Internal versus External Growth in Industries with Scale Economies: A Computational Model of Optimal Merger Policy*

Ben Mermelstein
Northwestern University

Volker Nocke
University of Mannheim and CEPR

Mark Satterthwaite
Northwestern University

Michael D. Whinston
M.I.T. and NBER

July 6, 2013

Abstract

We study optimal merger policy in a dynamic model in which the presence of scale economies imply that firms can reduce costs through either internal investment in building capital or through mergers. The model, which we solve computationally, allows firms to invest or propose mergers according to the relative profitability of these strategies. An antitrust authority is able to block mergers at some cost. We examine the optimal policy when the antitrust authority can commit to a policy rule and when it cannot commit, and consider both consumer value and aggregate value as possible objectives of the antitrust authority. We find that optimal policy can differ substantially from what would be best considering only welfare in the period the merger is proposed. We also find that the ability to commit can lead to a significant welfare improvement. In general, firms' optimal investment behavior can be greatly affected by the antitrust policy, and the optimal policy can in turn be greatly affected by firms' investment behavior.

*We thank Dennis Carlton, Alan Collard-Wexler, Uli Doraszelski, Gautam Gowrisankaran, and Ariel Pakes for their comments, as well as seminar audiences at Bates White, Chicago, ECARES, Harvard, NYU, Penn, Stanford, the 2012 the 2013 Northwestern Searle Antitrust conference, the 2012 SciencesPo Workshop on Dynamic Models in IO, the 2013 CRESSE Conference, and the 2013 SFB-TR15 Meeting. Nocke gratefully acknowledges financial support from the European Research Council (ERC Starting Grant 313623). Whinston thanks the National Science Foundation and the Toulouse Network for Information Technology for financial support.

1 Introduction

Most analyses of optimal horizontal merger policy are static.[1] But many real-world mergers occur in markets in which dynamic issues are a central feature of competition among firms. In this paper, we analyze merger policy in the context of a model in which the presence of economies of scale presents firms with the opportunity to lower their average and marginal costs through capital accumulation. These scale economies are also the source of merger-related efficiencies, as a merger of two equal-sized firms lowers average and marginal cost at the merging firms' pre-merger joint output level. Thus, in such settings, an antitrust authority's merger approval decisions must weigh any extra cost reductions gained by allowing a merger (compared to insisting on internal growth) against the deadweight losses arising from increased market power.

As one example, consider the 2011 attempted merger between AT&T and t-Mobile. The merger would have combined the network infrastructure of the two firms. Proponents of the merger argued that this combination would greatly improve both firms' service. Opponents countered that the merger would increase market power, and that absent the merger the two firms would each have incentives to independently increase their networks. Thus, the FCC and Department of Justice faced the question of whether any efficiency gains from increased infrastructure scale due to the merger (which in this case were realized on the demand side through enhanced quality) were sufficient to justify the increase in market power.

We study these issues computationally in a dynamic industry model in which in each period active firms compete and also make investments to increase their capital stock. Economies of scale in production imply that mergers generate efficiencies. The model is similar to Pakes and McGuire (1994), but with some important differences. Most significantly, we modify the investment technology to make it *merger neutral*; that is, so that mergers do not change the investment opportunities that are available in the market. Our investment technology also allows for significantly richer investment dynamics than do most computational dynamic models, as firms can increase their capital stocks by multiple units, and new entrants can choose endogenoeously how many units of capital to build when entering.

In addition, we introduce the possibility for firms to merge, as well as an antitrust authority who can block proposed mergers. The decision to propose a merger is endogeneous and determined through a bargaining process. In general, bargaining over mergers involves externalities and the theory literature currently has few satisfying general solutions for such settings. For this reason, the present paper restricts attention to industries in which there are at most two active firms in any period. Doing so allows us to use the familiar Nash bargaining solution, and makes clear how the prospect of bargaining over mergers impacts investment incentives. Our approach to modeling the antitrust authority considers both the case in which the authority can commit to a policy rule and the case in which commitment is impossible. We also consider both maximization of consumer surplus and of aggregate surplus as possible objectives of the authority.

We begin in Section 2 by describing our model. Section 3 formally defines a Markov perfect equlibrium and discusses how we identify these equilibria computationally.

Section 4 analyzes firm behavior under two extreme antitrust policies: one in which no

[1] For example, see the classic papers by Williamson (1968) and Farrell and Shapiro (1990).

mergers are allowed, and the other in which all are. We examine firms' investment behavior and merger decisions in three different markets: a large one, an intermediate one, and a small one. We first describe firm behavior and industry dynamics for these three markets when no mergers are allowed. In the large market steady state, the industry spends most of its time in states with relatively symmetric capital levels for the firms, although should the industry through chance depreciation end up at a highly asymmetric position, it stays there for a long time. In contrast, the small market steady state is highly asymmetric, with one firm often dominating the industry. The intermediate market no-mergers equilibrium lies between these two.

We then explore the impact of merger policy by studying the Markov perfect equilibria when instead all mergers are allowed. We find a number of striking features. Not surprisingly, the steady state when all mergers are allowed involves a monopoly or near monopoly market structure much more often than when mergers are prohibited. It also involves a lower average level of capital. This arises because total investment is lower in monopoly and near monopoly states. Investment behavior also changes when mergers are allowed. Particularly striking is a significantly greater investment by small firms in states where one firm is very dominant, a form of "entry for buyout" [Rasmusen (1988)]. The discounted expected value of consumer surplus, aggregate surplus, and incumbent firm profits all decline when all mergers are allowed, while the discounted expected value of total industry profit (including entrants) is essentially unchanged. The surprising reduction in profit is driven by the behavior, just noted, of new entrants after a merger. This investment is done at high investment costs and dissipates a great deal of industry profit.

In Section 5 we examine optimal merger policy, considering as objectives both discounted expected consumer surplus ("consumer value") and discounted expected aggregate surplus ("aggregate value"). We begin by looking at the static benchmark, examining which mergers would be approved from a myopic perspective; that is, considering only the effect on welfare in the period the merger is proposed. From that perspective, very few mergers are consumer surplus-enhancing, while many mergers increase aggregate surplus.

We then identify both the Markov perfect policy (the no commitment policy outcome) and the optimal commitment policy under both objectives. With a consumer value objective, the Markov perfect policy and the no commitment policy are almost identical and basically allow no mergers, just as with the static consumer surplus criterion.

With an aggregate value objective, however, the no commitment and commitment policies differ substantially from what is statically optimal and each allows very few mergers. The reason is that, as seen in Section 4, allowing mergers leads to inefficient entry for buyout behavior, which makes mergers much less attractive, whether or not commitment is possible. Commitment can lead to a significant gain in aggregate value. Moreover, we find that endowing the antitrust authority with a consumer value objective achieves a substantial gain in aggregate value when the antitrust authority cannot commit to its approval policy. This finding is consistent with the suggestion of Lyons (2002), but for a different reason: in Lyons (2002) this gets the firms to propose more attractive mergers, while here it induces much better investment behavior. Overall, we find that optimal merger policy — whether with commitment or without commitment — is significantly affected by firms' investment behavior, and firms' investment behavior is in turn significantly affected by merger policy.

In Section 6 we compare the optimal merger policies to two forms of regulation: (i) second-best regulation in which a regulator who seeks to maximize aggregate surplus determines firms' investments and mergers, but not their prices/output levels in static competition, and (ii) a franchised monopoly. The outcome with second-best regulation always results in a monopoly market structure in the three markets, despite the fact that the intermediate and large markets seem workably competitive when mergers are prohibited. y construction, it leads to an improvement in aggregate value over the level that can be achieved with merger policy. With a franchised monopoly, which eliminates the possibility of entry for buyout beahvior, aggregate surplus is surprisingly high, slightly better in fact that under the best merger policy with commitment. Consumers, however, do extremely poorly with this structure.

Finally, in Section 7 we explore several extensions/reobustnbess checks. First, we examine the effect of parameter changes that improve the investment effiicency of small vs. large firms. This change reduces the social costs of entry for buyout behavior. Second, we examine equilibria when the new entrants that appear after a merger are instead run by the manager/owners of acquired firms. Third, we explore whether our model may have multiple equilibria.

Section 8 concludes.

The paper is related to several strands of literature. The first is theoretical work on dynamic merger policy. Most of this work examines models in which two mergers between two non-overlapping pairs of firms can take place sequentially in static models of competition [e.g., Nilssen and Sorgard (1998), Motta and Vasconcelos (2005), and Matushima (2001)]. An exception is Nocke and Whinston (2010). They study a many-period dynamic model in which mergers become feasible stochastically through time and establish conditions under which the optimal dynamic (commitment) policy of an antitrust authority who maximizes consumer value is the fully myopic policy that approves a merger if and only if it would raise consumer surplus in the period it is proposed. The model in this paper departs from Nocke and Whinston (2010) in a number of ways, most notably in introducing investment by firms and in locating the efficiency gains from merger in the achievement of scale economies through capital acquisition.[2]

A second related strand of literature examines dynamic models of industry equilibrium with investment, most notably Pakes and McGuire (1994). Some of this literature has examined the effects of one-time mergers on industry evolution [e.g., Berry and Pakes (1993), Cheong and Judd (2000), Benkard, Bodoh-Creed, and Lazarez (2010)]. Closest to our work are Gowrisankaran (1997) and (1999). Gowrisankaran (1999) introduces an endogeneous merger bargaining game into the Pakes-McGuire model and examines industry evolution when firms can choose whether, when, and with whom to merge. Our model differs in a number of respects: First, as mentioned above, we modify the Pakes-McGuire investment technology to make it merger neutral, and give entrants the same technology as incumbents with zero capital. Second, we locate the efficiency effects of mergers in scale economies achieved through capital acquisition, rather than in randomly drawn synergy gains. Third, we focus on settings with just two active firms and use the Nash bargaining solution over mergers. While restrictive, we do this because it allows us to examine a case in which the bargaining model is well accepted and easily understood. In unpublished work, Gowrisankaran (1997) introduces antitrust policy

[2] The model here also differs from Nocke and Whinston (2010) in that firms that do not merge in a given period may consummate a merger with different efficiencies (i.e. with different capital levels) in future periods.

into the Gowrisankaran (1999) model. Specifically, he examines the effect of commitments to Herfindahl-based policies that block mergers if they result in a Herfindahl index above some maximum threshold and finds little effect of varying the threshold on welfare. We differ in considering a broader range of possible policy commitments and in examining the equilibrium policy when the antitrust authority cannot commit. We also find quite different results, with policy having significant effects. In both papers, optimal policy differs substantially from what would be myopically (i.e., statically) optimal.

2 The Model

We study a dynamic industry model in which firms may invest in capacity, or alternatively merge, to increase their capital stocks and harness scale economies. The model follows in broad outline Pakes and McGuire (1994) and Ericson and Pakes (1995), but with some important differences in its investment technology, as well as in the introduction of mergers and merger policy.

2.1 Static demand, costs, and competition

In each period, active firms produce a homogeneous good in a market in which demand is $Q(p) = B(A-p)$. The production technology, which requires capital and labor, is described by the production function $F(K,L) = K^{\beta\theta}L^{(1-\beta)\theta}$, where the capital share parameter is $\beta \in (0,1)$ and the scale economy parameter is $\theta > 1$. Normalizing the price of labor to be 1, for a fixed level of capital K, this production function gives rise to the short-run cost function

$$C(Q|K) = \frac{Q^{1/(1-\beta)\theta}}{K^{\beta/(1-\beta)}}$$

with marginal cost

$$C_Q(Q|K) = \left(\frac{1}{(1-\beta)\theta}\right)\frac{Q^{[1/(1-\beta)\theta]-1}}{K^{\beta/(1-\beta)}}.$$

With this technology, a merger of two identical firms reduces both average and marginal cost if their joint output remains unchanged. This effect will be the source of merger-related efficiencies in our model. Letting R measure the extent of this cost reduction, we have

$$R \equiv \frac{C_Q(2Q|2K)}{C_Q(Q|K)} = \frac{C(2Q|2K)/Q}{C(Q|K)/Q} = 2^{\left(\frac{1}{1-\beta}\right)\left(\frac{1-\theta}{\theta}\right)}.$$

Note in particular that the marginal cost reduction depends on the scale economy parameter θ and capital share β, but is independent of the output level (and hence demand). In our computations we will focus on a case in which $\beta = 1/3$. For this value of β, the magnitude of R for various values of θ is shown in Table 1.

Table 1: Marginal and Average Cost Reductions given θ

$\boldsymbol{\theta}$	1.05	1.1	1.15	1.2	1.3	1.4
R	0.95	0.91	0.87	0.84	0.79	0.74

In each period, active firms engage in Cournot competition given their capital stocks (a firm with no capital produces nothing), resulting in profit $\pi(K_i, K_{-i})$ for a firm with capital stock K_i when its rival has capital stock K_{-i}.

2.2 Investment and Depreciation

In Pakes and McGuire (1994) a firm chooses in each period how much money to invest, with the probability of successfully adding one unit of capital increasing in the investment level. We depart from this technology because in a model of mergers it would impose a significant inefficiency to mergers, as each merger between two firms would remove an investment possibility from the market.[3] Instead, we specify an investment technology that is *merger neutral* at a market level. By that we mean that a planner who controlled the firms and wanted to achieve at least cost any fixed increase in the market's aggregate capital stock would be indifferent about whether the firms merge. With this assumption we isolate the market-level efficiency effects of mergers fully in the scale economies of the production function.[4] Specifically, we imagine that there are two ways that a firm can invest.

The first is *capital augmentation*: each unit j of capital that a firm owns can be doubled at some cost $c_j \in [\underline{c}, \overline{c}]$ drawn from a distribution F. The draws for different units of capital are independent and identically distributed. Thus, for a firm that has N_K units of capital, there are N_K cost draws. Given these draws, if the firm decides to augment m units of capital it will do so for the capital units with the cheapest cost draws. Note that capital augmentation is completely merger neutral: when two firms merge, their collective investment possibilities do not change.

The second is *greenfield investment*: a firm can build as many capital units as it wants at a cost $c_g \in [\overline{c}, \overline{c}_g]$ drawn from a distribution G. Greenfield investment allows a firm whose capital stock is zero to invest, albeit at a cost that exceeds that of capital augmentation. We also choose the range of greenfield costs $[\overline{c}, \overline{c}_g]$ to be small so that this investent technology is approximately merger neutral. (It would be fully merger neutral if $\overline{c}_g = \overline{c}$; in our computations we introduce uncertain greenfield investment costs to ensure existence of equilibrium.)

As we discuss shortly, our model allows for entry. In contrast to Pakes and McGuire (1994), we endow an entrant with the same investment technology as incumbents. The entrant, however, starts with no capital, so it must initially do greenfield investment.

Put together, the capital augmentation and greenfield investment processes allow for significantly richer investment dynamics than in the typical dynamic industry model. Firms can expand their capital by multiple units at a time through either investment method. And firms with no capital, including new entrants, can decide endogenously how far to "jump" up in their capital stock.

A state is a pair (K_1, K_2). In our computations firms will be restricted to some number S of possible capital levels, with this number chosen to be non-binding.

Capital also depreciates: in each period a unit of capital has a probability $d > 0$ of becoming worthless (including for any future capital augmentation). Depreciation realizations are independent across units of capital. This depreciation process is also merger neutral. Finally, the firms discount the future according to discount factor $\delta < 1$.

---

[3] Alternatively, if the merged firm kept both investment processes we would need to keep track, as a separate state variable, of how many investment processes a firm possesses, which has no natural bound.

[4] Of course, because of noncooperative investment behavior, there could be efficiency benefits of the merger in actually achieving a given amount of market-wide capital growth at least cost. Also, note that investent opportunities will be merger neutral at the market level, but not at the firm level — larger firms will have (stochastically) lower investment costs. We return to this point in Section 7.1.

2.3 Mergers and Bargaining

In each period, firms can propose a merger. Following a merger, a new entrant appears in the market with zero capital.[5]

Proposing a merger involves a cost $\phi \in [\underline{\phi}, \overline{\phi}]$ drawn each period in an iid fashion from distribution Φ. Firms engage in Nash bargaining to decide whether to merge. Thus, they propose their merger provided the expected gain in their joint continuation value, taking into account the likelihood the merger will be approved, exceeds ϕ. If they merge, they make a side transfer to split evenly the joint value gain from the merger. (In the event the antitrust authority rejects the proposed merger, they split the proposal cost evenly.) The disagreement values in this bargaining are the two firms' continuation values in the event they do not merge this period. Let $\overline{V}(K_1, K_2)$ denote the (interim) value of a firm with K_1 units of capital when its rival has K_2 units of capital just after the merger proposal and approval stage is complete within a period (in the timing given below, this interim value is calculated at the beginning of stage 5). If the capital stocks prior to the merger stage are (K_1, K_2), then the joint value gain from merging (gross of any proposal cost) is

$$\Delta_G(K_1, K_2) \equiv \{\overline{V}(K_1 + K_2, 0) - [\overline{V}(K_1, K_2) + \overline{V}(K_2, K_1)]\}, \tag{1}$$

where the first term is the joint (interim) value in case the merger takes place and the second term is the sum of the "disagreement payoffs" (i.e., the sum of the interim values if no merger occurs).

2.4 Merger Policy

The antitrust authority has the ability to block mergers. Blocking a merger involves a cost $b \in [\underline{b}, \overline{b}]$ drawn each period in an iid fashion from a distribution H. We will consider two possible scenarios. In one, we suppose that the antitrust authority can commit to a deterministic policy $a(K_1, K_2) \in \{0, 1\}^{S^2}$ that specifies whether a proposed merger would be approved ($a = 1$) or not ($a = 0$) in each state (K_1, K_2). These commitment policies will be restricted further to two classes of policies described in Section 5. We also consider cases in which the antitrust authority cannot commit to its policy. In that case, in any state (K_1, K_2) it will decide whether to block a merger by comparing the increase in its welfare criterion from blocking (we will consider both consumer value and aggregate value) to its blocking cost realization b. In that case, a Markovian strategy for the antitrust authority is a state contingent threshold $\widehat{b}(K_1, K_2)$ describing the highest blocking cost at which the authority will block a merger in a given state (K_1, K_2). Equivalently, this can be translated into a merger acceptance probability $a(K_1, K_2) \in [0, 1]$. We call the equilibrium policy that emerges a "Markov perfect policy." Identifying this policy is of interest for both positive and normative reasons. First,

[5] Note that entry is allowed only once a merger has occurred, but not before. The reason is that we cannot evaluate the profitability of entry for a third firm without having a solution for the multi-firm bargaining with externalities problem that would arise after its entry. We have also analyzed the case in which only the two manager-owners possess the knowledge of how to operate a firm in this industry; see Section 7.2.

on a positive level, the antitrust authority may well lack an ability to commit to its future approval policy. For example, while both the DOJ and FTC in the U.S. periodically issue *Horizontal Merger Guidelines*, which may serve to partially commit these agencies, it is also true that over time their actual policy often comes to deviate substantially from the *Guidelines'* prescriptions. On a normative level, gains from commitment may provide a justification for legislatively endowing the antitust authority with an objective function different from the true social goal; e.g., specifying that the antitrust authority seek to maximize consumer surplus rather than agrgegate surplus in deciding whether to approve a merger.

2.5 Timing

In each period, the timing of the model is as follows:

1. Firms observe each others' capital stocks.
2. The firms observe their proposal cost ϕ and bargain over whether to propose a merger.
3. If a merger is proposed, the antitrust agency observes its blocking cost b and decides whether to block it. (This is when commitment is not possible; the antitrust authority simply follows its commitment strategy when commitment is possible.) If a merger is consummated in state (K_1, K_2), the merged firm's capital stock is $K_1 + K_2$.
4. If a merger occurred, an entrant enters with no capital.
5. Firms choose their output levels simultaneously and the market price is determined.
6. Firms privately observe their capital augmentation and greenfield cost draws and decide on their investments.
7. Stochastic depreciation occurs, resulting in the capital levels at which firms begin the next period.

3 Equilibrium and Computation

In this section, we explain more formally firm policies, the authority's merger approval policy, and our definition of Markov perfect equilibrium. We also discuss the algorithm we use for numerically computing equilibria.

3.1 Firm Policies

We focus on firm policies and approval policies that are symmetric with respect to the industry state (K_1, K_2), where $K_i \in \mathcal{S} \equiv \{0, 1, ..., S\}$. We distinguish between states at two points within a period:

1. The *ex ante* stage at the beginning of each period (before the merger proposal cost is revealed). The *value* of firm i at this ex ante stage is denoted $V(K_i, K_{-i})$.
2. The *interim* stage just after the merger stage and before firms compete in quantities. The firm's *interim value* is denoted $\overline{V}(K_i, K_{-i})$.

