 | 55% |
| | 0.99 | 0.3020 | 0.0363 | −88% | −4.0221 | 0.7358 | 118% | −8.7691 | −1.8152 | 79% |

*: 50 periods after merger.
[a] Assuming soft capacity constraints and using true parameter values.
[b] Assuming asymmetric costs and using estimated parameter values.
[c] Bias%=(AC−SCC)/|SCC|*100%.

**Table 7**
Long-run* bias in evaluations of type III mergers

| δ | θ | Change in average price | | | Change in total surplus | | | Change in consumer surplus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] |
| 0.1 | 0.9 | 0.2192 | 0.1168 | −47% | −3.7524 | 0.5599 | 115% | −7.5395 | −4.4623 | 41% |
| | 0.95 | 0.1210 | 0.0756 | −38% | −2.0668 | 0.6282 | 130% | −4.0852 | −2.8875 | 29% |
| | 0.99 | 0.1065 | 0.0148 | −86% | −1.4873 | 0.4600 | 131% | −3.1305 | −0.8406 | 73% |
| 0.2 | 0.9 | 0.2231 | 0.1223 | −45% | −4.1964 | 0.8029 | 119% | −7.1620 | −4.4408 | 38% |
| | 0.95 | 0.2542 | 0.0895 | −65% | −3.9588 | 0.8467 | 121% | −7.8137 | −3.4106 | 56% |
| | 0.99 | 0.2241 | 0.0358 | −84% | −3.2336 | 0.6803 | 121% | −6.2743 | −1.6640 | 73% |
| 0.3 | 0.9 | 0.1865 | 0.1297 | −30% | −3.7107 | 1.0090 | 127% | −6.3236 | −4.8013 | 24% |
| | 0.95 | 0.2968 | 0.0996 | −66% | −4.5474 | 0.9010 | 120% | −8.9225 | −3.7668 | 58% |
| | 0.99 | 0.2863 | 0.0354 | −88% | −3.8352 | 0.7587 | 120% | −8.2951 | −1.7846 | 78% |

*: 50 periods after merger.
[a] Assuming soft capacity constraints and using true parameter values.
[b] Assuming asymmetric costs and using estimated parameter values.
[c] Bias%=(AC−SCC)/|SCC|*100%.

41% to 67%, and underestimates the long-run decreases in consumer surplus by 35% to 61%. The AC specification also predicts increases in total surplus when in fact it decreases, and the percentage bias ranges from 91% to 115%. The different values of ρ have only small impact on these results.

We then conduct this robustness check under two alternative assumptions regarding the merging firms' shares of the merged firm's value: (1) the shares are proportional to the merging firms' stand-alone values, and (2) the shares are proportional to the merging firms' market shares. The results, not reported here, are similar to those in Table 9, and show that our findings are robust to these alternative assumptions, too.

### 4.4. Antitrust implications

Since Williamson (1968), economists have a tradition to base their antitrust analysis regarding mergers on total surplus considerations. In this subsection, we focus on the long-run predicted TS changes under both the SCC specification and the AC specification to explore the antitrust implications.

Our primary interest is the following: if SCC is the true specification, in which direction will the long-run AC predictions be biased?

Define

$$B \equiv \frac{\Delta\widehat{\mathrm{TS}} - \Delta\mathrm{TS}}{|\Delta\mathrm{TS}|}, \tag{31}$$

where $\Delta\widehat{\mathrm{TS}}$ and ΔTS are long-run predicted changes in TS under AC and SCC, respectively, and |ΔTS| is the absolute value of ΔTS. $B$ measures the percentage bias of the long-run AC prediction and bears the sign of the bias.

Fig. 12 presents the histograms of $B$ for our baseline model. From top to bottom are the histograms for type I mergers, type II mergers, and type III mergers, respectively. The histograms show that the AC predictions are severely biased upward most of the time: the mode of $B$ is at about 1, and the values of the percentage bias cluster around the mode, regardless of the type of the mergers. For type I mergers, the AC predictions are greater than the SCC predictions 76.2% of the time. That number is 73.7% for type II mergers, and 77.9% for type III mergers. That means the AC predictions generally underestimate mergers' welfare-reducing effects, or even predict to the opposite.

