Horizontal Mergers and Innovation in Concentrated Industries

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Abstract

An open question in antitrust economics is whether allowing rival firms to merge increases or decreases incentives to invest and innovate? I examine this in a dynamic oligopoly model with endogenous investment, entry, exit and horizontal mergers. Firms produce differentiated goods and may merge with rival firms to gain market power and increase the quality of their product. I extend previous work on dynamic mergers by allowing for differentiated goods with competition in prices, more than 2 firms in the market, and an endogenous long run rate of innovation. In equilibrium, horizontal mergers are mostly harmful to consumers in the short run, but the prospect of a buyout creates a powerful incentive for firms to enter the industry and invest to make themselves an attractive merger partner. The result is significantly higher total innovation with mergers than without and significantly higher long-run consumer welfare as well. This result also helps shed light on the larger question of the relationship between the competition and innovation. Further results show that long run welfare is increased most by mergers in industries with low consumer switching costs or brand loyalty, as well as in industries where large and rapid innovation is possible.

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1 Introduction

In a concentrated industry, does allowing rival firms to merge increase or decrease investment and innovation? Antitrust authorities increasingly deal with industries characterized by high levels of investment and rapid changes in firm market share and product quality resulting from innovations produced by this investment.[1] For these industries, the effects of a merger on dynamic considerations such as investment, entry and exit are large relative to the standard considerations of market power and price increases when determining the merger's likely effect on consumer welfare. The relationship between industry concentration and innovation is itself complex and non-monotonic.[2] Furthermore, few things matter more for consumer welfare than the long run rate of innovation, and its determinant is a central question in economics. Nevertheless, the relationship between horizontal mergers and innovation remains poorly understood.

Following recent work by Mermelstein et al. (2014), who study optimal merger policy in a 2 firm model of dynamic, endogenous mergers and capital investment, I adopt a similar investment technology, described in more detail below, but study a model with a number of features that are better suited to the study of innovative industries. First, I allow for more than 2 firms and hence mergers that do not result in monopoly, a practice rarely allowed under current policy. Second, instead of firms producing homogenous goods and competing by setting quantity, firms produce differentiated goods and compete in prices. Third, the role of mergers is not to reduce production costs but to improve product quality. Finally, I alter the investment technology to allow for an endogenous and variable long run rate of innovation.

Mergers between rival firms may affect investment incentives in several ways. Investment typically imposes a negative externality on the industry, as some portion of the gains from a successful innovation come from stealing business from rival firms. By merging, firms will internalize this effect and reduce their investment accordingly. Firms may also buy out a smaller rival to acquire its new innovation, and so use the merger as a substitute for

[1] Katz and Shelanski (2006) and Gilbert (2006) discuss the increasing importance of innovation in merger analysis. The 2010 Horizontal Merger Guidelines introduced a section dealing with innovation, and in the years 2013-2015, the Department of Justice challenged mergers in part due to concerns about innovation incentives in the chemicals industry, online platforms, online display advertising, computer circuits, aircraft components and beer. For more see the Annual Report on Competition Policy Developments in the United States for those years, jointly produced by the DOJ and FTC.

[2] A long literature in economics considers this topic. Notably, Aghion et al. (2005) has shown a inverted-U shaped relationship between industry concentration and innovation.

investing in the new technology itself. On the other hand, the prospect of being bought out may also encourage entry into the market by new firms, encouraging development of new products and technologies. A merger may also increase the new firm's ability to innovate via economies of scale or complementarities between the two firms' R&D capabilities. Because the relationship between mergers and innovation depends in a complex way on both pre and post-merger market structure, to determine the interplay between and relative importance of these effects requires modeling industry dynamics such as entry and investment along with endogenous mergers.

Empirical work on this question is limited and faces several challenges.[3] Instead, this paper contributes to our understanding of the impact of mergers on R&D investment by modeling a concentrated industry with fully endogenous entry, exit, quality investment and horizontal mergers. While a model combining these elements presents many challenges, it is necessary in order to consider questions regarding innovation, which is inherently dynamic.[4] Future investment, exit, and entry, along with the potential for other future mergers, can have a dramatic effect on the welfare implications and profitability of today's potential merger, and despite the complexity it entails, a dynamic model containing each of these features is necessary to consider this question.