Firm i has two types of decisions to make: First, at the merger proposal stage (after learning the realization of the proposal cost ϕ) to decide whether or not to propose a merger to the antitrust authority (AA). Second, at the investment stage (after learning the K_i independent draws of the capital augmentation cost c_j and the realization of the greenfield cost c_g) how many units of capital (if any) to add.

Merger proposals. Let us first consider the merger proposal decision. As described in the previous section, we assume that firms 1 and 2 propose a merger if and only if doing so induces an increase in their joint (interim) value (net of the proposal cost). That is, if the AA approves the merger with probability $a(K_1, K_2) \in [0, 1]$, the firms propose a merger if and only if the realized proposal cost ϕ is such that

$$\phi < a(K_1, K_2)\Delta_G(K_1, K_2),$$

where $\Delta_G(K_1, K_2)$ is the joint gain from merger (gross of the proposal cost) defined in (1). This implies that the ex ante probability of a merger proposal in state (K_1, K_2) is

$$\psi(K_1, K_2) \equiv \Phi(a(K_1, K_2)\Delta_G(K_1, K_2)), \tag{2}$$

and the probability of a merger occurring is $a(K_1, K_2)\psi(K_1, K_2)$. We thus obtain the following relationship between beginning-of-period and interim values:

$$V(K_i, K_{-i}) = \overline{V}(K_i, K_{-i}) + \psi(K_1, K_2)\frac{1}{2}\left\{a(K_1, K_2)\Delta_G(K_1, K_2) - \mathcal{E}\left[\phi|K_1, K_2\right]\right\}, \tag{3}$$

where

$$\mathcal{E}\left[\phi|K_1, K_2\right] \equiv \frac{\int_{\underline{\phi}}^{a(K_1,K_2)\Delta_G(K_1,K_2)} \phi d\Phi(\phi)}{\psi(K_1, K_2)}$$

is the expected proposal cost, conditional on the merger being proposed. In equation (3), the term in curly brackets is the expected gain from proposing a merger, conditional on the merger being proposed, which will be split equally between the two merger partners, according to the Nash bargaining rule. If a merger in ex ante state (K_1, K_2) has been proposed and approved, the industry transits either to interim state $(K_1 + K_2, 0)$ or to $(0, K_1 + K_2)$, each with probability 1/2. This transition rule ensures that the steady state distribution over states is indeed symmetric.

Investment. We now turn to firms' investment decisions. Let $\xi(\cdot|K_i, K_{-i}) : \mathcal{S}^2 \to [0, 1]^{S-K_i+1}$ denote firm i's investment policy function at the interim stage, which gives the probability $\xi(k|K_i, K_{-i})$ of adding $k \in \{0, 1, ..., S - K_i\}$ units of capital (prior to learning the cost draws). Recall that, after the investment stage, each unit of capital depreciates with probability d. So, if firm i enters the depreciation stage with K_i' units of capital after the investment stage, the probability that it exits the stage with K_i'' units of capital is given by

$$\kappa(K_i''|K_i') = \begin{cases} \binom{K_i'}{K_i''}(1-d)^{K_i''} d^{K_i'-K_i''} & \text{if } K_i'' \in \{0, 1, ..., K_i'\}, \\ 0 & \text{otherwise.} \end{cases}.$$

Given that firm i follows investment policy $\xi(\cdot|K_i, K_{-i})$, in state (K_i, K_{-i}) the probability (at the interim stage) of firm i leaving the period with $K_i'' \in \{0, 1, ..., S\}$ units of capital is

$$\tau(K_i''|K_i, K_{-i}; \xi) = \sum_{m=0}^{S-K_i} \xi(m|K_i, K_{-i})\kappa(K_i''|K_i + m). \tag{4}$$

Prior to making its investment decision, firm i privately observes K_i draws of the capital augmentation cost $c_j \in [\underline{c}, \overline{c}]$ and one draw of the greenfield cost $c_g \in [\overline{c}, \overline{c}_g]$. For a given realization of the $(K_i + 1)$-dimensional vector of cost draws, let $c_{K_i}(\cdot)$ denote the resulting cost function, where $c_{K_i}(k)$ is the minimum cost of adding k units of capital. Let $\mathcal{C}_{K_i}$ be the domain of $c_{K_i}(\cdot)$ and h_{K_i} the associated density (which is determined by the distributions F and G of the cost draws). For a given cost function $c_{K_i}(\cdot)$, rival investment policy ξ_{-i}, and value function $V(\cdot)$, firm i thus sets k_i so as to maximize its expected continuation value minus the investment cost:

$$\max_{k_i \in \{0,1,\ldots,S-K_i\}} -c_{K_i}(k_i) + \delta \sum_{K_i'' \in \mathcal{S}} \sum_{K_{-i}'' \in \mathcal{S}} \kappa(K_i''|K_i + k_i)\tau(K_{-i}''|K_{-i}, K_i; \xi_{-i})V(K_i'', K_{-i}'').$$

Let k_i^* denote the solution to to this optimization problem (which, generically, is unique), and define $\omega(k_i, c_{K_i}, K_i, K_{-i}|\xi_{-i}, V)$ to be the indicator function with value 1 if $k_i = k_i^*$ and 0 otherwise. Firm i's investment policy function therefore satisfies

$$\xi(k_i|K_i, K_{-i}) = \int_{\mathcal{C}_{K_i}} \omega(k_i, c_{K_i}, K_i, K_{-i}|\xi_{-i}, V)h_{K_i}(c_{K_i})dc_{K_i}, \tag{5}$$

which gives rise to the following expected investment cost in state (K_i, K_{-i}):

$$\mathcal{E}c(K_i, K_{-i}|\xi_{-i}) = \int_{\mathcal{C}_{K_i}} \sum_{k_i \in \{0,1,\ldots,S-K_i\}} \omega(k_i, c_{K_i}, K_i, K_{-i}|\xi_{-i}, V)c_{K_i}(k_i)h_{K_i}(c_{K_i})dc_{K_i}.$$

Denoting $\pi(K_i, K_{-i})$ firm i's single-period Cournot profit in interim state (K_1, K_2), we can write the following Bellman-type equation for firm i's value at the interim stage in a symmetric equilibrium:

$$\begin{aligned} \overline{V}(K_i, K_{-i}) \;&=\; \pi(K_i, K_{-i}) - \mathcal{E}c(K_i, K_{-i}|\xi) \\ &\quad +\delta \sum_{K_i'' \in \mathcal{S}} \sum_{K_{-i}'' \in \mathcal{S}} \tau(K_i''|K_i, K_{-i}; \xi)\tau(K_{-i}''|K_{-i}, K_i; \xi)V(K_i'', K_{-i}''). \end{aligned} \tag{6}$$

We also calculate a value function for all future entrants. Future entrants' profits are not included in $V(K_i, K_{-i})$ or $\overline{V}(K_i, K_{-i})$ but should be considered by an antitrust authority. We define a function $EV(K_1, K_2)$ to represent the beginning of period discounted value of future profits for all future entrants. We define the following Bellman-type equation for $EV(K_1, K_2)$:

$$\begin{aligned} EV(K_1, K_2) \;&=\; (1 - a(K_1, K_2)\psi(K_1, K_2)) \left[\delta \sum_{K_1'' \in \mathcal{S}} \sum_{K_2'' \in \mathcal{S}} \tau(K_1''|K_1, K_2; \xi)\tau(K_2''|K_2, K_1; \xi)EV(K_1'', K_2'') \right] \\ &\quad +a(K_1, K_2)\psi(K_1, K_2) \left[\begin{array}{c} \overline{V}(0, K_1 + K_2) + \delta \sum_{K_0'' \in \mathcal{S}} \sum_{K_{1+2}'' \in \mathcal{S}} \tau(K_0''|0, K_1 + K_2; \xi)\times \\ \tau(K_{1+2}''|K_1 + K_2, 0; \xi)EV(K_0'', K_{1+2}'') \end{array} \right] \end{aligned}$$

where (K_0'', K_{1+2}'') is the end of period capital levels when firms with capital levels K_1 and K_2 merge resulting in interim capital levels of 0 and $K_1 + K_2$.

3.2 Antitrust Policy

As discussed in the previous section, we focus on two alternative objective functions for the AA: consumer value maximization and aggregate value maximization. Moreover, we restrict attention to symmetric merger approval policies; that is, $a(K_1, K_2) = a(K_2, K_1)$ for all (K_1, K_2).

We distinguish between two settings, depending on whether the AA can commit to its future policy or not.

Welfare criterion. Let $w(K_1, K_2)$ denote the static welfare level resulting from Cournot competition in state (K_1, K_2), where the welfare criterion may be consumer surplus, i.e., $w(K_1, K_2) = CS(K_1, K_2)$, or aggregate surplus, i.e., $w(K_1, K_2) = AS(K_1, K_2) \equiv CS(K_1, K_2) + \pi(K_1, K_2) + \pi(K_2, K_1)$. Let $W(K_1, K_2)$ denote the expected net present value (ENPV) of the welfare criterion (which may be consumer value, $W = CV$, or aggregate value, $W = AV$) when the industry is in the (ex ante) state (K_1, K_2), and let $\overline{W}(K_1, K_2)$ denote that value at the interim stage (K_1, K_2).

Commitment. In this setting, the AA commits to a pure action $a(K_1, K_2) \in \{0, 1\}$ for each state (K_1, K_2) so as to maximize the steady state value of its welfare criterion. Note that, in this setting, the AA never incurs any blocking cost: If the AA commits to allow a proposed merger in state (K_1, K_2), i.e., $a(K_1, K_2) = 1$, then trivially no blocking cost is incurred whereas if the AA commits to block a merger in that state, i.e., $a(K_1, K_2) = 0$, then from (2), the merger will not be proposed in the first place, $\psi(K_1, K_2) = 0$, implying that no blocking cost is incurred either.

No commitment. In this setting, the AA acts as a third player who, unable to commit, makes its approval decision in every state (K_1, K_2) so as to maximize its welfare criterion, given the (Markov perfect) equilibrium in the continuation game. The welfare gain (gross of the blocking cost) from approving a proposed merger at beginning-of-period state (K_1, K_2) is therefore given by

$$\Delta_W(K_1, K_2) \equiv \overline{W}(K_1 + K_2, 0) - \overline{W}(K_1, K_2).$$

Observing the realized value of its blocking cost, $b \in \left[\underline{b}, \overline{b}\right]$, the AA thus approves a proposed merger if and only if

$$b \geq \widehat{b}(K_1, K_2) \equiv -\Delta_W(K_1, K_2).$$

Before the blocking cost is observed, the probability that a proposed merger in state (K_1, K_2) is approved is thus given by

$$a(K_1, K_2) = 1 - H(\widehat{b}(K_1, K_2)). \tag{7}$$

The expected blocking cost in state (K_1, K_2), conditional on the merger being proposed, is

$$\mathcal{E}[b|K_1, K_2] = \int_{\underline{b}}^{H^{-1}(1-a(K_1,K_2))} b dH(b).$$

Bellman equations. The AA's value functions are recursively defined by

$$W(K_1, K_2) = \overline{W}(K_1, K_2) + \psi(K_1, K_2) \left\{a(K_1, K_2)\Delta_W(K_1, K_2) - \mathcal{E}[b|K_1, K_2]\right\} \tag{8}$$

and

$$\begin{aligned} \overline{W}(K_1, K_2) \quad = \quad & w(K_1, K_2) - \iota_W \left[\mathcal{E}c(K_1, K_2|\xi) + \mathcal{E}c(K_2, K_1|\xi)\right] \\ & + \delta \sum_{K_1'' \in \mathcal{S}} \sum_{K_2'' \in \mathcal{S}} \tau(K_1''|K_1, K_2; \xi)\tau(K_2''|K_2, K_1; \xi) W(K_1'', K_2''), \end{aligned} \tag{9}$$

where ι_W is the weight the AA puts on producer value (i.e., $\iota_W = 0$ if the AA maximizes consumer value and $\iota_W = 1$ if the AA maximizes aggregate value).

We will also later refer to consumer value, incumbent value, producer value, and aggregate value. Consumer Value $CV(K_1, K_2)$ is given by equations (8) and (9) with $w(K_1, K_2) = CS(K_1, K_2)$ and $\iota_W = 0$. Producer value is the sum of incumbent value, $V(K_1, K_2) + V(K_2, K_1)$, and the value of all future entrants, $EV(K_1, K_2)$. Aggregate value is the sum of consumer and producer value: $AV(K_1, K_2) \equiv CV(K_1, K_2) + V(K_1, K_2) + V(K_2, K_1) + EV(K_1, K_2)$.

3.3 Markov Perfect Equilibrium

A Markov perfect equilibrium consists of (i) firm policy functions ψ and ξ, (ii) firm value functions V and $\overline{V}$, (iii) an antitrust policy function a, and (iv) antitrust value functions W and $\overline{W}$, satisfying equations (2), (3), (5), (6), (8), (9), and – if the AA does not commit to its policy – (7). In case the AA does commit to its policy, the approval policy a from equation (7) is replaced by the one that maximizes the steady state value of the AA's welfare criterion, taking account of the equilibrium that results among the firms, which satisfies equations (2), (3), (5), (6), (8), and (9).

3.4 Computation

The algorithm that we use to numerically solve for equilibria is a version of the well-known Pakes-McGuire (1994) algorithm. It is a straightforward iterative process. For a given merger policy a (or, equivalently, $\widehat{b}$), this procedure works as follows. Given an initial guess of the interim value function, $\overline{V}^{(0)}$, and the investment policy function, $\xi^{(0)}$, we first compute an initial value of the merger proposal function, $\psi^{(0)}$, using (2), and of the beginning-of-the-period value function, $V^{(0)}$, using (3). Plugging $V^{(0)}$ and $\xi^{(0)}$ into the RHS of (5), we then compute an updated estimate $\xi^{(1)}$ of the investment policy function. As this is a difficult integral to evaluate, we use Monte Carlo integration: for a given set of random cost draws, value function $V^{(0)}$, and the rival's investment policy function $\xi^{(0)}$ (which induce rival transition probabilities via equation (4)), we can identify the firm's optimal investment decision. Repeating this over and over again (using 5000 or more cost draws), we obtain $\xi^{(1)}$. Inserting $\xi^{(1)}$ into (6), yields an updated estimate $\overline{V}^{(0)}$ of the interim value function. We continue with this iterative procedure until $\left\| \overline{V}^{(\ell+1)} - \overline{V}^{(\ell)} \right\| \leq \varepsilon$ for some small $\varepsilon > 0$.

4 Investment and Merger Incentives under Fixed Merger Policies

In this section we have three goals. First, we describe the specific parameterization of the model that we employ and discuss the properties of the static monopoly and Cournot equilibria that this parameterization implies. Second, we consider the Markov perfect equilibrium when mergers are prohibited—the "no-mergers" case. We report its long-run steady distribution over the state space $\mathcal{S}^2$, the producer and consumer values it generates, and the investment incentives it creates. Third, we consider the Markov perfect equilibrium when firms are permitted to merge in any state where it is profitable for them to do so—the "all-mergers-allowed" case. We report its steady state, measures of the consumer and producer values it generates, and the investment incentives it provides the firms. The all-mergers-allowed equilibrium is very different than the no-mergers equilibrium in structure, incentives, and welfare measures. Merging causes the industry to be much more concentrated than in the no-merger case. Not surprisingly, expected consumer value is on average substantially reduced. But, surprisingly, expected incumbent value is also reduced, though not by nearly the same amount, and expected producer value (which includes the value of future entrants) is essentially unchanged. The key factor behind this result is the effect of merger policy on firms' investment behaviors.

4.1 Three Markets

In our main analysis, we examine three markets that are identical except for the level of market demand. The market demand takes the form $Q(p) = B(3 - p)$ with $B = 30$ for the "large" market, $B = 26$ for the "intermediate" market, and $B = 22$ for the "small" market. We will see that the small market is a natural monopoly, the large market is a workable duopoly, and the intermediate market is between those two. Firms' production function takes the Cobb-Douglas form $Q = \left(K^{\beta} L^{(1-\beta)}\right)^{\theta}$ with capital share parameter $\beta = 1/3$, and scale parameter $\theta = 1.1$. Thus, as noted in Table 1, a merger between two equal-sized firms who do not alter their output levels lowers marginal and average costs by 9 percent. The wage rate is normalized to 1. Firms have integer-valued capital stocks.

Table 2 gives a sense of the intermediate market's fundamental static properties with its strong economies of scale and linear demand. It shows the static Cournot equilibrium outcomes for three different states: $(1, 0)$, $(10, 0)$, and $(5, 5)$. The first two states are monopoly states since the second firm has zero units of capital. The comparison between the two monopoly states shows the substantial effects of the scale economies on marginal cost. It also shows for state $(1, 0)$ the effect of linear demand when price is high and quantity small: demand is quite elastic causing a small price-cost markup.

Table 2: Intermediate Market Static Equilibrium

State	$(1, 0)$	$(10, 0)$	$(5, 5)$
Marginal Cost (MC)	2.56	1.32	1.54
Price (P)	2.78	2.16	2.02
$P \div MC$	1.09	1.63	1.32
Total Quantity	5.67	21.8	25.4
Total Profit	5.12	26.0	22.8
Consumer Surplus	0.619	9.14	12.4
Aggregate Static Surplus	5.74	35.12	35.16

The monopoly in state $(10, 0)$ exerts its market power to restrict output and raise price to 2.16 compared to the duopoly's 2.02. Per period consumer surplus as a consequence falls from 12.4 to 9.14, a change of 3.3. But the market's strong scale economies gives the monopolist a marginal cost of 1.38 compared to the duopolist's marginal cost of 1.54. This results in total profits in the (10, 0) monopoly being 26.0 instead of 22.8 in the (5, 5) duopoly, an increase of 3.2. Aggregate static surplus in the $(10, 0)$ state is therefore almost identical to that in the $(5, 5)$ state.

Turning to investment costs, we assume that the capital augmentation cost for a given unit of capital is independently drawn from a uniform distribution on the interval $[3, 6]$, while the greenfield investment cost c_g is drawn from a uniform distribution on the interval $[6, 7]$. (Recall that a potential entrant has no capital, so it is only able to purchase greenfield capital at the price c_g per unit.) Firms' discount factor is $\delta = 0.8$, which corresponds to a period length of about 5 years. Each unit of capital depreciates independently with probability $d = 0.2$ per period. We take the state space to be $\{0, 1, \ldots, 20\}^2$, so each active firm can accumulate up to 20 units of capital. In these markets, firms almost never end up outside of the quadrant $\{0, 1, \ldots, 10\}^2$; we allow for capital levels up to 20 so that we can calculate values for mergers and avoid boundary effects.

4.2 Equilibrium with No Mergers Allowed

We begin by examing equilibria in these markets when no mergers are allowed. Figure 1 shows the resulting steady state distribution in the intermediate market. The horizontal plane shows the quadrant $\{0, 1, \ldots, 10\}^2$ of the state space, while the height of each pin represents the probability that the industry is in a given state. As can be seen there, the industry spends most of its time in duopoly states in which both firms are active, but also spends roughly 18 percent of the time in monopoly states. In fact, if the industry finds itself in a monopoly state, it can stay there a long time; for example, starting in state $(5, 0)$, the probability that it is in a monopoly 5 periods later is 0.84. Figure 2 shows the one-period transition probabilities starting from state $(5, 0)$. Figure 3 illustrates the equilibrium transitions more generally. In that figure, each arrow represents the average movement over five periods starting in each state. The lack of movement away from state $(5, 0)$ is also evident there.