The reason lies in the fact that the AC assumption attributes the persistent asymmetries in market shares to the differences in marginal costs and suggests that there would be substantial effects of cost savings resulting from a merger, when in fact there would be little cost savings because firms actually have little difference in their marginal costs—in this case the real source of the persistent asymmetries in market shares is the asymmetric capacities.

Figs. 13 and 14 present the histograms of $B$ with $\delta$ changed to 0.2 (Fig. 13) or $\theta$ changed to 0.8 (Fig. 14). These histograms are qualitatively the same as the ones in Fig. 12. Further changes in $\delta$ or $\theta$ or changes in other parameters have minimal effects on the histograms, showing that our conclusions are robust to changes in parameter values.

Our analysis thus shows that if the AC specification is assumed when the true specification is SCC, a merger that would result in a

**Table 8**
Long-run* bias in merger evaluations — alternative specifications

| | Type | Change in average price | | | Change in total surplus | | | Change in consumer surplus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SCC[1] | AC[2] | Bias%[3] | SCC[1] | AC[2] | Bias%[3] | SCC[1] | AC[2] | Bias%[3] |
| a | I | 0.2503 | 0.1322 | −47% | −4.2489 | 0.1122 | 103% | −8.4506 | −5.0097 | 41% |
| | II | 0.2129 | 0.1253 | −41% | −3.6534 | 0.3138 | 109% | −7.3015 | −4.7632 | 35% |
| | III | 0.2192 | 0.1168 | −47% | −3.7524 | 0.5599 | 115% | −7.5395 | −4.4623 | 41% |
| b | I | 0.2381 | 0.1249 | −48% | −2.9108 | 0.2009 | 107% | −6.7635 | −4.0776 | 40% |
| | II | 0.2179 | 0.1235 | −43% | −2.5040 | 0.2328 | 109% | −6.3252 | −4.0366 | 36% |
| | III | 0.2239 | 0.1205 | −46% | −2.7061 | 0.2993 | 111% | −6.4122 | −3.9467 | 38% |
| c | I | 0.2503 | 0.1322 | −47% | −4.0871 | 0.1122 | 103% | −8.4506 | −5.0097 | 41% |
| | II | 0.2129 | 0.1253 | −41% | −3.2325 | 0.3138 | 110% | −7.3015 | −4.7632 | 35% |
| | III | 0.2192 | 0.1168 | −47% | −3.2073 | 0.5599 | 117% | −7.5395 | −4.4623 | 41% |
| d | I | 0.2503 | 0.2015 | −20% | −4.2489 | −2.8740 | 32% | −8.4506 | −6.9842 | 17% |
| | II | 0.2129 | 0.1934 | −9% | −3.6534 | −2.5814 | 29% | −7.3015 | −6.7272 | 8% |
| | III | 0.2192 | 0.1377 | −37% | −3.7524 | −0.1895 | 95% | −7.5395 | −5.1406 | 32% |

*: 50 periods after merger.
1: Assuming soft capacity constraints and using true parameter values.
2: Assuming asymmetric costs and using estimated parameter values.
3: Bias%=(AC−SCC)/|SCC|*100%.
a: Baseline case.
b: Firms have different marginal costs in the SCC specification.
c: Investment costs are excluded from TS and PS in the SCC specification.
d: The merged firm's marginal cost is the average of the merging firms' in the AC specification.