Despite this, the dynamic effects of horizontal mergers have rarely been studied. Cheong and Judd (2006) and Chen (2009) present numerical results showing that the welfare conclusions of static models can be overturned in the long run, and that temporary increases in profits can make otherwise unprofitable mergers worthwhile. In two recent companion papers Marshall and Parra (2016a) and Marshall and Parra (2016b) modify classic patent race models to study the relationship between market structure, mergers, and innovation. In these papers a measure of firms invest in $R\&D$ to become a market leading monopolist and they explore the implications of reducing the number of firms and combing their in-

[3]Mergers are frequently a response to a larger shock to technology, preferences or regulations that would cause firms or the entire industry to expand or contract in the absence of a merger Harford (2005), for instance, shows that industry level merger waves are primarily driven by "economic, regulatory or technological shocks." In addition, mergers strongly cluster over time and industries, and both the decision to merge and the decision to invest have strong strategic components that depend on rivals' actions. These factors make finding causal evidence from pre and post-merger R&D levels very difficult. Even if a plausible instrument could be found, it is unlikely the effects of mergers induced by this instrument would be generalizable to other settings. See Nevo and Winston (2010) for more on this point. Recent attempts have been made to estimate structural models of merger dynamics, including Jeziorski (2014) in the radio industry, Igami and Uetake (2015) the hard disk drive industry, and Nishida and Yang (2014) in retail.

[4]Gowrisankaran (1999) discusses the challenges of solving a dynamic model with endogenous mergers and presents a lengthy discussion of the flaws inherent in static models and models of exogenously imposed mergers.

novation capacities, finding that mergers or reductions in product market competition can increase $R\&D$ and consumer welfare under certain conditions. Each of these consider only exogenous mergers.

Endogeneity of mergers is crucial to understand their dynamic effects because the set of future merger possibilities effects both current merger decisions and entry and investment decisions. That mergers occur in waves within industries is well documented. Despite this, very few studies have been done where mergers arise endogenously in a dynamic context. Along with Mermelstein et al. (2014), Pesendorfer (2005) and Gowrisankaran (1999) have explored this. Pesendorfer (2005) derives theoretical predictions from a Cournot model with entry, exit and mergers and finds that the standard Cournot result is overturned if firms expect the possibility of mergers in the future. Gowrisankaran (1999) models a dynamic oligopoly with capacity-constrained, homogenous goods producers. In each period, firms make sequential bids to merge with smaller firms. Because firms only merge to increase market share, investment always declines as firms internalize the investment externality and the impact on total welfare is ambiguous.

As described above, Mermelstein et al. (2014) develop a investment technology that is merger neutral and use it to study the relationship between capital investment and mergers in a two firm, homogenous good model where investment lowers production costs. They find mergers decrease long term consumer surplus as well as incumbent profits, but that antitrust policy can increase aggregate value. Along with the different modeling choices described above and the different focus on innovation, I find very different results on the relationship between mergers and consumer welfare. Despite both involving investment, building physical capital and investing in innovations to improve product quality are quite distinct and interact with mergers distinctly as well.

I proceed by embedding an endogenous merger stage game into an Ericson-Pakes style dynamic oligopoly model where firms produce differentiated goods and compete in prices. They engage in entry, exit, and invest in future product quality. In each period firms may enter merger negotiations with one another. At this time they observe a private signal of "synergy" value, reflecting the complementarities between their products. If the firms merge, in the following period they will produce a new, higher-quality product. Embedded in the model is an antitrust authority, who evaluates mergers and solves for the optimal antitrust policy. This model represents a substantial increase in realism and generality over previous

attempts to model the dynamic effects of mergers, which generally have been limited to exogenous mergers or mergers to monopoly between two firms, a practice rarely allowed in reality, while also extending the setting to differentiated goods and an endogenous rate of innovation.