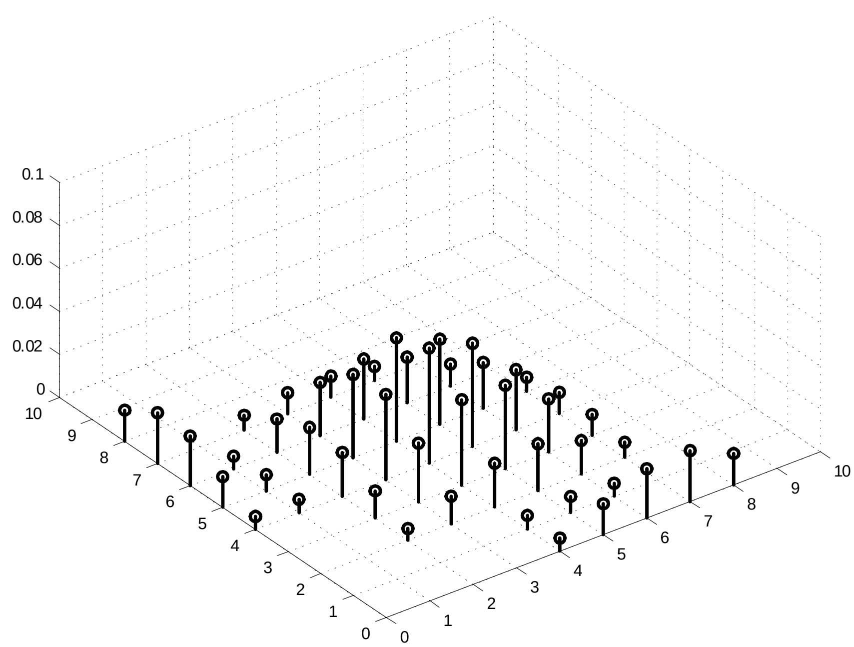

Figure 1: Steady state in the intermediate market with no mergers allowed

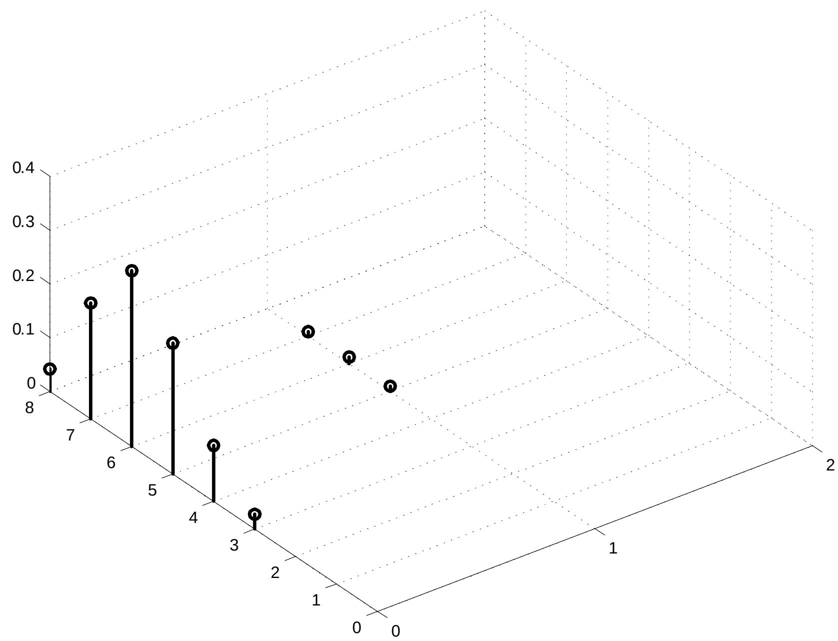

Figure 2: One-period transition from the state (5,0) in the intermediate market with no mergers allowed

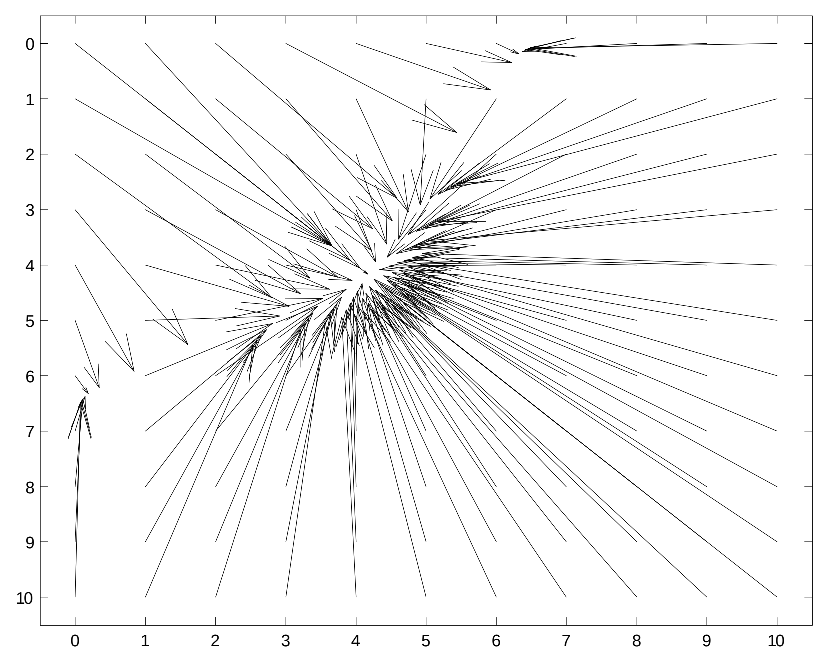

Figure 3: Arrows show the expected transitions over 5 periods in the intermediate market with no mergers allowed

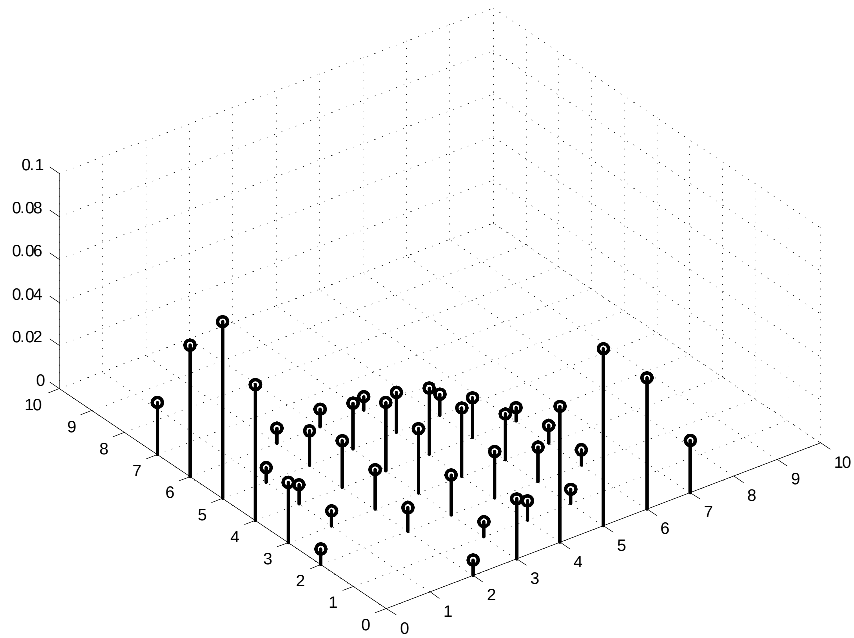

Figure 4: Steady state in the small market with no mergers allowed

There are two cost-based reasons why it is so hard for an entrant starting in state $(5, 0)$ to catch up. First, the entrant pays much more per unit of capital purchased: the large firm can add a unit of capital using the lowest of its five cost draws from the uniform distribution on $[3, 6]$, whereas the entrant (who chooses to add at most 1 unit) has to engage in greenfield investment using a cost draw from the uniform on $[6, 7]$. Second, the large firm's production scale economies are great: with a capital level of 5 its marginal cost as a monopolist is 1.70 while setting a price of 2.35. If the potential entrant should enter with 2 units of capital, then at state $(5, 2)$ the dominant firm sells quantity 14.6 at a price of 2.18 with a marginal cost of 1.62. The entering firm sells 6.7 units with a marginal cost of 1.92. Profits are 18.6 and 5.1 respectively.

Figures 4 through 7 show the steady state distributions and five-period transitions for the small and large markets. The small market is in a monopoly state almost 60 percent of the time, while the large market finds itself in such a state only a little over 2 percent of the time. The equilibria involve larger capital levels as the market size grows.

The left-hand side of Table 3 describes some features of the no-mergers equilibria in the three markets. The second and third rows from the bottom show the probability of being in a monopoly state at the time of static competition (noted above), as well as the probability of being in neither a monopoly nor a near-monopoly state ("% $\min\{K_1, K_2\} \geq 2$"). Also shown are the average total capital, average total output, aggregate value (the ENPV of aggregate surplus; all values refer to ex ante/start-of-period values), and consumer value (the ENPV of consumer surplus), each of which is not surprisingly increasing in market size. Finally, the average price is somewhat lower the larger the market.

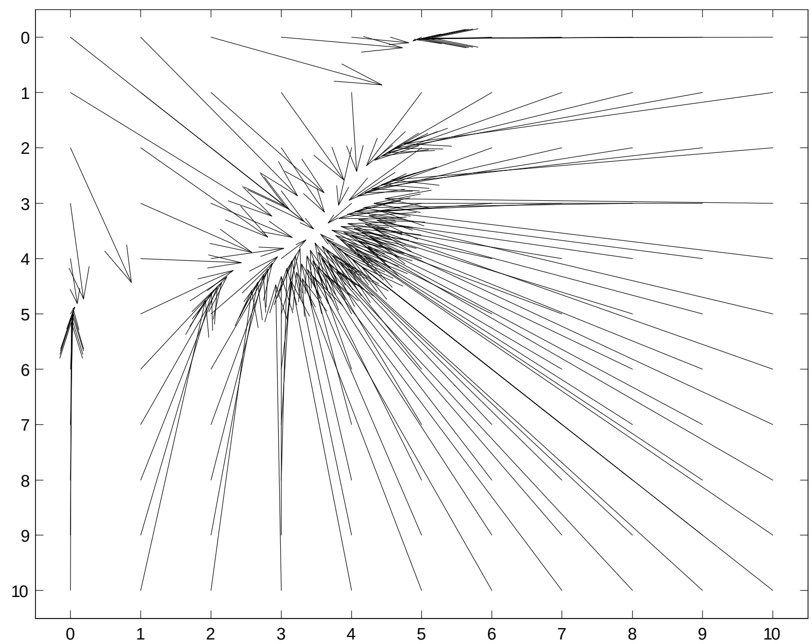

Figure 5: Arrows show the expected transitions over 5 periods in the small market with no mergers allowed

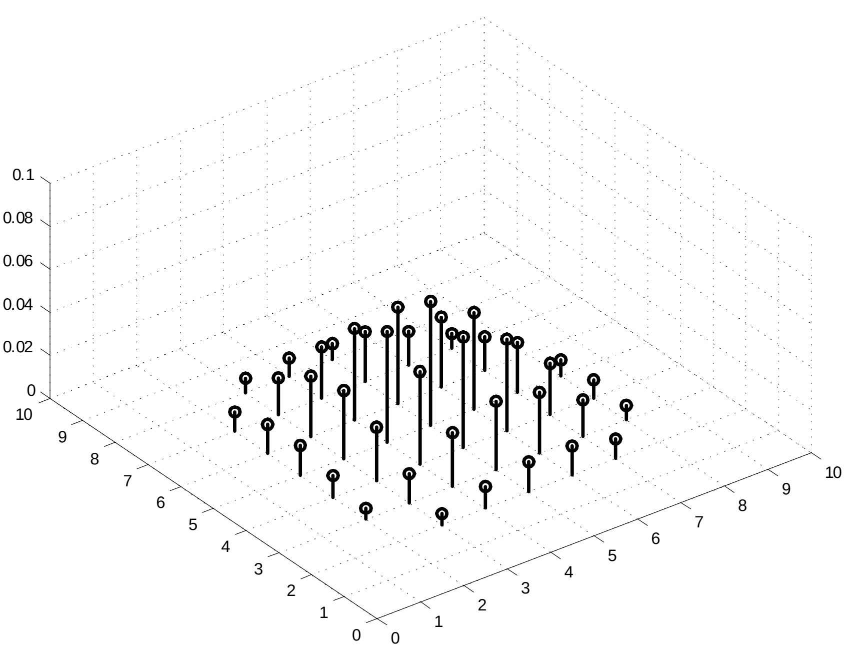

Figure 6: Steady state in the large market with no mergers allowed

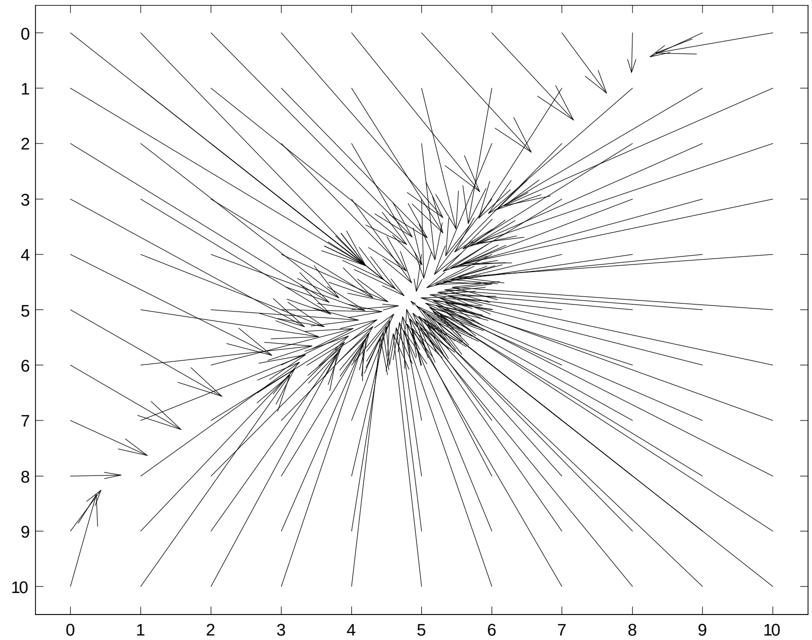

Figure 7: Arrows show the expected transitions over 5 periods in the large market with no mergers allowed

Table 3: Steady State Equilibrium Averages

	No-Mergers			All-Mergers-Allowed		
Performance measure	Intermediate	Small	Large	Intermediate	Small	Large
Consumer Value	48.1	31.8	61.3	35.8	28.8	44.1
Incumbent Value	69.4	57.8	81.0	68.1	56.3	80.8
Entrant Value	-	-	-	1.9	1.1	2.2
Aggregate Value	117.5	89.6	142.3	105.8	86.2	127.2
Price	2.15	2.25	2.10	2.26	2.28	2.24
Quantity	22.2	16.5	27.0	19.2	15.8	22.9
Total capital	7.98	5.79	9.58	7.01	5.88	8.29
Merger frequency	-	-	-	37.7%	33.9%	33.6%
% in monopoly	18.6%	58.2%	2.3%	86.0%	95.2%	68.4%
$\% \min\{K_1, K_2\} \geq 2$	75.7%	35.9%	94.4%	0.9%	0.1%	3.8%

4.3 Equilibria with All Mergers Allowed

Equilibria with all mergers allowed are quite different. Figure 8 shows, for the intermediate market, the steady state distribution that this equilibrium generates as well as the probability that a merger actually happens in each state. As before, the steady state distribution (at the start of the period, before mergers occur) is represented by the height of the pins. Now, in addition, each cell is shaded from light to dark grey, with a darker shade representing a higher probability of a merger happening in a state. For example, a merger happens with probability 1 in state $(3, 3)$, with probability zero in state $(2, 2)$, and with probability 0.59 in state $(2, 3)$.

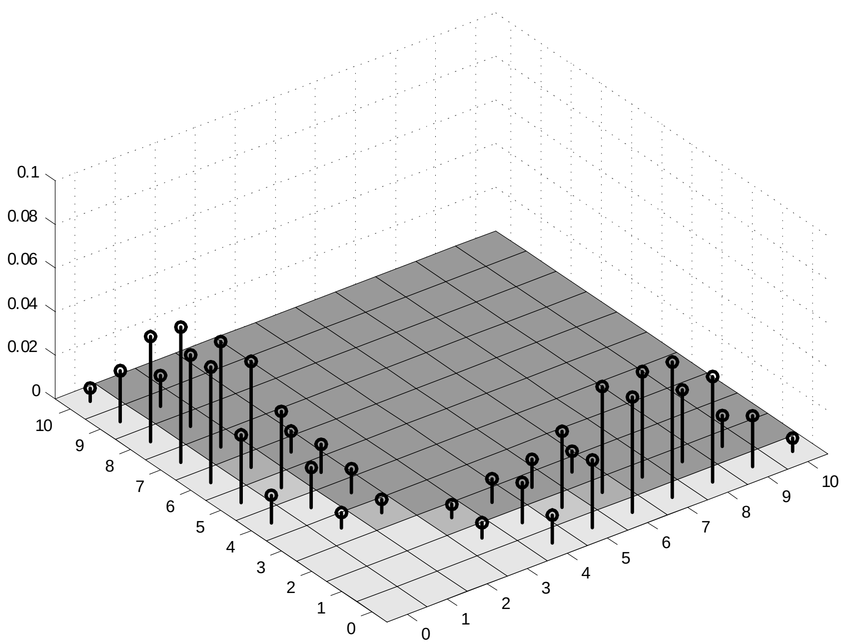

Figure 8: Steady state in the intermediate market with all mergers allowed. Darker shading indicates a merger is more likely to happen.

As is also apparent, the firms do not merge in all states, even though they would be allowed to. In particular, in states in which their capital stocks are both low, a merger would allow a new entrant to come into the industry, dissipating the gains from merger.[6]

The righthand side of Table 3 shows the properties of the all-mergers-allowed equilibria in the intermediate market. The third row from the bottom shows that mergers happen 37.7% of the time. This results in the market being in a monopoly state (at the time of short-run competition) 86.0% of the time, and in a near monopoly 99.1% of the time. As a result of allowing mergers, average output falls from 22.2 to 19.2, while the average price rises from 2.15 to 2.26. Average total capital falls from 7.98 to 7.01. Also shown are consumer, incumbent, entrant, and aggregate value. Not surprisingly, the change in policy leads to substantial negative changes in consumer value, which falls from 48.1 to 35.8. More surprisingly, average incumbent value falls despite the fact that the firms are now allowed to merge whenever they want. This is despite the success that unrestricted mergers have from the firms' point in view in raising expecting price, reducing expected quantity, and limiting total capital. Even once one accounts for entrants' value, producer value (the sum of incumbent and entrant values) barely rises. Combined with the dramatic reduction in consumer value, aggregate value falls substantially, from 117.5 to 105.8.

It is interesting to explore further the reasons behind these results. Consider, first, the reduction in total capital. Allowing mergers does two things. First, it changes the states in which investments are taking place by moving the market to monopoly positions. The average capital addition in the no-mergers steady state is 1.994. If we keep firms' investment behavior

[6] This finding may be due in part to the fact that we allow entry only when a merger occurs. For a discussion of the case where the entrant is run by the manager of one of the merging firms, see Section 7.2.

fixed at their no-mergers equilibrium levels but change the weighting over states to be that in the all-mergers-allowed steady state the average capital addition drops to 1.462.[7] Second, firms' investment policies change; holding the distribution over states fixed at the all-mergers-allowed steady state and changing investment policies increases average capital additions from 1.462 to 1.763.

To understand the change in investment policies, consider how the prospect of merger affects the incentive for a firm i to invest in state (K_i, K_{-i}) if its rival does not. When mergers are not allowed, this incentive comes from the marginal effect on the firm's value, $\partial V(K_i, K_{-i})/\partial K_i$. When, instead, a merger is certain to occur in the next period, the effect of investment on firm i's bargaining position (i.e., the disagreement payoffs) matter as well. Specifically, the marginal effect on a firm's value is $\partial V(K_i, K_{-i})/\partial K_i + \partial \Delta_G(K_i, K_{-i})/\partial K_i$, where $\Delta_G(K_i, K_{-i})/\partial K_i$ is the affect of K_i on the gain from merger defined in (1). In the all-mergers-allowed steady state, the firms find themselves in states where $\partial \Delta_G(K_i, K_{-i})/\partial K_i$ is positive 100% of the time.[8,9]

Why does average producer value not rise when all mergers are allowed? Allowing mergers puts the market in monopoly states with high probabilities. In these states, when all mergers are allowed, an entrant with zero capital frequently invests with the hope of being bought out, that is, we see a great deal of "entry for buyout" [Rasmussen (1988)]. Indeed, entrants invests much more than when no mergers are allowed. Figure 9 shows the one-period transition probabilities for an entrant in state $(5, 0)$ when all mergers are allowed which can be compared to the previous Figure 2 which shows the same for when no mergers are allowed. The probability that the entrant invests is 0.58 in the former case, versus 0.04 in the latter; a merger happens 49% of the time after the entrant invests when all mergers are allowed. (The entrant's increased incentive also lowers the incentive of the incumbent to invest.) Unfortunately for producer value, these investments are made, on average, at very high cost.[10]

The entry for buyout incentive also reduces aggregate value. To illustrate why, Figures 10 and 11 show the difference between the private and social incentives to invest. Specifically, they show, starting in each state (K_1, K_2), the effects of the row firm adding one unit of capital on its value less its affect on aggregate value (so positive numbers indicate a socially excessive incentive to invest, while negative numbers indicate an socially insufficient inventive). Figure 10 shows this for the no-mergers case, while Figure 11 shows the all-mergers-allowed case. As can be seen there, dominant firms generally have insufficient incentives, while entrants have excessive incentives. The entry for buyout phenomenon therefore causes a shift in investment away from the dominant firm, whose incentives are already insufficient, toward the entrant, whose incentives are excessive.