**Table 9**
Long-run* bias in merger evaluations — anticipated mergers

| ρ | Type | Change in average price | | | Change in total surplus | | | Change in consumer surplus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] | SCC[a] | AC[b] | Bias%[c] |
| 0 | I | 0.2503 | 0.1322 | −47% | −4.2489 | 0.1122 | 103% | −8.4506 | −5.0097 | 41% |
| | II | 0.2129 | 0.1253 | −41% | −3.6534 | 0.3138 | 109% | −7.3015 | −4.7632 | 35% |
| | III | 0.2192 | 0.1168 | −47% | −3.7524 | 0.5599 | 115% | −7.5395 | −4.4623 | 41% |
| 0.01 | I | 0.2704 | 0.1242 | −54% | −4.4655 | 0.0842 | 102% | −9.0097 | −4.7232 | 48% |
| | II | 0.2367 | 0.1179 | −50% | −3.9177 | 0.2667 | 107% | −7.9985 | −4.4966 | 44% |
| | III | 0.2364 | 0.1093 | −54% | −3.9171 | 0.5134 | 113% | −8.0332 | −4.1846 | 48% |
| 0.1 | I | 0.6019 | 0.2088 | −65% | −8.4868 | −0.4096 | 95% | −21.1611 | −8.4407 | 60% |
| | II | 0.5669 | 0.2007 | −65% | −7.8939 | −0.1214 | 98% | −20.0266 | −8.1404 | 59% |
| | III | 0.5501 | 0.1940 | −65% | −7.6640 | 0.1176 | 102% | −19.5081 | −7.8924 | 60% |
| 0.2 | I | 0.6727 | 0.2250 | −67% | −9.3573 | −0.8726 | 91% | −23.9527 | −9.3068 | 61% |
| | II | 0.6257 | 0.2222 | −64% | −8.6122 | −0.7615 | 91% | −22.4592 | −9.2039 | 59% |
| | III | 0.6201 | 0.2187 | −65% | −8.5344 | −0.6265 | 93% | −22.2972 | −9.0761 | 59% |

*: 50 periods after merger.
[a] Assuming soft capacity constraints and using true parameter values
[b] Assuming asymmetric costs and using estimated parameter values.
[c] Bias%=(AC−SCC)/|SCC|*100%.

substantial reduction in total welfare might actually be approved based on total welfare considerations.

## 5. Conclusion

The U.S. antitrust law enforcement agencies often base their assessment of horizontal merger effects on a model with asymmetric costs. However, a large number of merger cases investigated involve near-homogeneous product industries, and there are good reasons to believe that cost differences are minor in some of those industries. Capacity differences seem a more reasonable explanation of heterogeneity among firms.

The purpose of this paper is to see how much the assessment of merger effects would change when the industry is more aptly described by a dynamic model of capacity accumulation. In the model firms produce near-homogeneous products and compete in prices. A key feature is that firms are *ex ante* identical and face the same cost structure but develop persistent differences in their capacities and market shares due to idiosyncratic shocks to their investments and depreciation. Our simulations show that mergers are welfare-reducing and that their long-run effects are worse than their short-run effects: in the long run average price increases further while total surplus and consumer surplus decrease further. The worsening of the merger effects in the long run results from the fact that certain firms in the postmerger industry optimally choose to let their capacities shrink, resulting in higher prices, lower total surplus, and lower consumer surplus.

We then fit the simulated data with an asymmetric costs model (firms are *ex ante* asymmetric by having different but constant marginal costs). The misspecification results in systematic underestimation of the long-run welfare-reducing effects of mergers, which can give rise to misguided antitrust policies. In particular, a merger that would result in a substantial reduction in total welfare may actually be approved based on total welfare considerations. These findings argue against using the asymmetric costs model—the current practice of antitrust agencies—in industries in which capacity