I take advantage of two recent methodological advances necessary to approach this topic. First, I follow Goettler and Gordon (2014) in modifying the Pakes and McGuire (1994) framework to allow for a long run rate of innovation that is endogenous. In addition, Mermelstein et al. (2014) show that in the Pakes and McGuire (1994) framework, the industry-wide investment opportunity set is reduced by mergers, which necessarily reduce the number of firms. I adapt their investment framework which allows for rich and flexible investment patterns that are merger neutral and allow entrants to endogenously choose the quality of their product at the time of entry.

I solve numerically for Markov Perfect Equilibrium for several types of counterfactuals. In a baseline with no mergers allowed, the industry exists primarily in a state of duopoly with one firm near the technological frontier and another offering an inferior product and investing little. Entry and net innovation are rare. When mergers are allowed, they frequently arise, and there is substantially more entry. This includes firms who enter in states where their static profits are negative, because the prospect of a buyout is so lucrative. New entrants occasionally generate rapid and large innovations which make them the leading firm. As a result the rate of innovation is dramatically higher than in a setting without mergers. While most of the mergers reduce static consumer surplus and increase prices in the short term, the long term effect of allowing these anti-competitive mergers is much higher average consumer welfare as consumers benefit from the increased entry and innovation.

Next I consider what industry characteristics make this result more or less likely. Specifically, I examine the role of "contestability" as described by Shapiro (2010), meaning the degree to which firms who successfully innovate can capture higher market share as a result.[5] This could be thought of as representing consumer switching costs, brand loyalty, or the ease of distribution. I show that when contestability is high, the result is as described above, where mergers (including anti-competitive mergers) increase long-run consumer surplus. When contestability is low, however, this is no longer true. While this paper effectively argues for leniency in horizontal merger review, this result suggests greater attention

[5] Specifically, Shapiro (2010) uses the definition "The prospect of gaining or protecting profitable sales by providing greater value to customers."

should be paid by antitrust authorities to actions taken by firms which decrease contestability. These include long-term contracts and bundling requirements which increase switching costs or other practices that make it difficult for innovative products to be accessed through dominant platforms.

I also consider a related industry characteristic which I call "disruptability," reflecting how capable firms are of generating large innovations quickly, including entering firms. While contestability describes consumer preferences, disruptability describes the industry's investment and innovation technology. I show that in highly "disruptable" industries, mergers generate long-run increases in consumer surplus. In less disruptable industries the reverse is true and consumer welfare is lowered by mergers in the long run. In practice, this feature can be observed by policymakers by considering relative rates of patent filings, product life-cycles, and the underlying technology.

This paper also helps answer the larger question of what is the relationship between competition and innovation?[6] Theoretical work on this question dates back to Schumpeter (1942) and Arrow (1962). Recently, Aghion et al. (2005), suggests an inverted-U shaped relationship with low rates of innovation in highly competitive and monopolistic settings, and high innovation in intermediate settings. Goettler and Gordon (2014) find a similar result. Segal and Whinston (2007) contribute to this literature by showing in a general model that antitrust policy which protects entrant profits leads to higher innovation. They demonstrate this result for competition policy related to exclusive contracts and network externalities, I show a result for horizontal mergers that is contradictory in the sense that stricter antitrust policy slows innovation, but via a complementary mechanism. In this case, while mergers are anti-competitive, they increase the value of entry by allowing for potentially lucrative buyouts of small firms.

The rest of this paper will be organized as follows, section 2 describes the model, section 3 describes the nature of equilibrium and method of computation, and section 4 presents results.

[6]Shapiro (2010) calls this "arguably the most important question in the field of industrial organization."

2 Model

Industry dynamics are based on the Ericson and Pakes (1995) framework, in which a set of firms invest, enter, and exit endogenously in discrete time with an infinite horizon. This model and its properties and many applications are reviewed at length in Doraszelski and Pakes (2008), and will be given a shorter treatment here with more emphasis on the model's novel elements. In the model, a set of constant marginal cost firms produce differentiated goods and compete in prices. The goods differ with respect to their level of quality and firms can invest in future product quality using a stochastic R&D technology that combines features of Mermelstein et al. (2014) and Goettler and Gordon (2014). Importantly, the total set of possible investment is not necessarily reduced by a merger and the long run rate of innovation is endogenous. Each period, firms are allowed to enter merger negotiations with any other firm following a random sequence. Firms will attempt to merge if the net gain to the acquiring firm is greater than the reservation value of the acquired firm. Mergers are quality-increasing, in that the merger results in a new, higher quality product.