Similar welfare effects arise for similar reasons in the small and large markets, as is evident in Table 3. Overall, allowing all mergers has the greatest effect in the large market and the least effect in the small market. Indeed, the small market's time spent in monopoly states

[7] The average capital addition in the all-mergers-allowed steady state is 1.763. Keeping investment behavior fixed at the all-mergers-allowed equilibrium behavior and reweighting by the steady state probabilities in the no-mergers equilibrium, the average capital addition increases from 1.763 to 2.239.

[8] In the no-mergers steady state, they are in states in which $\partial \Delta_G(K_i, K_{-i})/\partial K_i$ is positive 97.5% of the time.

[9] A second effect of allowing mergers, of course, is that the value function V changes.

[10] By affecting the value of a merged firm, these reductions in producer value at monopoly states also affect investment incentives at non-monopoly states at which mergers are likely.

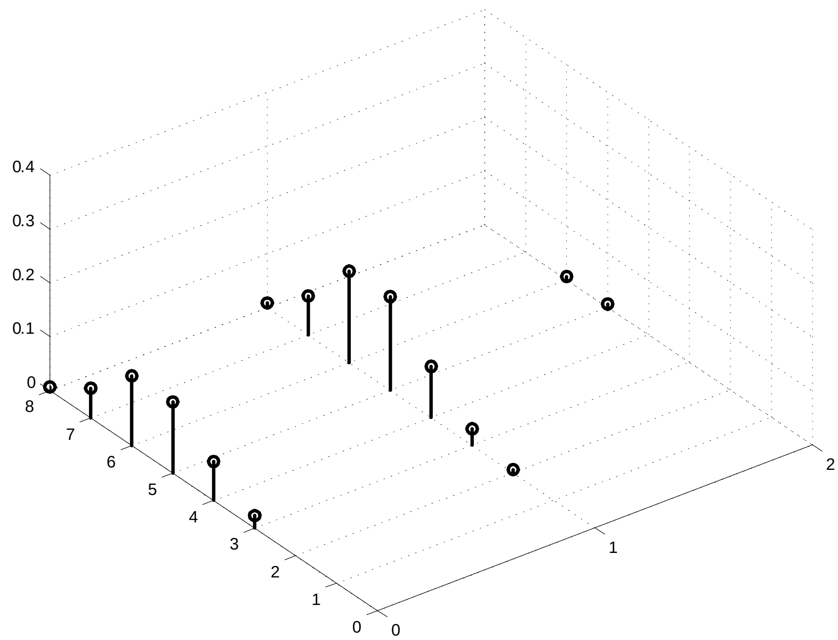

Figure 9: One-period transition from the state (5,0) in the intermediate market with all mergers allowed

	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	(0.6)	(0.2)	0.9	3.1	4.5	5.3	5.5	5.5	5.5	5.4	5.3
k1=1	(0.1)	(1.4)	(0.2)	0.3	0.7	1.0	1.2	1.4	1.5	1.7	1.6
k1=2	1.1	(1.5)	(0.7)	(0.3)	(0.1)	0.1	0.3	0.4	0.6	0.6	0.6
k1=3	0.4	(1.2)	(0.8)	(0.5)	(0.3)	(0.2)	(0.0)	0.1	0.2	0.2	0.2
k1=4	(0.0)	(1.0)	(0.8)	(0.6)	(0.4)	(0.3)	(0.2)	(0.1)	0.0	(0.0)	0.0
k1=5	(1.0)	(1.0)	(0.8)	(0.6)	(0.4)	(0.3)	(0.2)	(0.2)	(0.1)	(0.1)	(0.1)
k1=6	(1.2)	(0.9)	(0.7)	(0.6)	(0.4)	(0.4)	(0.3)	(0.2)	(0.2)	(0.2)	(0.1)
k1=7	(1.1)	(0.8)	(0.7)	(0.5)	(0.4)	(0.3)	(0.3)	(0.2)	(0.3)	(0.2)	(0.2)
k1=8	(1.0)	(0.7)	(0.6)	(0.5)	(0.5)	(0.4)	(0.3)	(0.3)	(0.3)	(0.3)	(0.2)
k1=9	(0.9)	(0.7)	(0.6)	(0.6)	(0.5)	(0.4)	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)
k1=10	(1.2)	(0.8)	(0.6)	(0.5)	(0.5)	(0.4)	(0.3)	(0.4)	(0.3)	(0.3)	(0.3)

Figure 10: Private incentive of the row firm to invest minus the social incentive for the row firm to invest in the intermediate market with no mergers allowed

	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	(0.6)	(0.2)	0.5	1.2	2.2	3.0	3.5	3.9	4.2	4.4	4.6
k1=1	(1.2)	(1.3)	0.3	0.9	1.4	1.6	1.9	2.1	2.2	2.3	2.3
k1=2	(1.7)	(1.3)	(0.4)	0.1	0.4	0.7	0.9	1.0	1.2	1.3	1.3
k1=3	(1.4)	(1.2)	(0.6)	(0.2)	0.0	0.2	0.4	0.5	0.6	0.7	0.8
k1=4	(1.3)	(1.1)	(0.7)	(0.4)	(0.2)	0.0	0.1	0.3	0.3	0.4	0.4
k1=5	(1.3)	(1.0)	(0.7)	(0.4)	(0.3)	(0.1)	(0.0)	0.1	0.2	0.2	0.3
k1=6	(1.2)	(0.9)	(0.7)	(0.5)	(0.3)	(0.2)	(0.1)	(0.0)	0.1	0.1	0.1
k1=7	(1.1)	(0.9)	(0.6)	(0.5)	(0.4)	(0.3)	(0.2)	(0.1)	(0.0)	0.0	0.1
k1=8	(1.0)	(0.8)	(0.6)	(0.5)	(0.4)	(0.3)	(0.2)	(0.1)	(0.1)	(0.0)	0.0
k1=9	(0.9)	(0.8)	(0.7)	(0.6)	(0.5)	(0.4)	(0.3)	(0.2)	(0.2)	(0.1)	(0.0)
k1=10	(1.0)	(0.9)	(0.7)	(0.6)	(0.5)	(0.4)	(0.3)	(0.2)	(0.2)	(0.1)	(0.1)

Figure 11: Private incentive of the row firm to invest minus the social incentive for the row firm to invest in the intermediate market with all mergers allowed

increases only three percent when all mergers are allowed.

5 Optimal Merger Policy

In this section, we analyze the antitrust authority's optimal merger approval policy. In our discussion, we focus initially on the intermediate market analyzed in the previous section; we discuss the results for the small and large markets afterward.

5.1 Feasible Policies

We consider two different types of settings, depending upon whether or not the authority can commit to its decision in a given state:

No Commitment In this setting, we assume that the antitrust authority cannot commit to its policy. Like each of the firms, the authority is thus a player in a dynamic game. If the authority chooses to block a proposed merger in state (K_1, K_2), it has to pay the blocking cost b which it privately observes prior to making its decision. Recall that a Markovian strategy for the antitrust authority is a state-contingent threshold $\widehat{b}(K_1, K_2)$ specifying the highest blocking cost at which the authority will block a merger in a given state (K_1, K_2). Appealing to the one-stage deviation principle, strategy $\widehat{b}(\cdot) : \mathcal{S}^2 \to [\underline{b}, \overline{b}]$ is a Markov-perfect merger policy if the authority has no incentive to deviate from $\widehat{b}(\cdot)$ at any decision node, assuming it follows $\widehat{b}(\cdot)$ in the continuation game.[11]

Commitment In this setting, we assume that the antitrust authority can commit ex ante to a pure action $a(K_1, K_2) \in \{0, 1\}$ for each state (K_1, K_2), where $a = 1$ if the merger is approved when proposed and $a = 0$ if it is blocked. Observe that there are 2^{100} possible deterministic symmetric merger policies. Thus, for computational reasons, we

[11] Part of our motivation for introducing the blocking cost is to insure existence of equilibrium by smoothing out the antitrust authority's behavior.

restrict the space of feasible commitment policies, focusing on two classes of deterministic commitment policies:[12]

Herfindahl-based Policy Under this type of policy, a proposed merger in state (K_1, K_2) is approved if and only if the capital stock-based Herfindahl index in that state, denoted $H(K_1, K_2)$, satisfies the inequality $H(K_1, K_2) \geq \underline{H}$, where $\underline{H} \in [0, 1]$ is the authority's policy variable.[13] Note that because there are only two firms, the post-merger Herfindahl index always equals one: $H(K_1 + K_2, 0) = H(0, K_1 + K_2) = 1$. So, this policy of setting a lower bound on the pre-merger Herfindahl index is equivalent to requiring that the increase in the Herfindahl index is below some threshold: $\Delta H(K_1, K_2) \leq \underline{\Delta H} \equiv 1 - \underline{H}$. For illustration, Figure 12(a) shows the policy $\underline{H} = 0.65$, where states with $a(K_1, K_2) = 1$ are shaded (only states with $\max\{K_1, K_2\} \leq 10$ are shown), while Figure 12(b) shows the policy $\underline{H} = 0.8$.

Capital-stock-based Policy Under this type of policy, a proposed merger in state (K_1, K_2) is approved if and only if $K_1 + K_2 \in [\underline{K}, \overline{K}]$ and $\min\{K_1, K_2\} \geq \underline{K}_i$, where $\overline{K}$, $\underline{K}$ and $\underline{K}_i$ are the authority's policy variables.[14] Figure 13(a), for example depicts the policy $(\overline{K}, \underline{K}, \underline{K}_i) = (4, 10, 1)$, where states with $a(K_1, K_2) = 1$ are shaded (only states with $\max\{K_1, K_2\} \leq 10$ are shown), while Figure 13(b) shows the policy $(\overline{K}, \underline{K}, \underline{K}_i) = (4, 10, 3)$.

Observe that under a deterministic commitment policy, such as those outlined above, the antitrust authority never incurs any blocking costs since if it commits to block a merger in state (K_1, K_2) the merger will not be proposed in the first place (the firms will not want to incur a proposal cost).

5.2 Static Benchmarks

As a benchmark, and to understand some of the forces behind the optimal merger policy, Figure 14 shows for the intermediate market the static change in consumer surplus [panel (a)] and aggregate surplus [panel (b)] from allowing a merger (the figures show only states with $\max\{K_1, K_2\} \leq 10$; states with positive surplus effects are shaded). This is the change in CV or AV due to production and consumption in the period the merger occurs.

In the intermediate market, only in state $(K_1, K_2) = (1, 1)$ does a merger generate a static increase in consumer surplus, and there the gain is only 0.1.[15] In contrast, many mergers increase aggregate surplus. In general, these tend to be states in which the total capital in

[12] The particular form these simple commitment policies take is partly motivated by which mergers are AV-increasing as one-shot deviations.

[13] In the computations, we restrict attention to $\underline{H} \in \{0.6, 0.6 + \Delta, 0.6 + 2\Delta, ..., 0.925 - \Delta, 0.925\}$, where $\Delta = 0.25$.

[14] In the computations, we restrict attention to $\overline{K} \in \{2, 4, ..., 10, 12\}$, $\underline{K} \in \{6, 8, ..., 18, 20\}$ and $\underline{K}_i \in \{1, 2, ..., 6, 7\}$.

[15] For a merger among symmetrically-positioned firms to increase consumer surplus, the marginal cost reduction at the pre-merger output Q of the merging firms, $C_Q(Q|K) - C_Q(2Q|2K)$, must exceed the pre-merger price cost margin, $P(2Q) - C_Q(Q|K)$; see Farrell and Shapiro (1990) and Nocke and Whinston (2010).

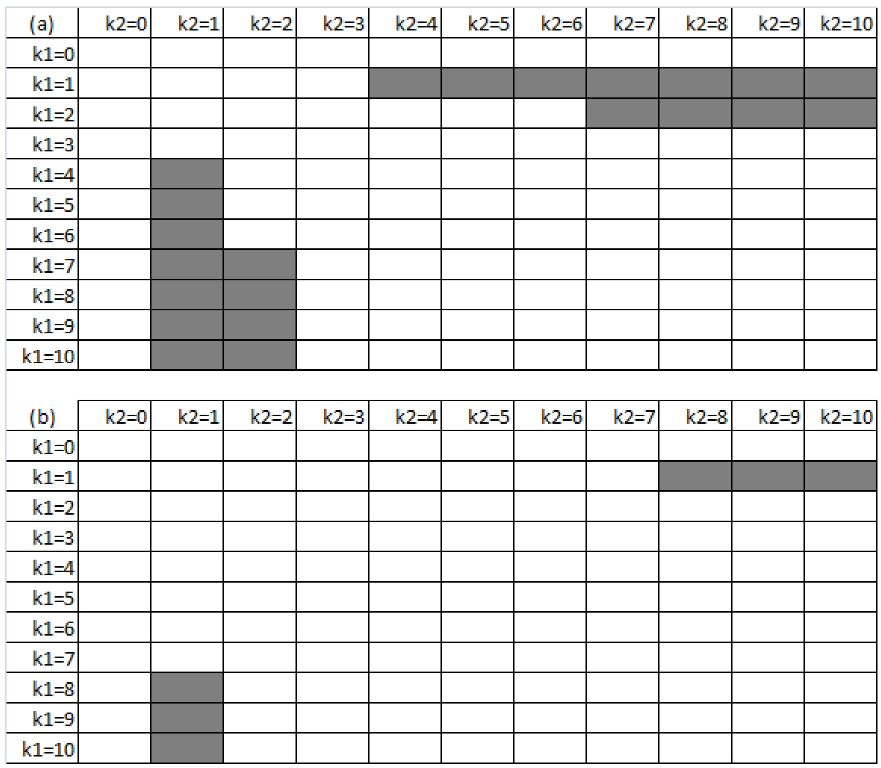

Figure 12: Herfindahl-based commitment policy: (a) is $\underline{H} = 0.65$ and (b) is $\underline{H} = 0.80$. The shaded states are those in which $a(K_1, K_2) = 1$

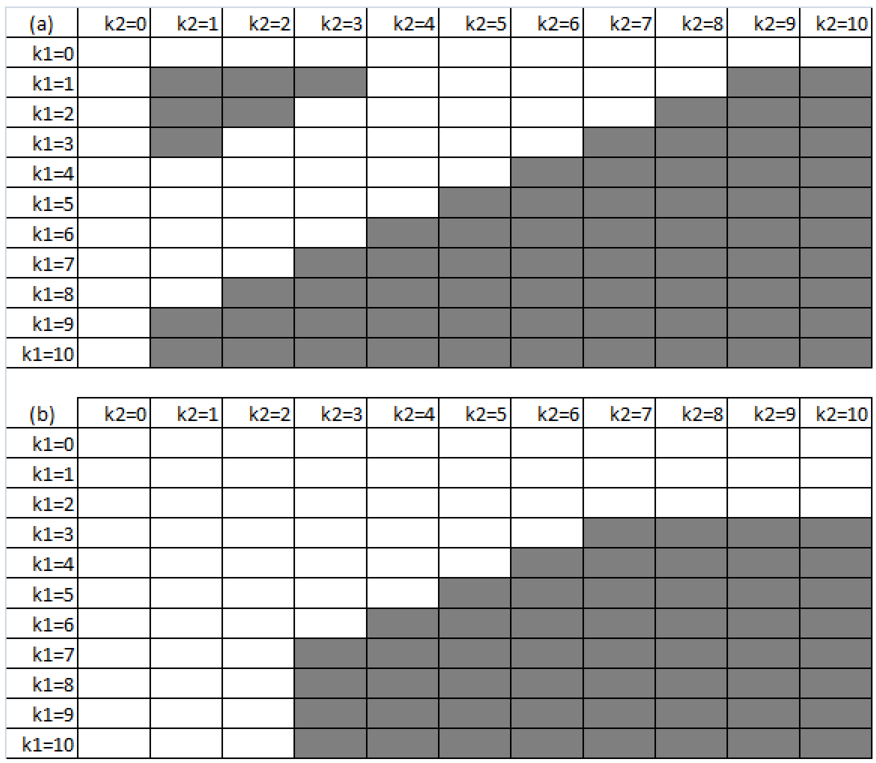

Figure 13: Capital-stock-based commitment policy: (a) is $(\overline{K}, \underline{K}, \underline{K}_i) = (4, 10, 1)$ and (b) is $(\overline{K}, \underline{K}, \underline{K}_i) = (4, 10, 3)$. The shaded states are those in which $a(K_1, K_2) = 1$.

(a)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	-	-	-	-	-	-	-	-	-	-	-
k1=1	-	0.1	(0.2)	(0.4)	(0.5)	(0.7)	(0.8)	(0.8)	(0.9)	(0.9)	(1.0)
k1=2	-	(0.2)	(0.6)	(1.0)	(1.3)	(1.5)	(1.7)	(1.9)	(2.0)	(2.0)	(2.1)
k1=3	-	(0.4)	(1.0)	(1.5)	(2.0)	(2.3)	(2.5)	(2.7)	(2.8)	(3.0)	(3.1)
k1=4	-	(0.5)	(1.3)	(2.0)	(2.4)	(2.8)	(3.1)	(3.3)	(3.5)	(3.7)	(3.8)
k1=5	-	(0.7)	(1.5)	(2.3)	(2.8)	(3.2)	(3.6)	(3.9)	(4.1)	(4.3)	(4.4)
k1=6	-	(0.8)	(1.7)	(2.5)	(3.1)	(3.6)	(4.0)	(4.3)	(4.5)	(4.7)	(4.9)
k1=7	-	(0.8)	(1.9)	(2.7)	(3.3)	(3.9)	(4.3)	(4.6)	(4.9)	(5.1)	(5.3)
k1=8	-	(0.9)	(2.0)	(2.8)	(3.5)	(4.1)	(4.5)	(4.9)	(5.2)	(5.4)	(5.6)
k1=9	-	(0.9)	(2.0)	(3.0)	(3.7)	(4.3)	(4.7)	(5.1)	(5.4)	(5.7)	(5.9)
k1=10	-	(1.0)	(2.1)	(3.1)	(3.8)	(4.4)	(4.9)	(5.3)	(5.6)	(5.9)	(6.2)

(b)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	-	-	-	-	-	-	-	-	-	-	-
k1=1	-	1.7	1.6	1.4	1.2	1.0	0.9	0.8	0.7	0.6	0.5
k1=2	-	1.6	1.6	1.4	1.2	0.9	0.8	0.6	0.5	0.4	0.3
k1=3	-	1.4	1.4	1.1	0.9	0.6	0.4	0.2	0.1	0.0	(0.1)
k1=4	-	1.2	1.2	0.9	0.5	0.3	0.0	(0.1)	(0.3)	(0.4)	(0.5)
k1=5	-	1.0	0.9	0.6	0.3	(0.0)	(0.3)	(0.5)	(0.7)	(0.8)	(0.9)
k1=6	-	0.9	0.8	0.4	0.0	(0.3)	(0.6)	(0.8)	(1.0)	(1.2)	(1.3)
k1=7	-	0.8	0.6	0.2	(0.1)	(0.5)	(0.8)	(1.1)	(1.3)	(1.5)	(1.6)
k1=8	-	0.7	0.5	0.1	(0.3)	(0.7)	(1.0)	(1.3)	(1.5)	(1.7)	(1.9)
k1=9	-	0.6	0.4	0.0	(0.4)	(0.8)	(1.2)	(1.5)	(1.7)	(1.9)	(2.1)
k1=10	-	0.5	0.3	(0.1)	(0.5)	(0.9)	(1.3)	(1.6)	(1.9)	(2.1)	(2.3)

Figure 14: Static change in (a) consumer surplus and (b) aggregate surplus from a merger in the intermediate market.

the industry is not too large: in the intermediate market, there is a static gain in aggregate surplus in any state in which total capital is not more than 10. (There are also asymmetric states with total capital above that level in which a merger creates a static aggregate surplus gain.) The gains in aggregate surplus are generally smaller the larger is the total capital in the industry.[16] Holding total capital fixed, an increase in the asymmetry of capital positions (holding total capital fixed) has varying effects on the static gains in aggregate surplus from a merger. This gain gets smaller with increased asymmetry at low levels of total capital, but grows larger with increased asymmetry at greater levels of total capital.