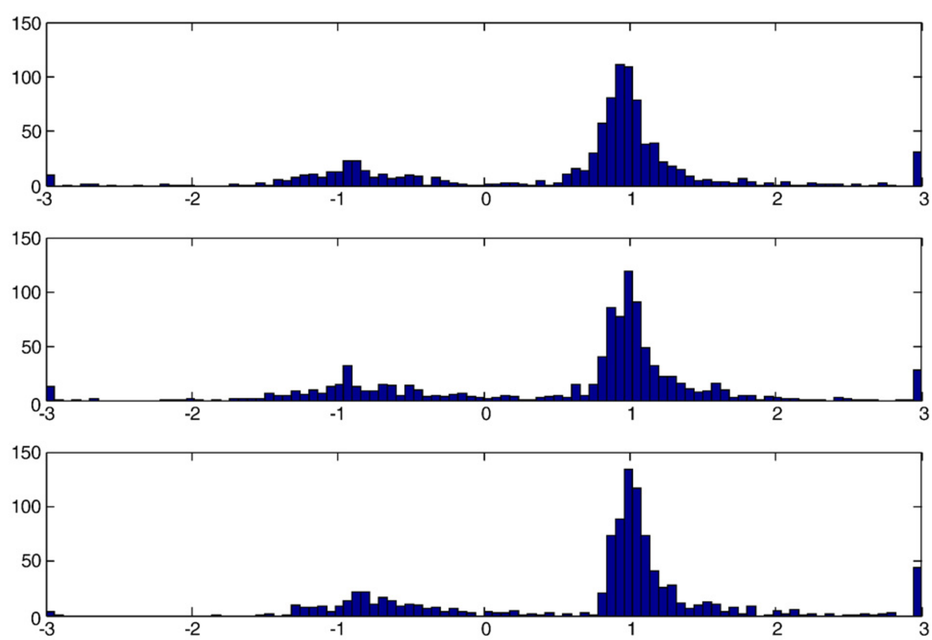


**Fig. 12.** Histograms of *B* for the baseline model. From top to bottom: type I mergers, type II mergers, and type III mergers.

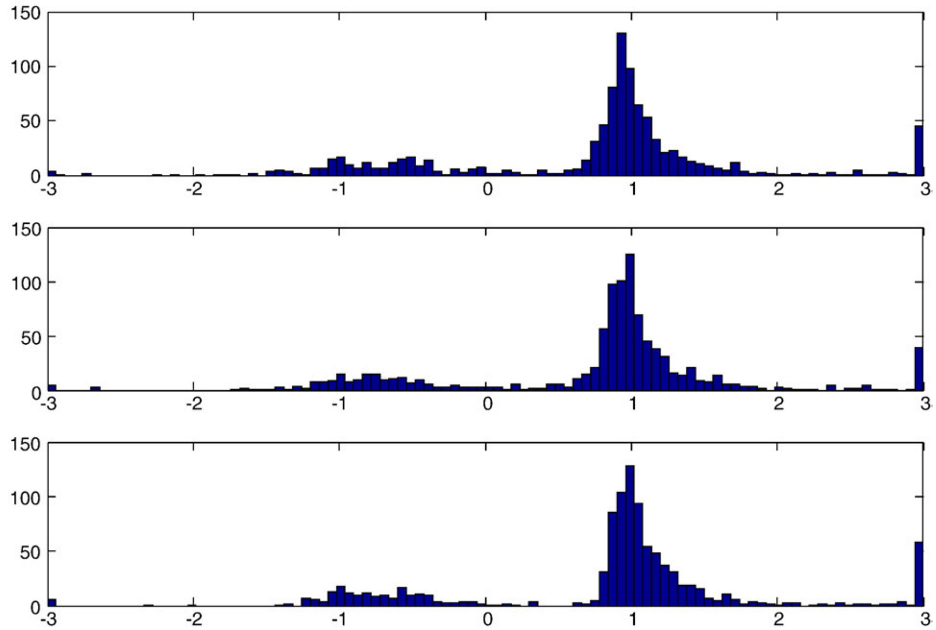

Fig. 13. Histograms of $B$ for the baseline model with $\delta$ changed to 0.2. From top to bottom: type I mergers, type II mergers, and type III mergers.

constraints are important, and call for future research on methods that can empirically distinguish between the two models.

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## Appendix A. Unprofitable mergers can arise endogenously

Unprofitable mergers result in the merged firm having a value lower than the values of the merging firms combined. Below we show that such mergers can arise endogenously, by providing an example. The intuition is that if a merger between two rivals of a firm would have a large negative impact on the firm's value, then the firm may have an incentive to merge with one of those rivals—even if such a merger would be unprofitable and the firm would be made worse off—in order to prevent a merger between those rivals from happening.

Consider the following merger game in an industry with three firms. The game is based on a finite-horizon bargaining model with externalities using the market bargaining framework in Binmore (1985).

In step 1, firm 1 announces an asking price $v_1 \in \mathbb{R}$. In step 2, firm 2 decides whether to accept $v_1$ or to reject it. If it accepts $v_1$, then the merger game ends. The industry structure becomes $(s_1+s_2, s_3)$, and the payoffs are $(v_1, V_1(s_1+s_2, s_3) - v_1, V_2(s_1+s_2, s_3))$. If firm 2 rejects $v_1$, then it is its turn to announce an asking price $v_2 \in \mathbb{R}$. Afterwards the game proceeds to step 3, the final step, in which firm 3 chooses