2.1 Incumbent Firms

Product Market Competition At any given time there are $n \leq \overline{n}$ firms active in the market, each producing a good of quality $\omega_i \in \{\omega_1, ..., \overline{\omega}_{max}\}$. This "quality" can be thought of broadly, including as a function over a bundle of characteristics. For instance, the quality of a wireless company's product is a function of its coverage network, the quality of the network, the quality and variety of handsets, the distribution network, etc. The set of firms' qualities will be referred to as $\Omega = \{\omega_1, ..., \omega_n\}$. This is public information and represents the state of the industry.

Consumer preferences are represented by $u(\cdot)$, where consumer k's utility from good i given by $u_{k,i} = \omega_i + log(y - p_i) + \epsilon_{k,i}$, where $\epsilon_{i,k}$ represents consumers' differing tastes. Each consumer purchases one unit of the product which gives them the highest utility. They may also purchase an "outside option" whose utility is normalized to 0. Following the work of McFadden (1974), if ϵ is drawn from an extreme value distribution with dispersion parameter ϕ_ϵ^{-1}, this results in the logit demand system:

$$q_i(p_1, ...p_n; \Omega) = M \frac{exp(\phi_\epsilon(\omega_i + log(y - p_i)))}{1 + \sum_j exp(\phi_\epsilon(\omega_j + log(y - p_j)))} \quad (1)$$

where $q_i(\cdot)$ is firm i's demand and M is the size of the market, or the measure of consumers. In this setting, ϕ can be thought of as the degree of horizontal differentiation in consumer preferences, such that when ϕ is high, having a higher ω than your competitor will result in a higher market share. Firms face symmetric marginal costs mc and choose prices conditional on the set of goods in the market to maximize profits, such that:

$$\pi(p_i, p_{-i}) = q_i(p_1, ..., p_n; \Omega)(p_i - mc) \tag{2}$$

Investment Firms invest in their future quality with a stochastic R&D technology. This technology follows recent work by Mermelstein, Nocke, Satterthwaite and Whinston (2014) (hereafter MNS&W.) Their key insight was to recognize that in the original Pakes and McGuire (1994) framework, mergers reduce the industry-wide investment possibility set by directly reducing the number of firms who can invest. In the MNS&W framework, the set of possible investments and investment costs are purely a function of a firm's current state ω_i. Thus, when firms merge and combine products, this action does not necessarily reduce the total set of possible investments. If the new product is $\omega_i' = \omega_i + \omega_j$, the firm's investment problem is unchanged from the pre-merger problems of both firms, except that they have been internalized. This distinction is crucial for examining the relationship between mergers and innovation, since previous investment technology mechanically generates a negative relationship.

At the beginning of each period, all firms have an opportunity to increase their product quality ω_i, which takes an integer value. Firm i draws a set of investment costs $\{c_j\}_{j=1}^{\omega_i} \in [\underline{c}, \overline{c}]$ for each unit that makes up ω_i. This is the cost of upgrading that unit by 1. MNS&W refer to this technology as *capital augmentation* although in this context it might better be thought of as *quality augmentation*. In addition, firms draw another cost, which MNS&W refer to as a *greenfield cost*, from some distribution $[\overline{c}, c_g]$. This determines the cost of product improvement for investment levels above ω_i. After observing stochastic investment costs, the investment function is deterministic. Thus, any firm can reach any greater state in each period, and firms with higher quality products are more likely to get low cost draws for some number of innovations and increase their quality. In some counterfactuals which follow, I cap the amount of innovation a firm is capable of at some level, which can be thought of as an infinite investment cost beyond that level.