Finally, firms always have a static profit gain from merging, as a merger creates a monopoly in the period in which it occurs.

5.3 Markov Perfect Policy

We first examine the Markov perfect merger policy. To do so, we start with the policy of allowing no mergers and the associated equilibrium strategies for the firms (discussed in Section 4), and iteratively update the antitrust authority's policy and the firm's strategies until we converge to an equilibrium. In the first iteration, we identify for each state (K_1, K_2) the antitrust authority's optimal approval rule given its expectation that its own behavior in the future will be to approve no mergers and that the firms will conform to their equilibrium strategies given that policy. We then update firms' equilibrium strategies given this new approval policy by the antitrust authority. We continue to iterate in this fashion until the antitrust authority has no incentive to deviate from its current policy.[17]

Figures 15 and 16 show the first step in this iteration process. Figure 15 shows for each state the gain (before blocking costs) in CV or AV from a one-time merger approval given the expectation that no mergers will be approved in the future and that firms' strategies will be the ones that form an equilibrium given that no mergers would be allowed. For both the CV and AV welfare criteria, the set of states in which there is a gain (before blocking costs) from a one-time merger approval is very close to the set of states in which a merger is statically beneficial. For example, the merger increases CV in state $(1, 1)$ where the gain is 1.1. So, with a CV criterion, a merger is approved with probability one in that state. In all other states the change in CV is less than -1, so with blocking costs drawn from the uniform distribution on $[0, 1]$ a merger is blocked with probability 1 in all of these states. In contrast, every state with total capital no greater than 9 (as well as some others) has an increase in AV from merger approval. We will let $\widehat{b}_1(K_1, K_2)$ denote the policy that emerges from this first step in the iteration. Figure 16 shows

[16] To understand this result, observe that the change in aggregate surplus from a merger in a symmetric state is approximately

$$Q\left[\left(\frac{\Delta Q}{Q}\right)(P - MC) - \left(1 - \frac{\Delta Q}{Q}\right)\left(\frac{\Delta AC_M}{AC_M}\right)AC_M\right],$$

where $(P - MC)$ is the premerger price-cost margin, AC_M is the average cost if no merger occurs but the output level changes to its post-merger level, and ΔAC_M is the change in average cost at the post-merger output level due to the combination of capital. At larger capital levels, $(P - MC)$ and $|\Delta Q/Q|$ are both greater, $(\Delta AC_M/AC_M)$ is unchanged, and AC_M is smaller, making the sign of the effect on aggregate surplus more likely to be negative. For example, $(P - MC)$ is 0.32 at state $(2, 2)$ and 0.45 at state $(4, 4)$, $(\Delta Q/Q)$ is -0.062 at $(2, 2)$ and -0.125 at $(4, 4)$, and AC_M is 27% lower at $(4, 4)$ than at $(2, 2)$.

[17] For reasons of computational efficiency and to aid with convergence, this is not exactly what our code does. The discussion of these iterations serves to illustrate the economics.

(a)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	-	-	-	-	-	-	-	-	-	-	-
k1=1	-	1.1	(3.7)	(6.8)	(8.9)	(9.6)	(9.9)	(10.1)	(10.2)	(10.4)	(10.2)
k1=2	-	(3.7)	(8.1)	(11.0)	(12.3)	(13.1)	(13.6)	(13.9)	(14.3)	(14.2)	(14.2)
k1=3	-	(6.8)	(11.0)	(13.1)	(14.3)	(15.2)	(15.8)	(16.3)	(16.5)	(16.5)	(16.6)
k1=4	-	(8.9)	(12.3)	(14.3)	(15.6)	(16.6)	(17.4)	(17.7)	(17.9)	(18.0)	(18.2)
k1=5	-	(9.6)	(13.1)	(15.2)	(16.6)	(17.8)	(18.3)	(18.7)	(18.8)	(19.1)	(19.3)
k1=6	-	(9.9)	(13.6)	(15.8)	(17.4)	(18.3)	(18.9)	(19.3)	(19.5)	(19.8)	(20.1)
k1=7	-	(10.1)	(13.9)	(16.3)	(17.7)	(18.7)	(19.3)	(19.6)	(19.9)	(20.3)	(20.6)
k1=8	-	(10.2)	(14.3)	(16.5)	(17.9)	(18.8)	(19.5)	(19.9)	(20.4)	(20.9)	(21.3)
k1=9	-	(10.4)	(14.2)	(16.5)	(18.0)	(19.1)	(19.8)	(20.3)	(20.9)	(21.4)	(21.9)
k1=10	-	(10.2)	(14.2)	(16.6)	(18.2)	(19.3)	(20.1)	(20.6)	(21.3)	(21.9)	(22.5)

(b)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	-	-	-	-	-	-	-	-	-	-	-
k1=1	-	1.8	2.3	3.0	3.4	3.2	3.0	2.8	2.6	2.4	2.5
k1=2	-	2.3	2.9	3.1	2.8	2.5	2.2	1.9	1.7	1.8	1.8
k1=3	-	3.0	3.1	2.6	2.0	1.5	1.1	0.8	0.8	0.8	0.8
k1=4	-	3.4	2.8	2.0	1.2	0.7	0.2	0.0	(0.0)	(0.1)	(0.2)
k1=5	-	3.2	2.5	1.5	0.7	(0.1)	(0.4)	(0.6)	(0.7)	(0.9)	(1.0)
k1=6	-	3.0	2.2	1.1	0.2	(0.4)	(0.7)	(1.0)	(1.3)	(1.5)	(1.8)
k1=7	-	2.8	1.9	0.8	0.0	(0.6)	(1.0)	(1.4)	(1.8)	(2.1)	(2.4)
k1=8	-	2.6	1.7	0.8	(0.0)	(0.7)	(1.3)	(1.8)	(2.2)	(2.7)	(3.0)
k1=9	-	2.4	1.8	0.8	(0.1)	(0.9)	(1.5)	(2.1)	(2.7)	(3.1)	(3.6)
k1=10	-	2.5	1.8	0.8	(0.2)	(1.0)	(1.8)	(2.4)	(3.0)	(3.6)	(4.1)

Figure 15: Effect of a one-time merger on (a) CV and (b) AV in the intermediate market.

the resulting probabilities of merger approval in each state with the AV criterion. Given this new policy $\widehat{b}_1(K_1, K_2)$, we complete the iteration step by identifying firms' new equilibrium proposal and investment strategies, which we denote by $[\psi_1(K_1, K_2), \xi_1(K_1, K_2)]$. Figure 17 shows the firms' proposal behavior $\psi_1(K_1, K_2)$, indicating in each state the probability that a merger is proposed in panel (a), and the resulting probability that a merger happens in panel (b). (We will discuss the new investment strategy ξ_1 shortly.)

In the next step of the iteration process we determine the gains from a one-time merger approval in each state given that the antitrust authority will follow policy $\widehat{b}_1$ in the future, and firms' behavior is given by proposal and investment strategies (ψ_1, ξ_1). When we do this for the CV criterion, there is no change in the approval probabilities, so the approval policy shown in Figure 16(a) is in fact a Markov perfect policy. This equilibrium is essentially identical to the no-mergers equilibrium of Section 4.

For the AV criterion, however, the optimal policy changes dramatically in the second iteration. Figure 18 shows for each state the gain in AV (before blocking costs) from a one-time merger approval given the expectation that the antitrust authority will follow policy $\widehat{b}_1$ in the future and that firms' strategies will be (ψ_1, ξ_1). Except for states $(2, 3)$ and $(3, 2)$, only states in which $\min\{K_1, K_2\} \leq 2$ (and not all of them) have gains in AV from merger approval, while the states with a positive probability of merger approval given the blocking costs are those with $\min\{K_1, K_2\} \leq 3$, plus state $(4, 4)$ (these are the states in which AV falls by less than 1.0).

(a)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=1	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

(b)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=1	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
k1=2	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
k1=3	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
k1=4	0%	100%	100%	100%	100%	100%	100%	100%	100%	92%	84%
k1=5	0%	100%	100%	100%	100%	96%	66%	46%	32%	14%	0%
k1=6	0%	100%	100%	100%	100%	66%	27%	0%	0%	0%	0%
k1=7	0%	100%	100%	100%	100%	46%	0%	0%	0%	0%	0%
k1=8	0%	100%	100%	100%	100%	32%	0%	0%	0%	0%	0%
k1=9	0%	100%	100%	100%	92%	14%	0%	0%	0%	0%	0%
k1=10	0%	100%	100%	100%	84%	0%	0%	0%	0%	0%	0%

Figure 16: First policy iteration according to (a) CV criterion and (b) AV criterion in the intermediate market. Each cell shows the probability (stated as a %) that a merger is approved.

(a)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=1	0%	0%	0%	0%	0%	39%	73%	97%	100%	100%	100%
k1=2	0%	0%	0%	63%	100%	100%	100%	100%	100%	100%	100%
k1=3	0%	0%	63%	100%	100%	100%	100%	100%	100%	100%	100%
k1=4	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%
k1=5	0%	39%	100%	100%	100%	100%	100%	100%	100%	52%	0%
k1=6	0%	73%	100%	100%	100%	100%	97%	0%	0%	0%	0%
k1=7	0%	97%	100%	100%	100%	100%	0%	0%	0%	0%	0%
k1=8	0%	100%	100%	100%	100%	100%	0%	0%	0%	0%	0%
k1=9	0%	100%	100%	100%	100%	52%	0%	0%	0%	0%	0%
k1=10	0%	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%

(b)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=1	0%	0%	0%	0%	0%	39%	73%	97%	100%	100%	100%
k1=2	0%	0%	0%	63%	100%	100%	100%	100%	100%	100%	100%
k1=3	0%	0%	63%	100%	100%	100%	100%	100%	100%	100%	100%
k1=4	0%	0%	100%	100%	100%	100%	100%	100%	100%	92%	84%
k1=5	0%	39%	100%	100%	100%	96%	66%	46%	32%	7%	0%
k1=6	0%	73%	100%	100%	100%	66%	27%	0%	0%	0%	0%
k1=7	0%	97%	100%	100%	100%	46%	0%	0%	0%	0%	0%
k1=8	0%	100%	100%	100%	100%	32%	0%	0%	0%	0%	0%
k1=9	0%	100%	100%	100%	92%	7%	0%	0%	0%	0%	0%
k1=10	0%	100%	100%	100%	84%	0%	0%	0%	0%	0%	0%

Figure 17: The first iteration probability (stated as a %) of a merger (a) being proposed, and (b) happening, with the AV criterion.

	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	-	-	-	-	-	-	-	-	-	-	-
k1=1	-	1.1	0.1	(0.0)	0.1	0.2	0.2	0.3	0.3	0.3	0.5
k1=2	-	0.1	0.1	0.1	(0.0)	(0.1)	(0.2)	(0.2)	(0.2)	(0.0)	0.2
k1=3	-	(0.0)	0.1	(0.2)	(0.4)	(0.6)	(0.7)	(0.8)	(0.7)	(0.5)	(0.4)
k1=4	-	0.1	(0.0)	(0.4)	(0.7)	(1.0)	(1.2)	(1.3)	(1.2)	(1.1)	(1.0)
k1=5	-	0.2	(0.1)	(0.6)	(1.0)	(1.4)	(1.6)	(1.6)	(1.6)	(1.6)	(1.6)
k1=6	-	0.2	(0.2)	(0.7)	(1.2)	(1.6)	(1.8)	(1.9)	(2.0)	(2.2)	(2.3)
k1=7	-	0.3	(0.2)	(0.8)	(1.3)	(1.6)	(1.9)	(2.2)	(2.5)	(2.9)	(3.1)
k1=8	-	0.3	(0.2)	(0.7)	(1.2)	(1.6)	(2.0)	(2.5)	(3.1)	(3.5)	(3.8)
k1=9	-	0.3	(0.0)	(0.5)	(1.1)	(1.6)	(2.2)	(2.9)	(3.5)	(4.0)	(4.4)
k1=10	-	0.5	0.2	(0.4)	(1.0)	(1.6)	(2.3)	(3.1)	(3.8)	(4.4)	(4.8)

Figure 18: Change in AV from a merger given firm's behavior after the first policy iteration in the intermediate market.

To understand this dramatic change with the AV criterion, observe that once the merger policy changes from no mergers being allowed to policy $\widehat{b}_1$, the investment behavior of the firms (captured in ξ_1) changes dramatically, especially for new entrants. As policy $\widehat{b}_1$ allows many mergers, these changes in firms' behavior are similar to those we saw in Section 4 when all mergers were allowed. For example, starting at state $(6,0)$ the distributions of capital additions by the two firms when no mergers are allowed and under policy $\widehat{b}_1$ are shown in Table 4.

Table 4: Investments Starting at $(6,0)$	No mergers		Policy $\widehat{b}_1$	
Capital addition	firm 0	firm 6	firm 0	firm 6
0	100%	0%	38%	7%
1	0%	29%	62%	47%
2	0%	61%	0%	41%
3	0%	10%	0%	5%
4	0%	0%	0%	0%

As can be seen in Table 4, the entrant does not invest at all at state $(6,0)$ when mergers are not allowed, but under policy $\widehat{b}_1$ he builds a unit of capital 62% of the time. The incumbent, on the other hand, invests less under policy $\widehat{b}_1$. The entrant is doing this because of the prospect that he will get bought out. A merger happens with a high probability in the first period after this investment, provided the entrant's new unit of capital does not immediately depreciate (and provided the incumbent is not hit too badly by depreciation shocks, as otherwise the industry may move to a state in which mergers are not proposed even though they would be accepted). The cumulative probability that a merger occurs within various number of periods starting from state $(6,0)$ is shown in Table 5.

Table 5: Likelihood of a Merger Starting in State (6,0)	
Period	Cumulative merger probability
1	32.6%
2	58.1%
3	74.8%
4	85.1%
5	91.2%

More generally, when no mergers are allowed the entrant invests provided the capital stock of the incumbent is less than 6. His investment falls as the incumbent's capital stock grows, and the entrant stops investing once the incumbent's capital stock reaches 6. In contrast, under policy $\widehat{b}_1$, the entrant invests much more, and in response the incumbent's investments fall. As we have seen in Section 4 [and remains true under policy $\widehat{b}_1$], monopolists generally have insufficient investment incentives, while entrants' incentives are too large (leading them to invest at high cost). As a result, this change in investment behavior makes the movement to a monopoly state due to a merger much less attractive, causing the set of states in which mergers increase AV to shrink dramatically.

The Markov perfect policy with the AV criterion is even more restrictive than the policy discussed above for the second iteration. Figure 19 shows the merger acceptance probabilities, merger proposal probabilities, and the probabilities a merger actually occurs in various states in the Markov perfect policy.

Under the optimal approval policy without commitment, for states in which each firm has no more than 10 units of capital, the antitrust authority approves a proposed merger with probability one only in states $(1,1)$, $(2,1)$, and $(1,2)$. The authority approves a proposed merger with positive probability in near-monopoly states in which $\min\{K_1, K_2\} = 1$, as well as in states $(2,2)$, $(3,2)$, and $(2,3)$. Overall, the policy resembles one in which mergers are approved if one of the firms is "failing." Given this policy, mergers are proposed with probability one in all of these states, except in state $(1,1)$, where a merger is never proposed, and in states $(2,1)$, and $(1,2)$, where a merger is proposed with less than full probability.

Figure 20 shows the steady state distribution for the Markov perfect policy, and well as the probability that a merger happens in each state. (States in which a merger is not allowed are unshaded, while states in which a merger would be allowed with positive probability but are never proposed have the lightest shade of gray.) Table 6 shows some summary statistics for the Markov perfect policy equilibrium under the AV criterion, and for equilibria when either no mergers or all mergers are allowed. In the steady state induced by the Markov perfect policy,

the industry is in a monopoly state at the time of static competition 49.4% of the time, and in near-monopoly states 55.8% of the time. Compared to the steady state induced when no mergers are allowed, the economy spends much more time in such states. In addition, the average aggregate capital level is lower. The reason is the shift in the steady state distribution toward more symmetric states, in which investments are greater. For example, the average capital addition (gross of depreciation) by the two firms in the no-mergers steady state is 0.997 units of capital. Keeping firms' investment strategies fixed but changing the steady state distribution to the one in the Markov perfect equilibrium lowers the average capital addition to 0.874. If we then change firms' investment strategies to that in the Markov perfect equilibrium, the average capital addition rises from 0.874 to 0.960.

Table 6: Steady State Averages for the Intermediate Market under Various Policies

Performance measure	*MP-AV*	*No Mergers*	*All Mergers Allowed*
Consumer value	43.3	48.1	35.8
Incumbent value	69.9	69.4	68.1
Entrant value	0.5	0.0	1.9
Blocking cost	-0.1	0.0	0.0
AV	113.6	117.5	105.8
Price	2.19	2.15	2.26
Quantity	21.0	22.2	19.2
Total capital	7.65	7.98	7.01
Merger frequency	16.1%	0.0%	37.7%
% in monopoly	49.4%	18.6%	86.0%
% $\min\{K_1, K_2\} \geq 2$	44.2%	75.7%	0.9%

Most strikingly, the Markov perfect policy equilibrium with the AV criterion results in a level of steady state AV that is about 3% lower than with the no-mergers policy: AV is 113.6

(a)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=1	0%	100%	100%	93%	73%	67%	66%	69%	74%	80%	80%
k1=2	0%	100%	76%	22%	0%	0%	0%	0%	0%	0%	0%
k1=3	0%	93%	22%	0%	0%	0%	0%	0%	0%	0%	0%
k1=4	0%	73%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=5	0%	67%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=6	0%	66%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=7	0%	69%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=8	0%	74%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=9	0%	80%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=10	0%	80%	0%	0%	0%	0%	0%	0%	0%	0%	0%

(b)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=1	0%	0%	57%	100%	100%	100%	100%	100%	100%	100%	100%
k1=2	0%	57%	100%	100%	0%	0%	0%	0%	0%	0%	0%
k1=3	0%	100%	100%	0%	0%	0%	0%	0%	0%	0%	0%
k1=4	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=5	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=6	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=7	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=8	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=9	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=10	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%

(c)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=1	0%	0%	57%	93%	73%	67%	66%	69%	74%	80%	80%
k1=2	0%	57%	76%	22%	0%	0%	0%	0%	0%	0%	0%
k1=3	0%	93%	22%	0%	0%	0%	0%	0%	0%	0%	0%
k1=4	0%	73%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=5	0%	67%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=6	0%	66%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=7	0%	69%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=8	0%	74%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=9	0%	80%	0%	0%	0%	0%	0%	0%	0%	0%	0%
k1=10	0%	80%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Figure 19: The figure shows for the Markov perfect policy (AV criterion, intermediate market) the probabilities mergers are (a) allowed, (b) proposed, and (c) happen.

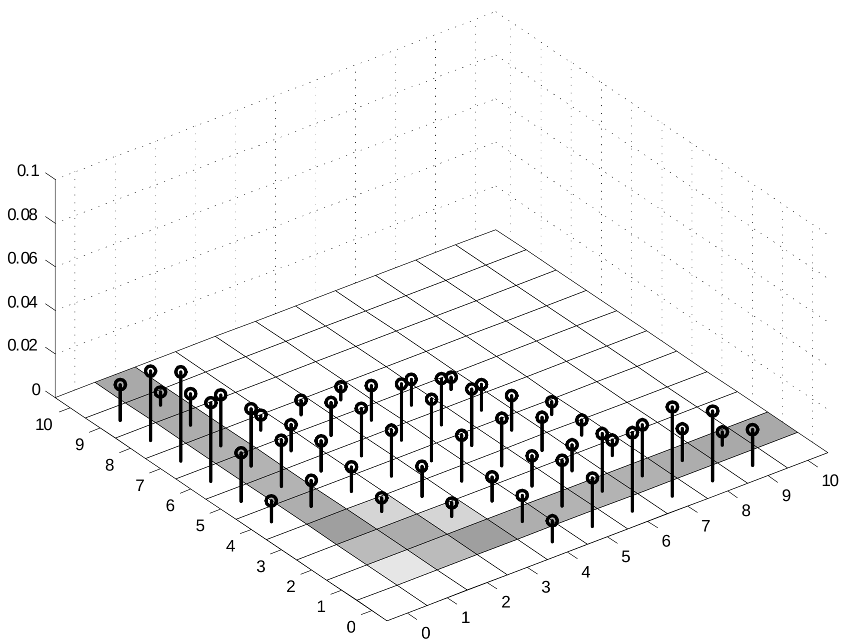

Figure 20: The figure shows the steady state distribution of the equilibrium generated by the Markov perfect policy (AV criterion) in the intermediate market. The height of each pin indicates the steady probability of that state. The shading of the cell reflects the probability of a merger happening (with a darker grey representing a higher probability). States in which a merger is not allowed are unshaded, while states in which mergers would be allowed with positive probability but are never proposed have the lightest shade of gray.

compared to 117.5 when no mergers are allowed. Firms are slightly better off while consumers are much worse off: CV is 43.3 (vs. 48.1) and producer value is 70.4 (vs. 69.4). Consumers are harmed both from the monopoly pricing and the reduction in capital, both of which lead to higher prices.