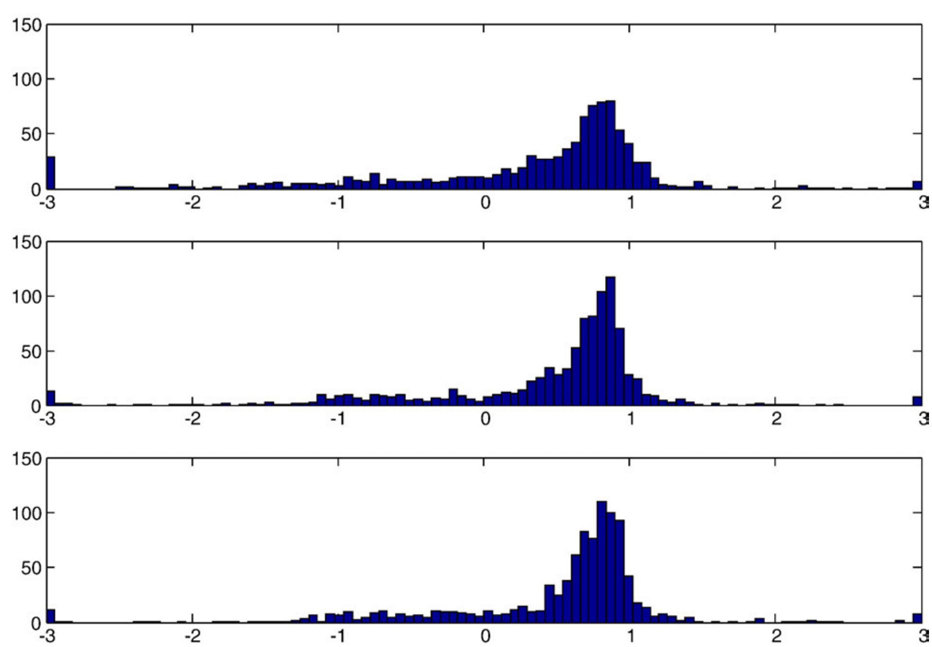

Fig. 14. Histograms of $B$ for the baseline model with $\theta$ changed to 0.8. From top to bottom: type I mergers, type II mergers, and type III mergers.

one out of the following three actions. (1) It may accept $v_1$. The industry structure becomes ($s_1+s_3$, $s_2$), and the payoffs are ($v_1$, $V_2(s_1+s_3, s_2)$, $V_1(s_1+s_3, s_2)-v_1$). (2) It may accept $v_2$. The industry structure becomes ($s_2+s_3$, $s_1$), and the payoffs are ($V_2(s_2+s_3, s_1)$, $v_2$, $V_1(s_2+s_3, s_1)-v_2$). (3) It may reject both $v_1$ and $v_2$. The industry structure remains ($s_1$, $s_2$, $s_3$), and the payoffs are ($V_1(s_1, s_2, s_3)$, $V_2(s_1, s_2, s_3)$, $V_3(s_1, s_2, s_3)$).

A firm accepts an asking price if it is indifferent between accepting and rejecting. Firm 3 accepts firm 1's asking price if firm 3 is indifferent between accepting the asking prices from firm 1 and firm 2. Without loss of generality, we normalize firms' premerger values to zero. Consider the merger game with

| | | |
|---|---|---|
| $V_1(s_1, s_2, s_3)=0$ | $V_1(s_2+s_3, s_1)=2$ | $V_2(s_2+s_3, s_1)=-5$ |
| $V_2(s_1, s_2, s_3)=0$ | $V_1(s_1+s_3, s_2)=6$ | $V_2(s_1+s_3, s_2)=-4$ |
| $V_3(s_1, s_2, s_3)=0$ | $V_1(s_1+s_2, s_3)=-2$ | $V_2(s_1+s_2, s_3)=-1$ |

In the subgame perfect equilibrium outcome, firm 1 announces an asking price of 1, firm 2 then accepts it, and the merger game ends. The resulting industry structure is ($s_1+s_2$, $s_3$), with payoffs (1, −3, −1). The merger between firm 1 and firm 2 arises endogenously, even though it is unprofitable (it reduces the two firms' combined value from 0 to −2). Firm 2 chooses to merge with firm 1 and obtain a negative payoff (−3), because a merger between firm 1 and firm 3 would make firm 2 even worse off (−4).

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