5.4 Commitment Policy

We now turn to the optimal commitment policy in the intermediate market. By this we mean the policy that leads to the largest steady state level of expected welfare, either CV or AV depending on the welfare criterion.[18] In contrast to the Markov perfect policy, the planner in the commitment case considers the impact his policy has on firms' strategies.[19]

In the intermediate market, the optimal commitment policy — for either a CV or AV standard — is the Herfindahl-type policy $\underline{H} = 0.775$. For states in which each firm has no more than 10 units of capital, this policy involves approving a merger only when the smaller firm has one unit of capital and the larger firm has at least seven units. (Wherever a merger is approved under this policy, it is also highly profitable to the merging firms and is proposed with probability one.) As a result, mergers occur only 3 percent of the time. Thus, the policy is fairly close to the no-mergers policy, but leads to some mergers.

Figure 21 shows the steady state distribution of the equilibrium induced by the optimal commitment policy. Table 7 shows steady state averages of various performance measures for this policy as well as for the Markov perfect policy (AV criterion), the no-mergers policy, and the all-mergers-allowed policy. The ability to commit leads to a 4% gain in AV compared to the Markov perfect equilibrium with the AV criterion, and a 2.5% gain in CV compared to the Markov perfect equilibrium with the CV criterion.

Table 7: Steady State Averages for the Intermediate Market under Various Policies

Performance measure	*Commitment (CV and AV)*	*MP-AV*	*No Mergers/MP-CV*	*All Mergers Allowed*
Consumer value	49.3	43.3	48.1	35.8
Incumbent value	68.8	69.9	69.4	68.1
Entrant value	0.0	0.5	0.0	1.9
Blocking cost	0.0	-0.1	0.0	0.0
AV	118.1	113.6	117.5	105.8
Price	2.14	2.19	2.15	2.26
Quantity	22.5	21.0	22.2	19.2
Total capital	8.17	7.65	7.98	7.01
Merger frequency	3.0%	16.1%	0.0%	37.7%
% in monopoly	14.3%	49.4%	18.6%	86.0%
% $\min\{K_1, K_2\} \geq 2$	78.8%	44.2%	75.7%	0.9%

Strikingly, even though mergers move the industry to a monopoly state, the industry spends

[18] This policy will generally differ from the policy that would be optimal given that the industry is starting in a particular state (K_1, K_2).

[19] A less obvious difference is that under commitment the antitrust authority considers the impact its policy has on proposal costs, while without commitment those costs are considered to be sunk at the time a merger is reviewed. [A similar point arises in Besanko and Spulber (1992).]

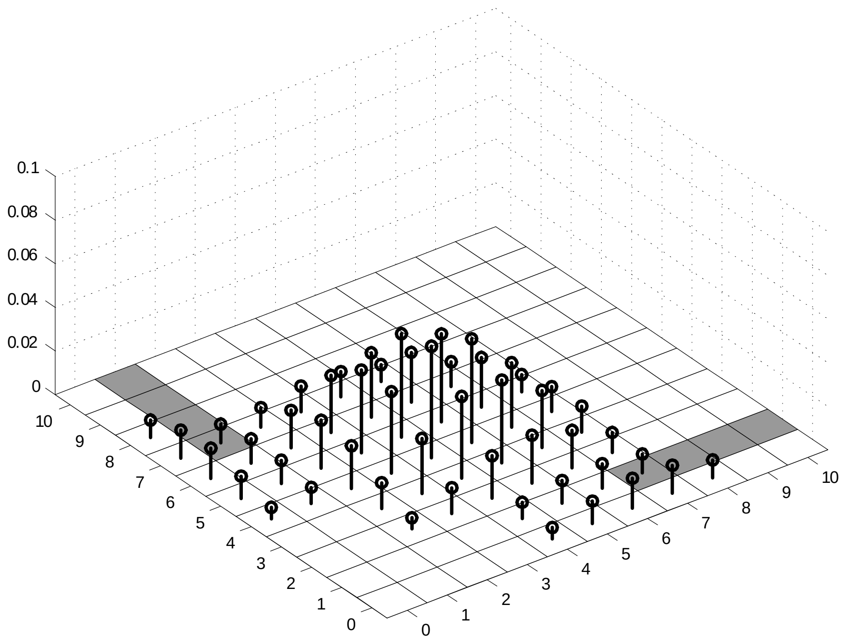

Figure 21: The figure shows the steady state distribution of the equilibrium generated by the optimal commitment policy (AV and CV criteria) in the intermediate market. The height of each pin indicates the steady probability of that state. Cells in which mergers are proposed and approved are darkly shaded.

less time in a monopoly state (at the static competition stage) with the optimal commitment policy than under the no-mergers policy (14.3% vs. 18.6%), and capital levels are higher (8.17 vs. 7.98). The reason there is less monopoly is that the prospect of merger induces entrants to invest, but the limited set of states in which mergers are allowed results in the industry often moving to symmetric duopoly positions following these investments. Indeed, the probability that the industry is in a monopoly state after five periods starting from state $(5, 0)$ is much lower than under the no-mergers policy: it is 0.45 vs. 0.84. The greater movement to symmetric, duopolistic states from monopoly ones can also be seen by comparing Figure 24 to Figure 5.

The greater permissiveness of the commitment policy compared to the no-mergers policy increases average AV because of this shift in the steady state distribution toward more symmetric duopoly states. As a general matter aggregate value falls in some states because of allowing these mergers and rises in others (it particulartly falls in monopoly states, because of its encouragement of entry for buyout). Were the distribution over states not to change, these changes in the value function would lead average aggregate value to fall from 117.5 to 116.9; the change in the steady state distribution, however, raises average aggregate value to 118.1.

While full commitment to policy may be difficult to achieve, an alternative is to endow the antitrust authority with an objective that may not be the true social objective. In this regard, note that the steady-state level of AV under the Markov perfect merger policy when the antitrust authority has a CV objective is higher than that when it has an AV objective. Thus, when the antitrust authority cannot commit, a CV-focused antitrust authority is better for AV in this market than an AV-focused authority. This is consistent with a suggestion of

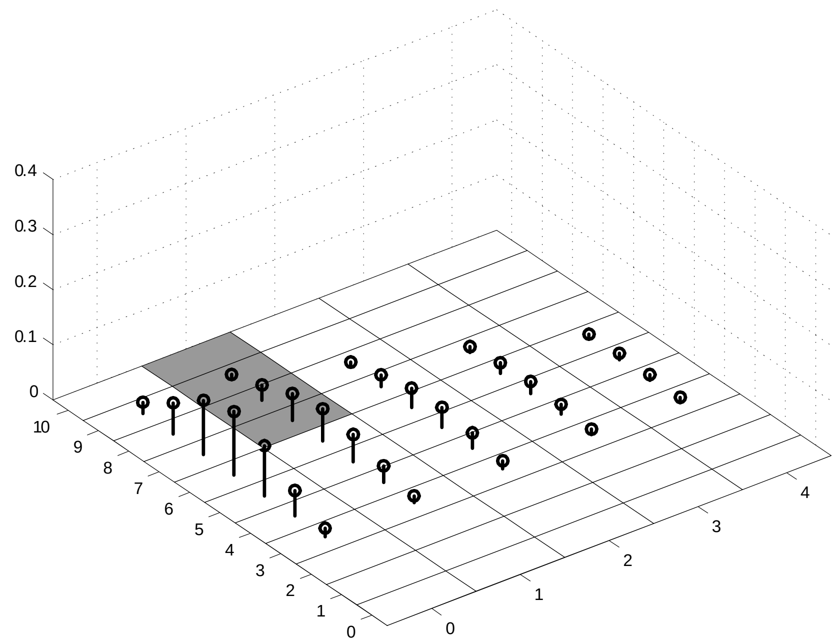

Figure 22: The figure shows the five-period transitions from state (5,0) under the optimal commitment policy. The height of each pin indicates the probability of the industry being in that state. Cells in which mergers are proposed and approved are darkly shaded.

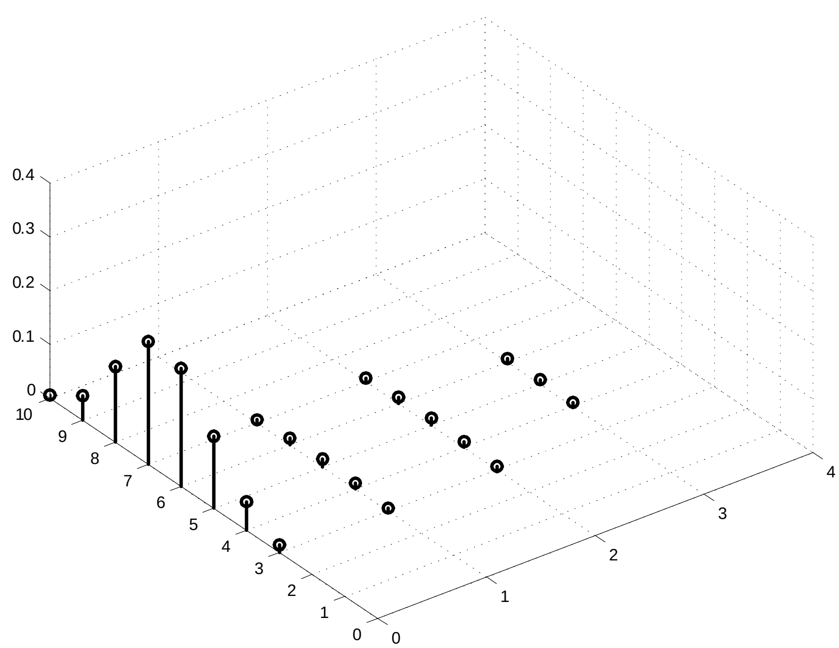

Figure 23: The figure shows the five-period transitions from state (5,0) under the no- mergers policy. The height of each pin indicates the probability of the industry being in that state.

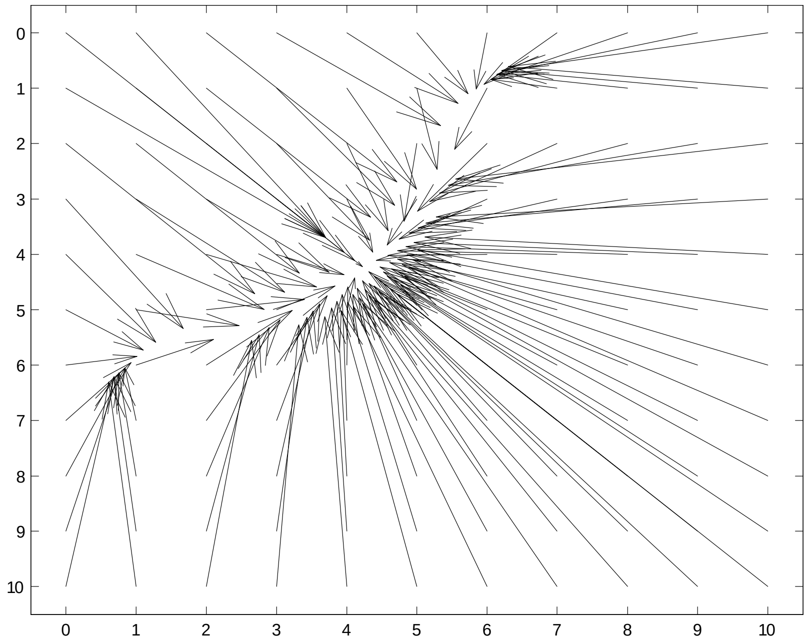

Figure 24: Arrows show the expected transitions over 5 periods in the optimal commitment policy.

Lyons (2002), but arises because of the policy's effect on investment, rather than inducing more desirable merger proposals.

5.5 Merger Policy in the Small and Large Markets

In this subsection, we describe our results for the optimal merger policy in the small and large markets, and compare them to our results for the intermediate market.

The static welfare effects of mergers are very similar in the three markets: in all of them only a merger in state $(1, 1)$ increases static consumer surplus, and in all of them, a merger in state (K_1, K_2) increases static aggregate surplus unless both K_1 and K_2 are "large," with the set of statically aggregate surplus-increasing mergers being larger in larger markets. Figure 25 shows the set of aggregate surplus-increasing mergers in the small and large markets.

As in the intermediate market, if the antitrust authority pursues a CV goal and cannot commit, the Markov perfect merger policies in the small and large markets are essentially equivalent to the no-mergers policy. [In the large market, the authority would approve mergers in states $(1, 1)$, $(2, 1)$, and $(1, 2)$ but such mergers are not dynamically profitable and therefore never proposed.]

When the antitrust authority pursues instead an AV goal, the Markov perfect merger policy again results in mergers only in monopoly or near-monopoly states in which the incumbent is sufficiently large. The larger the market, the more restrictive is the antitrust authority in equilibrium. Figures 26 and 27 show the steady state distribution and probabilities that a

(a)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	-	-	-	-	-	-	-	-	-	-	-
k1=1	-	1.5	1.4	1.1	1.0	0.8	0.7	0.6	0.5	0.4	0.4
k1=2	-	1.4	1.3	1.1	0.8	0.6	0.5	0.4	0.3	0.2	0.1
k1=3	-	1.1	1.1	0.8	0.5	0.3	0.1	(0.0)	(0.1)	(0.2)	(0.3)
k1=4	-	1.0	0.8	0.5	0.2	(0.0)	(0.3)	(0.4)	(0.5)	(0.6)	(0.7)
k1=5	-	0.8	0.6	0.3	(0.0)	(0.3)	(0.6)	(0.7)	(0.9)	(1.0)	(1.1)
k1=6	-	0.7	0.5	0.1	(0.3)	(0.6)	(0.8)	(1.0)	(1.2)	(1.3)	(1.4)
k1=7	-	0.6	0.4	(0.0)	(0.4)	(0.7)	(1.0)	(1.3)	(1.4)	(1.6)	(1.7)
k1=8	-	0.5	0.3	(0.1)	(0.5)	(0.9)	(1.2)	(1.4)	(1.7)	(1.8)	(2.0)
k1=9	-	0.4	0.2	(0.2)	(0.6)	(1.0)	(1.3)	(1.6)	(1.8)	(2.0)	(2.2)
k1=10	-	0.4	0.1	(0.3)	(0.7)	(1.1)	(1.4)	(1.7)	(2.0)	(2.2)	(2.3)

(b)	k2=0	k2=1	k2=2	k2=3	k2=4	k2=5	k2=6	k2=7	k2=8	k2=9	k2=10
k1=0	-	-	-	-	-	-	-	-	-	-	-
k1=1	-	1.8	1.9	1.7	1.4	1.2	1.1	1.0	0.8	0.8	0.7
k1=2	-	1.9	2.0	1.8	1.5	1.3	1.1	0.9	0.8	0.6	0.6
k1=3	-	1.7	1.8	1.5	1.2	1.0	0.7	0.5	0.4	0.3	0.2
k1=4	-	1.4	1.5	1.2	0.9	0.6	0.4	0.1	(0.0)	(0.2)	(0.3)
k1=5	-	1.2	1.3	1.0	0.6	0.3	0.0	(0.2)	(0.4)	(0.6)	(0.7)
k1=6	-	1.1	1.1	0.7	0.4	0.0	(0.3)	(0.6)	(0.8)	(1.0)	(1.1)
k1=7	-	1.0	0.9	0.5	0.1	(0.2)	(0.6)	(0.8)	(1.1)	(1.3)	(1.5)
k1=8	-	0.8	0.8	0.4	(0.0)	(0.4)	(0.8)	(1.1)	(1.3)	(1.6)	(1.8)
k1=9	-	0.8	0.6	0.3	(0.2)	(0.6)	(1.0)	(1.3)	(1.6)	(1.8)	(2.0)
k1=10	-	0.7	0.6	0.2	(0.3)	(0.7)	(1.1)	(1.5)	(1.8)	(2.0)	(2.2)

Figure 25: Static change in aggregate surplus for (a) the small market and (b) the large market.

merger happens in the two markets[20], while Tables 8 and 9 provide some summary statistics of these equilibria. The average merger probability is 30.6% in the small market, but only 3.0% in the large market (versus 16.1% in the intermediate market). In the small market the industry is almost always (98.6% of the time) in a monopoly state at the time of static competition, compared to 49.4% in the intermediate market, and only 8.2% in the large market. Just as in the intermediate market, absent commitment, the optimal merger policy of a CV-oriented authority induces a higher value of AV than that of an AV-oriented authority: the respective AV values are 89.6 vs. 87.9 in the small market and 142.3 vs. 141.3 in the large market.

[20] As before, states in which a merger is not allowed are unshaded, while states in which mergers would be allowed with positive probability but are never proposed have the lightest shade of gray.

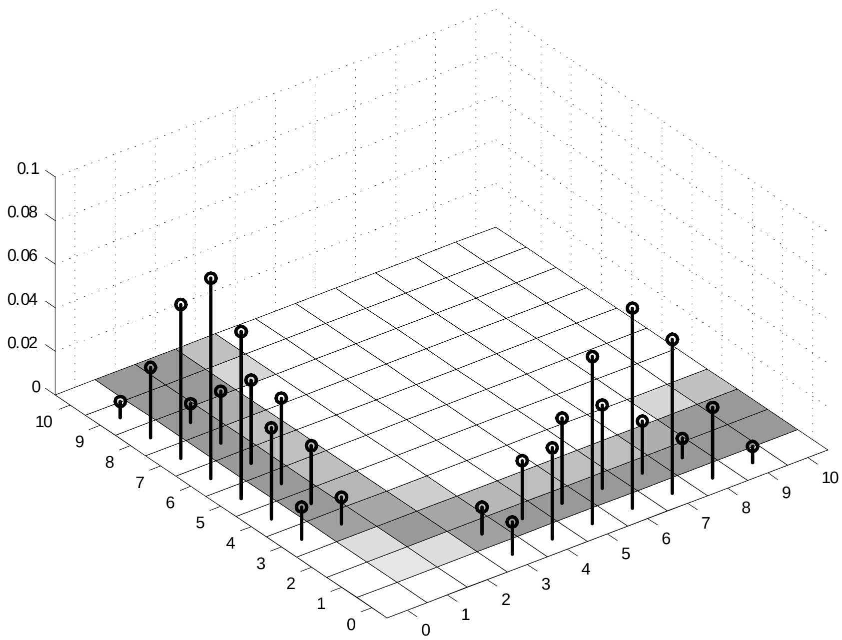

Figure 26: The figure shows the steady state distribution of the equilibrium generated by the Markov perfect policy (AV criterion) in the small market. The height of each pin indicates the steady probability of that state. The shading of the cell reflects the probability of a merger happening (with a darker grey representing a higher probability).

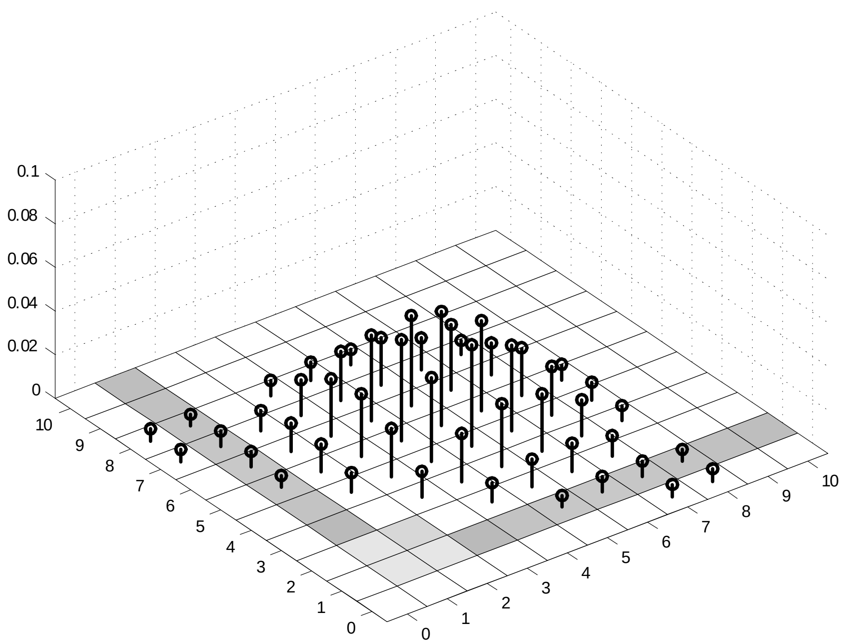

Figure 27: The figure shows the steady state distribution of the equilibrium generated by the Markov perfect policy (AV criterion) in the large market. The height of each pin indicates the steady probability of that state. The shading of the cell reflects the probability of a merger happening (with a darker grey representing a higher probability).

Table 8: Steady State Averages for the Small Market under Various Policies				
Performance measure	*Commitment AV*	*Commitment CV*	*MP-AV*	*No Mergers/MP-CV*
Consumer value	32.9	33.2	29.1	31.8
Incumbent value	61.0	57.8	58.0	57.8
Entrant value	0.0	0.1	0.8	0.0
Blocking cost	0.0	0.0	0.0	0.0
AV	94.0	91.1	87.9	89.6
Price	2.23	2.23	2.28	2.25
Quantity	16.9	16.9	15.9	16.5
Total capital	6.56	6.23	5.98	5.79
Merger frequency	6.8%	11.6%	30.6%	0.0%
% in monopoly	68.6%	60.8%	98.6%	58.2%
% $\min\{K_1, K_2\} \geq 2$	17.4%	32.3%	0.3%	35.9%

Table 9: Steady State Averages for the Large Market under Various Policies				
Performance measure	*Commitment AV*	*Commitment CV*	*MP-AV*	*No Mergers/MP-CV*
Consumer value	61.4	61.4	60.1	61.3
Incumbent value	81.1	80.8	81.1	81.0
Entrant value	0.0	0.0	0.1	0.0
Blocking cost	0.0	0.0	-0.1	0.0
AV	142.5	142.3	141.3	142.3
Price	2.10	2.10	2.11	2.10
Quantity	27.0	27.0	26.7	27.0
Total capital	9.60	9.58	9.49	9.58
Merger frequency	0.0%	0.1%	3.0%	0.0%
% in monopoly	2.3%	1.1%	8.2%	2.3%
% $\min\{K_1, K_2\} \geq 2$	94.5%	95.5%	87.9%	94.4%

If the antitrust authority can commit to its policy and pursues a CV goal, in all three markets mergers are approved only in near-monopoly states in which the incumbent is sufficiently large. This policy is more restrictive the larger is the market, with the merger probabilities ranging from 0.1% in the large market to 11.6% in the small market. Figures 28 and 29 show the steady state distributions and optimal merger policy for the small and large markets.

If the antitrust authority can commit to its policy and pursues an AV goal instead, it essentially does not approve any mergers in the large market, whereas in the small market it does approve mergers in states in which both firms are sufficiently large (resulting in a merger probability of 6.8%), which boosts firms' investment incentives (resulting in an almost 10% higher capital level compared to the MP-AV policy). Figures 30 and 31 show the steady state distributions and optimal merger policy for the two markets. Observe that the optimal commitment policy is more restrictive in larger markets even though the set of states in which mergers increase static aggregate surplus is larger in larger markets.

Independently of whether the authority pursues a CV or AV objective, the advantage that commitment has over no commitment is decreasing (both in absolute as well as in relative terms) with the size of the market. For example, compared to the AV-maximizing Markov

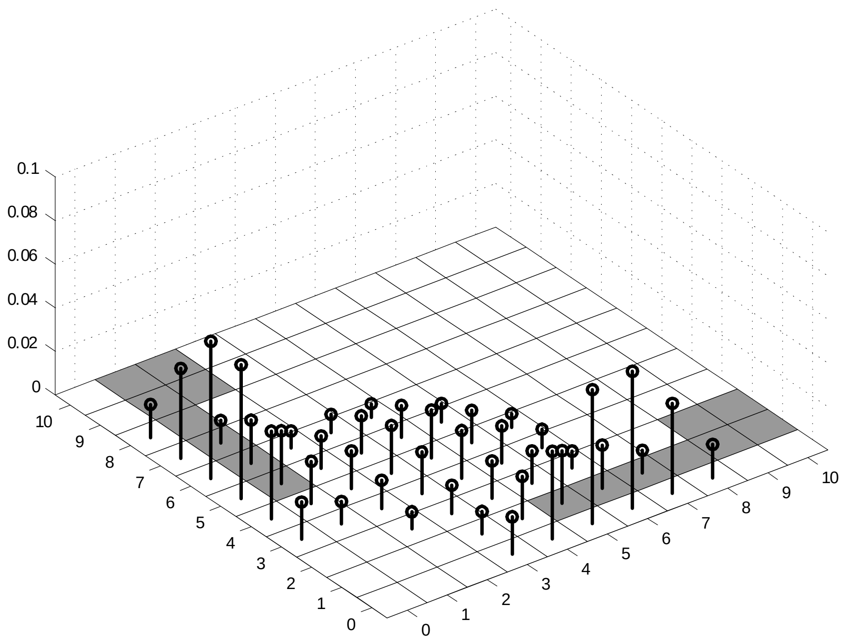

Figure 28: The figure shows the steady state distribution of the equilibrium generated by the best commitment policy (CV criterion) in the small market. The height of each pin indicates the steady probability of that state. The shading of the cell reflects the probability of a merger happening (with a darker grey representing a higher probability).

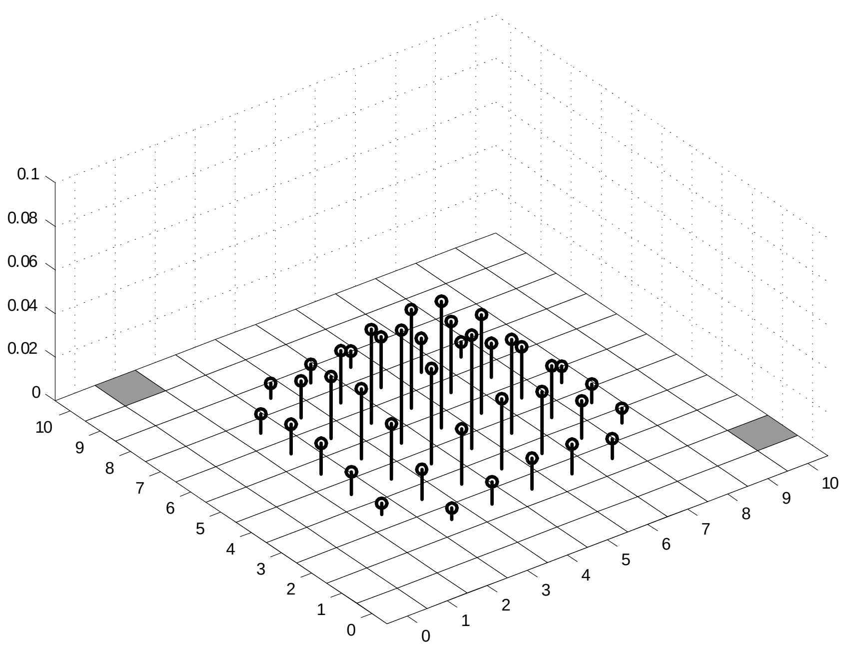

Figure 29: The figure shows the steady state distribution of the equilibrium generated by the best commitment policy (CV criterion) in the large market. The height of each pin indicates the steady probability of that state. The shading of the cell reflects the probability of a merger happening (with a darker grey representing a higher probability).

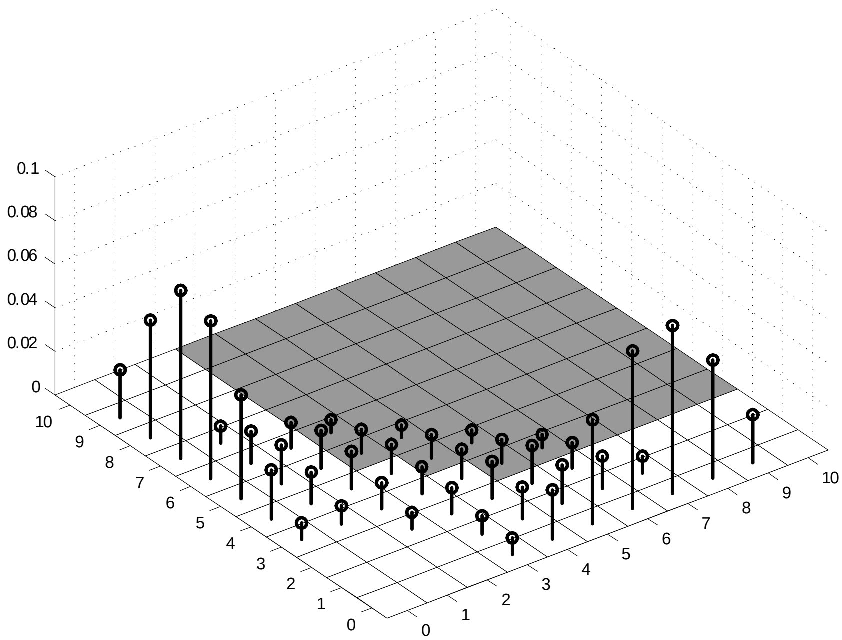

Figure 30: The figure shows the steady state distribution of the equilibrium generated by the best commitment policy (AV criterion) in the small market. The height of each pin indicates the steady probability of that state. The shading of the cell reflects the probability of a merger happening (with a darker grey representing a higher probability).

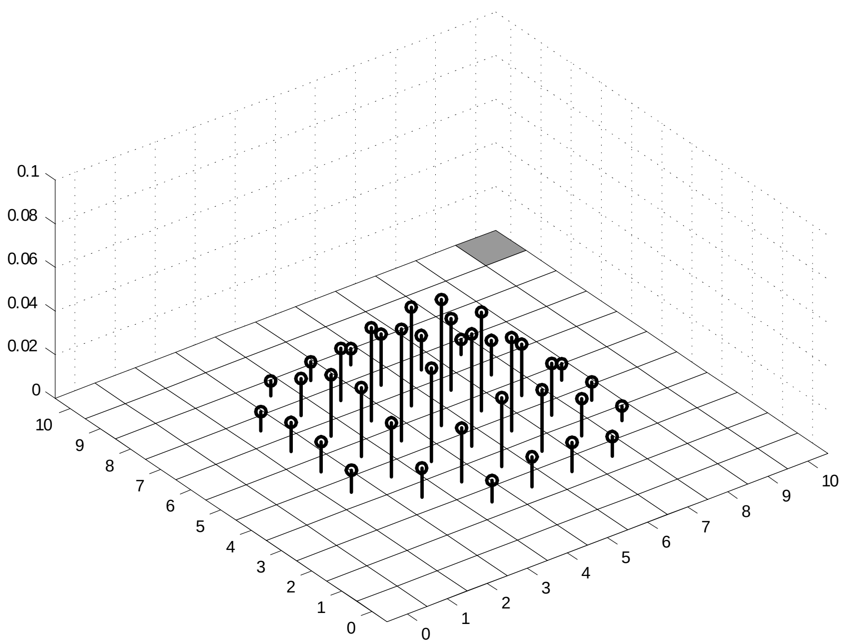

Figure 31: The figure shows the steady state distribution of the equilibrium generated by the best commitment policy (AV criterion) in the large market. The height of each pin indicates the steady probability of that state. The shading of the cell reflects the probability of a merger happening (with a darker grey representing a higher probability).

perfect policy, the AV-maximizing commitment policy induces an average AV that is 6.7% higher in the small market but only 0.8% higher in the large market.

6 Merger Policy vs. Regulation: The Planner's Solution

In this subsection, we consider the solution to the "second-best problem" where the planner controls not only firms' merger decisions but also their investment decisions, taking as given firms' static competition. We also ask whether a simple regulatory solution – namely, a franchised monopoly – may do better than merger policy. In our analysis, we confine attention to the intermediate market and the AV criterion.[21]

Our analysis above has revealed that the optimal merger policy in the intermediate market with commitment approves mergers only in monopoly (or near-monopoly) states in which the incumbent is very large. This is even though in many more states a merger raises static aggregate surplus. As we have seen, the reason why the optimal commitment policy is so restrictive is that a more permissive policy would lead to adverse effects on investment incentives, and in particular inefficient entry for buyout. This raises the question of which mergers an AV-maximizing social planner would approve if he could control not only mergers (independently of their private profitability) but also firms' investment decisions (assuming the planner has perfect information about firms' private cost draws), taking as given only that, in every period, firms compete in a Cournot fashion at stage 5. Figure 32 shows the solution to this second-best problem: the height of each pin gives the probability of the corresponding state in the steady state generated by this policy; the cells in which mergers are approved are darkly shaded. Two comments are in order. First, as the planner controls not only merger decisions but also firms' investment decisions, the planner does not face a time inconsistency problem; that is, the solution is independent of whether or not the planner can commit to his future decisions. Second, the existence of blocking costs is irrelevant for the solution to the second-best problem as it can never be optimal from the planner's point of view to propose a merger and subsequently block it in the event blocking costs are sufficiently low.

As Figure 32 shows, in the steady state generated by the planner's solution, the industry is always in a monopoly state. A merger is implemented in many states, unless these states involve high capital levels for both firms. In fact, the states in which mergers happen is almost identical to the set of states in which a merger is statically aggregate surplus-increasing (for reasons that will be discussed below). Table 10 summarizes various performance measures of the planner's solution. As can be seen from that table, the planner's solution does quite a bit better in terms of AV than the optimal merger policy with commitment (121.3 vs. 118.1). It does serve consumers very badly, however; worse in fact than even the Markov perfect merger policy (39.2 vs. 43.3), despite a higher average capital level (8.08 vs. 7.65). The reason behind this is, of course, the monopolist's market power which leads to low output (20.1, compared to 21.0 under the MP-AV policy, and 22.5 under the optimal merger policy with commitment).

The fact that, under the second-best solution, the industry is always in a monopoly state may be surprising at first: after all, when mergers are not allowed the industry seems to be a workable duopoly, and in the equilibrium generated by the optimal merger policy with

[21] Similar conclusions hold for the small and large markets.

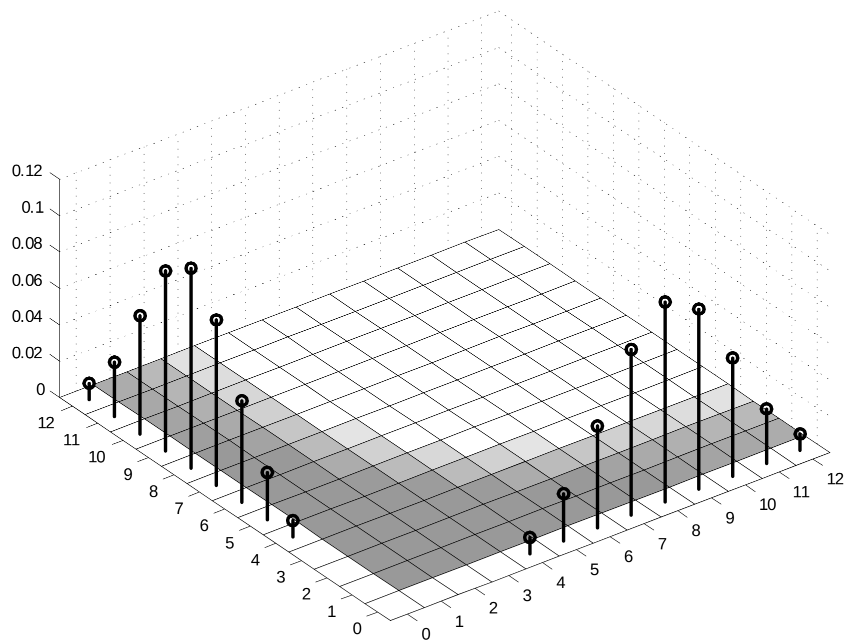

Figure 32: The figure shows the solution to the planner's second-best poblem (AV criterion) in the intermediate market. The height of each pin gives the probability of the corresponding state in the steady state generated by the planner's optimal policy. The shading of the cells indicates the merger probabilities, with a darker shading corresponding to a higher merger probability.

commitment, the industry spends only 14.3% of the time in a monopoly state. To understand this, suppose first that the planner could not only control mergers but also costlessly undo previously approved mergers, and suppose also that there were no merger proposal costs. What would the planner's optimal policy be in that case? In any state (K_1, K_2), the planner would optimally implement a merger if and only if the merger increases static aggregate surplus as this is statically optimal and also does not impede dynamic optimality as the planner controls investment and undoing a previously approved merger is assumed to be costless. Now, we have seen before that a merger increases static aggregate surplus whenever aggregate capital, $K_1 + K_2$, is not more than 9 (and sometimes even when $K_1 + K_2 > 9$). So, unless the planner wants to be in states with more than 9 units of capital, the steady state generated by the planner's policy will visit only monopoly states even if the planner cannot undo previously approved mergers and there are proposal costs — which is what is going on here. [In the steady state generated by the planner's solution, the industry is sometimes (21.4% of the time) in a monopoly state with more than 9 units of capital: the frequencies are 13.1% for state $(10, 0)$ and 6.1% for state $(11, 0)$. But recall from Figure 14(b) that there are many states with aggregate capital levels above 9 units in which a merger increases static aggregate surplus.] Note that this reasoning also explains why the set of states in which the planner implements mergers almost coincides with the set of statically aggregate surplus-increasing mergers. They do not coincide fully because of the presence of merger proposal costs, which the static criterion does not take into account.

Table 10: Steady State Averages for the Intermediate Market under Various Policies

Performance measure	*Franchised Monopoly*	*Planner*	*Commitment (CV and AV)*	*MP-AV*	*MP-CV*
Consumer value	28.0	39.2	49.3	43.3	48.1
Incumbent value	90.5	82.1	68.8	69.9	69.4
Entrant value	0.0	0.0	0.0	0.5	0.0
Blocking cost	0.0	0.0	0.0	-0.1	0.0
AV	118.6	121.3	118.1	113.6	117.5
Price	2.35	2.23	2.14	2.19	2.15
Quantity	16.9	20.1	22.5	21.0	22.2
Total capital	5.28	8.08	8.17	7.65	7.98
Merger frequency	0.0%	0.0%	3.0%	16.1%	0.0%
% in monopoly	100%	100%	14.3%	49.4%	18.6%
% $\min\{K_1, K_2\} \geq 2$	0.0%	0.0%	78.8%	44.2%	75.7%

In practice, it may be difficult, however, to directly control firms' investments. The facts that the planner's solution always results in a monopoly and that entry for buyout behavior creates losses suggests that a franchised monopoly might perform well without any need for antitrust policy. Figure 33 depicts the steady state distribution of such a franchised monopoly. The corresponding performance measures are summarized in Table 10.

In terms of AV, the franchised monopoly performs well (perhaps surprisingly so), slightly better in fact than the optimal merger policy with commitment: the average AV level is 118.6 (vs. 118.1 for the best merger policy). However, the franchised monopoly serves consumers very

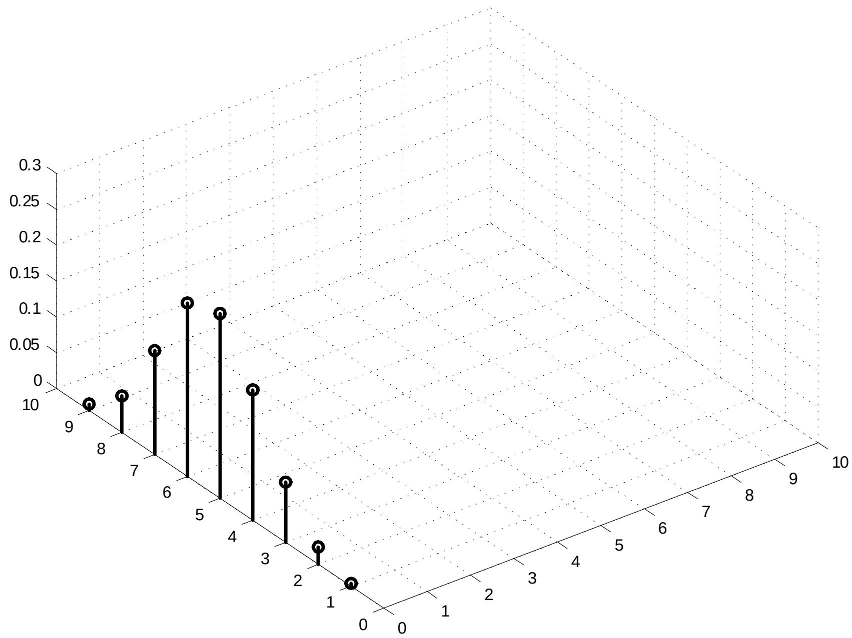

Figure 33: The figure shows the steady state distribution of a franchised monopoly in the intermediate market.

poorly: the average CV level is only 28.0, compared to 49.3 for the optimal merger policy with commitment, 43.3 for the MPP-AV policy, and 48.1 for the MPP-CV policy (corresponding to the no-mergers policy). This is in part because of the standard static monopoly distortion which results in too low output levels, given the short-run cost function. But this is also because the franchised monopoly induces very low capital levels: the average capital level is only 5.28, compared to 8.17 for the optimal merger policy with commitment. In the absence of competition, or the threat thereof, the monopolist does not have much incentive to invest, and lives a very quiet life.

So, if the social planner puts more weight on consumer value than on producer value, a franchised monopoly is likely to be dominated by a duopoly with a merger policy.

7 Extensions and Robustness

7.1 Entrant Investment Efficiency

In our analysis of the welfare effects of various merger policies, "entry for buyout" plays a prominent role. When mergers are allowed a new entrant's private benefit from investment significantly exceed the aggregate benefit of those investments, even while the aggregate benefit of the incumbent's investment exceeds its private benefit. As a result, the entrant invests too much and the incumbent invests too little. The entrant's high cost greenfield investment substitutes for the incumbent's lower cost investment done through capital augmentation and directly causes waste.

In practice, however, entrants' investments are not always less efficient than incumbents' investments, and may even be more efficient [Henderson (1993)]. In this section, we explore this point by changing the model's parameters to close the gap between the investment costs faced by small and large firms. We examine whether with these changes the inefficiencies caused by entry for buyout are largely eliminated by studying the effect of a change in policy from no-mergers to all-mergers-allowed.

Recall that capital augmentation each period enables a firm with K units of capital, if it wishes, to double each of those units at cost c_j drawn independently and uniformly from the interval $[\underline{c}, \bar{c}]$. If it wants to more than double its current stock of capital, then it can purchase additional greenfield units at constant unit cost c_g where c_g is uniformly drawn from $[\bar{c}, \bar{c}_g]$. Let $s = \bar{c} - \underline{c}$ and $s_g = \bar{c}_g - \bar{c}$ be the spread of capital augmentation costs and greenfield costs respectively. In the baseline industry analyzed in the previous sections the values are $\underline{c} = 3, \bar{c} = 6$, $\bar{c}_g = 7$, $s = 3$, and $s_g = 1$. To close the gap between entrant and incumbent investment costs we reduce s to 1 and s_g to 0.25. Since this change would otherwise reduce firms' investment costs, leading to less monopoly and very different merger behavior, we simultaneously raise $\underline{c}$ to a level that keeps the frequency of monopoly unchanged when no mergers are allowed. For example, in the intermediate market we increase $\underline{c}$ to 5.645, which keeps the frequency of monopoly at 18.6%.

Figure 34 shows results of this change in the small, intermediate, and large markets. The figure shows the same steady state performance measures as before, as well as several additional measures: "Inv Inc of Merger" reports the probability the industry is in a state in which $\partial\Delta_G(K_i, K_{-i})/\partial K_i$ is positive, "Inv Distortion All" is the average excess incentive to invest (using the steady state distribution), and "Inv Distortion Small" is the average excess incentive to invest by the smaller firm conditional on being in an asymmetric state, and "Mon$\longrightarrow$Merg Time" is the expected number of periods the industry takes to transit from a monopoly state to a state in which the incumbents merge.[22] Low values of this last measure indicates the quick entry followed by merger that is characteristic of entry for buyout.

Changing the policy from no-mergers to all-mergers-allowed induces almost identical entry for buyout behavior as earlier: the expected time from a monopoly state to the next merger is 2.1 periods when $s = 1$ and $s_g = 0.25$ compared to 2.6 periods when $s = 3$ and $s_g = 1$. The welfare effect of this behavior, however, changes radically when we reduce s from 3 to 1. In the baseline case with $s = 3$ and $s_g = 1$, when we allow all mergers aggregate value falls from 117.5 to 105.8, consumer value falls from 48.1 to 35.8, and producer value falls from 69.4 to 68.1. These large decreases contrast with the welfare effects of allowing all mergers when $s = 1$ and $s_g = 0.25$: aggregate value now falls from 87.9 to 87.4, consumer value falls from 34.9 to 30.5, and producer value increases from 53.1 to 54.9. This pattern is repeated in both the small and large markets, although in the small market aggregate value actually rises when all mergers are allowed. This shows that narrowing the investment cost differences between incumbents and entrants cause the welfare costs of entry for buyout behavior to decrease substantially.

[22] This uses the steady state distribution over monopoly states, and excludes state $(0, 0)$.

Small Market B = 22

	s = 3, $\underline{c}$ = 3			s = 1, $\underline{c}$ =5.501		
	No M	All M	MPP	No M	All M	MPP
Consumer Value	31.8	28.8	29.1	24.4	24.4	24.4
Incumbent Value	57.8	56.3	58.0	45.8	44.7	44.7
Aggregate Value	89.6	86.2	87.9	70.2	71.1	71.0
Price	2.45	2.47	2.39	2.34	2.34	2.34
Quantity	16.5	15.8	15.9	14.4	14.6	14.6
Merger Freq	0.0%	33.9%	30.6%	0.0%	46.3%	46.4%
Inv Inc of Merger	92.4%	100.0%	100.0%	72.7%	100.0%	100.0%
Monopoly Freq	58.2%	95.2%	98.6%	58.7%	79.9%	79.9%
K ≥ 2 Duopoly Freq	35.9%	0.1%	0.3%	31.2%	1.3%	1.2%
Ave Capital	5.8	5.9	6.0	4.3	4.7	4.7
Mon → Merg Time	10000.0	2.8	3.1	10000.0	2.0	2.0
Inv Distort All	0.6	1.2	0.9	0.5	0.0	0.0
Inv Distort Small	2.3	3.4	3.0	2.1	1.1	1.1

Intermediate Market: B = 26

	s = 3, $\underline{c}$ = 3			s = 1, $\underline{c}$ =5.645		
	No M	All M	MPP	No M	All M	MPP
Consumer Value	48.1	35.8	43.3	34.9	30.5	30.5
Incumbent Value	69.4	68.1	69.9	53.1	54.9	54.9
Aggregate Value	117.5	105.8	113.6	87.9	87.4	87.4
Price	2.26	2.36	2.19	2.14	2.20	2.20
Quantity	22.2	19.2	21.0	18.9	17.7	17.7
Merger Freq	0.0%	37.7%	16.1%	0.0%	42.6%	42.6%
Inv Inc of Merger	97.5%	100.0%	99.8%	86.5%	100.0%	100.0%
Monopoly Freq	18.6%	86.0%	49.4%	18.6%	79.4%	79.4%
K ≥ 2 Duopoly Freq	75.7%	0.9%	44.2%	68.6%	4.2%	4.2%
Ave Capital	8.0	7.0	7.7	5.6	5.7	5.7
Mon → Merg Time	10000.0	2.6	6.1	10000.0	2.1	2.1
Inv Distort All	0.1	1.2	0.1	0.0	0.1	0.1
Inv Distort Small	1.1	3.5	1.1	1.0	1.2	1.2

Large Market: B = 30

	s = 3, c = 3			s = 1, c =5.647		
	No M	All M	MPP	No M	All M	MPP
Consumer Value	61.3	44.1	60.1	44.1	37.4	37.4
Incumbent Value	81.0	80.8	81.1	62.0	65.2	65.2
Aggregate Value	142.3	127.2	141.3	106.1	105.4	105.3
Price	2.10	2.24	1.97	1.96	2.04	2.04
Quantity	27.0	22.9	26.7	22.8	21.1	21.1
Merger Freq	0.0%	33.6%	3.0%	0.0%	43.3%	43.2%
Inv Inc of Merger	100.0%	100.0%	100.0%	99.4%	100.0%	99.6%
Monopoly Freq	2.3%	68.4%	8.2%	2.3%	71.6%	71.4%
K ≥ 2 Duopoly Freq	94.4%	3.8%	87.9%	89.1%	10.1%	10.2%
Ave Capital	9.6	8.3	9.5	6.6	6.7	6.7
Mon → Merg Time	10000.0	3.0	33.9	10000.0	2.1	2.1
Inv Distort All	-0.3	1.2	-0.3	-0.4	0.1	0.1
Inv Distort Small	0.0	3.4	0.1	-0.1	1.1	1.1

Figure 34: Equilibrium metrics as s and $\underline{c}$ vary keeping the monopoly frequency when no mergers are allowed constant.

7.2 Entry

A key restriction in our model is that no more than two firms can be active at any one time. Throughout this restriction has been posed exogenously. Our baseline assumption is that the entering firm after a merger is owned by an entrepreneur who has never before been active within the industry. This assumption begs the question as to why he did not enter previously before the merger took place. A more satisfactory model would allow free entry with entry stopping only when the value of the potential entrant becomes negative. Implementing this creates two difficulties. With three or more active firms a merger between two of them may have positive externalities on one or more of the non-merging firms. A satisfactory model of bargaining with positive externalities and three or more principals has not yet been developed to our knowledge. Moreover, if one were developed, equilibrium behavior would almost certainly involve delay. That would create the additional difficulty of a second time scale within our model. Currently with a discount factor of $\delta = 0.8$ periods are on the order of five years. This is reasonable for a capital intensive industry that for both physical and regulatory reasons has a very long capital planning and construction cycle. This, however, is a completely unreasonable period length for a merger negotiation between two ambitious CEOs and their boards. Incorporating this second time scale into our model will necessitate some modeling and computational innovations.

An alternative to the exogenous restriction we have used is to assume that only two entrepreneurs have the necessary skill and knowledge set to compete in the industry. If that is the case and both entrepreneurs are active in the industry, then the owner/manager of the acquired firm would become the new entrant following a merger. (We assume there is not a "no-compete" clause in the acquisition agreement.) Equation (1) giving the joint value gain from merging then becomes

$$\Delta_G (K_1, K_2) \equiv \left\{ \left[\bar{V}(K_1 + K_2, 0) + \bar{V}(0, K_1 + K_2)\right] - \left[\bar{V}(K_1, K_2) + \bar{V}(K_2, K_1)\right] \right\}.$$

New to the definition is the entrant's ex ante value $\bar{V}(0, K_1 + K_2)$. It must be included because the entrepreneur who is bought out intends to re-enter. In other words, the two entrepreneurs will agree to merge—one buying out the other—if it pays them jointly to create temporarily a monopoly situation in the industry until that time the bought-out entrepreneur successfully returns to the industry. Since $\bar{V}(0, K_1 + K_2) \geq 0$ this weakly increases the merger frequency (holding the policy and value function constant). Figure 35 shows a side-by-side comparison for the intermediate market of the equilibria for these two different assumptions concerning entry. When all mergers are allowed, this change increases the frequency of mergers. (Although note that in the MP-AV policy the merger frequency ends up lower than before.) Inspection shows that, overall, our results are not qualitatively different from our earlier results.

7.3 Multiplicity of Equilibria

Dynamic games with infinite horizons generally have multiple equilibria. While we have not yet identified any points in the parameter space for which multiplicity exists, we have no reason to expect that such points do not exist. Within the context of the Pakes-Ericson-McGuire model of computable Markov perfect equilibria Besanko, Doraszelski, Kryukov, and Satterthwaite

Intermediate Market: B = 26

	New Entrant			Bought is Entrant		
	No M	All M	MPP	No M	All M	MPP
Consumer Value	48.1	35.8	43.3	48.2	35.6	45.4
Incumbent Value	69.4	68.1	69.9	69.4	68.7	69.6
Aggregate Value	117.5	105.8	113.6	117.6	104.3	115.0
Price	2.26	2.36	2.19	2.26	2.36	2.17
Quantity	22.2	19.2	21.0	22.2	19.2	21.5
Merger Freq	0.0%	37.7%	16.1%	0.0%	49.2%	11.8%
Inv Inc of Merger	97.5%	100.0%	99.8%	97.5%	100.0%	99.8%
Monopoly Freq	18.6%	86.0%	49.4%	18.3%	94.0%	35.9%
K ≥ 2 Duopoly Freq	75.7%	0.9%	44.2%	76.0%	0.1%	57.0%
Ave Capital	8.0	7.0	7.7	8.0	7.0	7.8
Mon → Merg Time	10000.0	2.6	6.1	10000.0	2.0	8.5
Inv Distort All	0.1	1.2	0.1	0.1	1.2	-0.1
Inv Distort Small	1.1	3.5	1.1	1.1	3.5	0.7

Figure 35: Equilibrium in the intermediate market under two entry assumptions. The left column shows equilibria in which entry is by an entrepreneur who is new to the industry. The right column shows equilibria in which entry is by the entrepreneur who until earlier in the period was active in the industry and agreed to be bought out.

(2010, section 3.1) developed a homotopy based method for tracing out paths on the equilibrium manifold and systematically finding points of multiple equilibria.[23] Visualize the manifold as a function of a parameter (e.g., market size on the x axis) determining some metric of the equilibrium (e.g., frequency of monopoly states on the y axis). If, as the parameter varies, the manifold folds back on itself in a "S" curve, then at all parameter values under the backward sloping portion of the S curve three equilibria are identified. The homotopy method creates a differential equation whose numerical solution step-by-small-step follows the manifold through the entire S fold. Using this technique Besanko et al. (2010) identified, for particular parameter values, as many as nine equilibria in their learning-by-doing/organizational forgetting model. Their technique, however, provides no guarantee that it will find all equilibria.

The homotopy technique depends on differentiating the equations that implicitly define the model's equilibria. This requirement makes it, as a practical manner, difficult to apply to our merger model because a key step in numerically solving for equilibria is a Monte Carlo integration. Numerically differentiating this integral with reasonable accuracy does not appear to be possible with the computing power to which we have access. Consequently we are implementing a cruder search for multiple equilibria that may fail to find cases of multiplicity that the homotopy technique would find if it were feasible.[24]

The idea is simple. Define a cube

$$D = \{(B, \underline{c}, s) | B \in [22, 30] \ \& \ \underline{c} \in [1, 6] \ \& \ s \in [1, 3]\} .$$

in our parameter space. Set all other parameters equal to their baseline values. Along lines within this cube calculate sequences of equilibria using the equilibrium values of one equilib-

[23] See Borkovsky, Doraszelski, and Kryukov (2010, 2012) for further discussion and illustration of how to use this homotopy technique.

[24] We thank Ulrich Doraszelski for suggesting this technique to us.

rium as the starting points for the next equilibrium computation. Specifically, for each $\lambda \in \{0, 0.025, 0.050, \ldots, 0.975, 1\}$, calculate equilibria along the line $(B, \underline{c}, s) \in \langle 22(1-\lambda) + 30\lambda, \underline{c},\ s\rangle$ where $\underline{c} \in \{1, 2, \ldots, 6\}$ and $s \in \{1.0, 1.5, \ldots, 3.0\}$. Start equilibrium calculations from both the $\lambda = 0$ and the $\lambda = 1$ ends of the line and use the equilibrium values calculated for a particular λ as the initial values for calculating the equilibrium at the next λ. If there is equilibrium multiplicity along the line, then the equilibrium values for a particular λ reached from the line's left end *may* not equal the equilibrium values for that same λ reached from the line's right end. This procedure checks for multiplicity along 30 lines parallel to the B axis within the parameter cube. In the same manner check for multiplicity along 25 lines parallel to the $\underline{c}$ axis and 30 lines parallel to the s axis.

Results of these intensive computations are not yet complete.

8 Conclusion

We have studied optimal merger policy in a dynamic industry model in which mergers offer the potential for cost reduction through the achievement of scale economies, but also increase market power. An antitrust authority must then weigh any potential gain in efficiency generated by the merger, over that which would be achieved by internal growth, against the losses from increased market power.

In terms of the trade-off between internal and external growth we see several things. First, the very nature of this trade-off depends on whether we are taking the perspective of an antitrust authority that cannot commit and must decide what to do about a given proposed merger, or the perspective of identifying an optimal commitment policy. From the former persective, we see that the desirability of approving a merger can indeed depend importantly on the investment behavior that will follow if it is or is not approved. However, this involves more than just the behavior of the merging firms, as the investment behavior of outsiders to the merger (here, new entrants) can have significant welfare effects. Moreover, these investment behaviors can be importantly influenced by firms' beliefs about future merger policy. From the perspective of identifying an optimal commitment policy, these potential effects on investment behavior can make the optimal commitment policy differ substantially from the policy that emerges when the antitrust authority instead considers mergers on a case-by-case basis without commitment. Moreover, in cases in which commitment is not possible and aggregate value is the true social onbjective, it can be better to endow the anttrust authority with a consumer value objective. Whether with or without commitment, however, we have found that in our model the optimal antitrust policy for maximizing aggregate value is significantly more restrictive than the optimal static policy that considers a merger's effects only at the time it would be approved.

Our model leaves a number of important research directions open. Most significant, in our minds, is the need to expand the analysis beyond the case of two active firms. This will require a model of bargaining with externalities among many parties which is tractible and offers sensible predictions.

References

[1] Berry S. and A. Pakes (1993), "Applications and Limitations of Recent Advances in Empirical Industrial Organization: Merger Analysis," *American Economic Review,* 83, 247-52.

[2] Besanko, D., U. Doraszelski, Y. Kryukov, and M. Satterthwaite. (2010). "Learning-by-Doing, Organizational Forgetting, and Industry Dynamics." *Econometrica* 78: 453-508.

[3] Besanko, D., and D.F. Spulber (1993), "Contested Mergers and Equilibrium Antitrust Policy," *Journal of Law, Economics, and Organization* 9:1-29.

[4] Borkovsky, R. N., U. Doraszelski, and Y. Kryukov. (2010). "A User's Guide to solving Dynamic Stochastic Games Using the Homotopy Method," *Operations Research* 58: 1116-32.

[5] Borkovsky, R. N., U. Doraszelski, and Y. Kryukov. (2012). "A Dynamic Quality Ladder Duopoly with Entry and Exit: Exploring the Equilibrium Correspondence Using the Homotopy Method," *Quantitative Marketing & Economics* 10: 197-229.

[6] Cheong, K.-S, and K.L. Judd (2000), "Mergers and Dynamic Oligopoly," unpublished working paper.

[7] Farrell, J. and C. Shapiro (1990), "Horizontal Mergers: An Equilibrium Analysis," *American Economic Review* 80: 107-26.

[8] Fauli-Oller, R. (2000), "Takeover Waves," *Journal of Economics and Management Strategy* 9: 189-210.

[9] Gowrisankaran, G. (1997), "Antitrust Policy Implications of a Dynamic Merger Model," unpublished working paper.

[10] Gowrisankaran, G. (1999), "A Dynamic Model of Endogenous Horizontal Mergers," *RAND Journal of Economics* 30: 56-83.

[11] Henderson, R. (1993), "Underinvestment and Incompetence as Responses to RAdical Innovation: Evidence from the Photolithographic Industry," *RAND Journal of Economics* 24: 248-70.

[12] Lyons, B. (2002), "Could Politicians be More Right than Economists? A Theory of Merger Standards," *CCR Working Paper* 02-01, University of East Anglia.

[13] McAfee, R. P. and M. A. Williams (1992), "Horizontal Mergers and Antitrust Policy," *Journal of Industrial Economics* 40: 181-7.

[14] Matsushima, N. (2001), "Horizontal Mergers and Merger Waves in a Location Model," *Australian Economic Papers* 40: 263-86.

[15] Motta, M. and H. Vasconcelos (2005) , "Efficiency Gains and Myopic Antitrust Authority in a Dynamic Merger Game," *International Journal of Industrial Organization,* 23: 777-801.

[16] Nilssen, T. and L. Sorgard (1998), "Sequential Horizontal Mergers," *European Economic Review* 42: 1683-1702.

[17] Nocke, V. and M.D. Whinston (2010), "Dynamic Merger Review," *Journal of Political Economy* 118: 1200-51.

[18] Nocke, V. and M.D. Whinston (2013), "Merger Policy with Merger Choice," *American Economic Review* 103: 1006-33.

[19] Pesendorfer, M. (2005), "Mergers Under Entry," *RAND Journal of Economics* 36: 661-79.

[20] Rasmussen, E. (1988), "Entry for Buyout," *Journal of Industrial Economics* 36: 281-300.

[21] Williamson, O.E. (1968), "Economies as an Antitrust Defense: The Welfare Tradeoffs," *American Economic Review* 58: 18-36.