As in Pakes and McGuire (1994), the industry as a whole also faces an exogenously

improving outside good. This is equivalent to reducing all firms product qualities by 1 unit, and occurs with probability δ. If firms innovate at a long-term rate greater than δ, the set of potential good qualities Ω becomes unbounded. To avoid the problems this would imply, I follow Goettler and Gordon (2014) in setting some $\overline{\omega}_{max}$ as the industry frontier. If in any period a firm innovates to a quality level $\omega_i > \overline{\omega}_{max}$, the result is that all firms experience a downward shock equal to $\omega_i - \overline{\omega}_{max}$. This keeps the frontier firm at level $\overline{\omega}_{max}$ and preserves the relative differences between the product qualities of all active firms. Because only these relative differences matter for profits, this does not effect equilibrium outcomes.[7]

Firms also face a flat, fixed operating cost FC which must be paid each period. In the beginning of each period, after observing investment costs $\{c_1, ..., c_{omega}\}$, firms choose whether to remain in business and pay FC or exit. They then choose investment level $x_i \in \{0, ..., \overline{\omega}_{max}\}$.

2.2 Merger Stage

The bulk of previous research studying the implications of horizontal mergers has examined the behavior of exogenously merged firms. This is due to the fact that, although clearly superior in many ways, modeling endogenous mergers poses a challenge. In many industries there may exist a set of profitable but mutually exclusive merger arrangements. The mergers in this set represent multiple equilibria and there is no clear equilibrium selection mechanism. The simplest solution is to model non-cooperative mergers, where firms propose buyout offers according to some defined sequence which provides a unique equilibrium in each stage.

Gowrisankaran (1999) follows this approach, embedding in an Ericson-Pakes model a stage game wherein the largest firm acts first. It has the ability to propose a merger to any other firm. If it chooses not to the second largest firm may propose, and so on. The stage game employed here is similar although the sequence by which firms may propose mergers is random. While this adds to the difficulty of solving the model, it should result in a richer pattern of outcomes.

At the beginning of each period, a firm is randomly chosen and allowed to enter merger negotiations with any other firm. Before choosing its partner, the offering firm observes a random "synergy" value for each rival firm $\sigma_{ij} \in [0, 1] \; \forall j$ which is uniform i.i.d. This

[7]When the market share of the outside option is large, absolute levels of ω, and not just relative values, do matter. Consequently, $\overline{\omega}_{max}$ is set so that the outside goods share is less than 1%. This can be thought of as a weak notion of industry technology spillovers.

represents the degree to which their products can be integrated into a new future product. The period following the merger, the new, combined firm will produce a product of quality $\omega_B + \sigma_{ij}\omega_S$, where subscripts indicate the buyer and seller. The degree of synergy might reflect the amount of overlap between the two firms' products pre-merger, particularly as products represent a bundle of characteristics or services. In addition, within a period $\sigma_{ij} = \sigma_{ji}$, meaning synergy values are fixed for any pair of firms.

Firms are fully forward-looking and strategic during the merger stage. Conditional on the set of synergies (or lack thereof), the proposing firm will either propose a merger with the firm offering the highest return in the merger stage or pass on the option. If the firm passes, a new firm is chosen at random and given the opportunity to offer a merger. The process continues until all firms have had an opportunity or a merger occurs. Because firms know that if they refuse a buyout offer they may be the next firm with the power to propose a merger, they may have the incentive to turn down a profitable merger foreseeing another, more profitable merger with some other firm. Similarly, they may accept or propose a less valuable merger to prevent two other firms in the market from merging and becoming too powerful. Because synergy values are random and private information, this merger stage game can be quite complex but results in a rich and fully endogenous pattern of mergers.

To evaluate a possible acquisition, firms calculate the potential surplus that would result from a merger and the size of the accompanying buyout payment. The merger's surplus is the difference between the combined firm's value and the sum of the separate firms' values. If there is a positive surplus from the firms' merger, it will be split between the two parties. This split results from Nash bargaining where reservation price of the firm being acquired is its value if the negotiation fails. The value to the acquiring firm is the difference in values between the combined firm and its value if negotiations fail. Let $V^B(\cdot)$ and $V^S(\cdot)$ be the values of the buyer and the seller at the beginning of the following period at market structure Ω, which are described in greater detail in the following section, and let m_{ij} indicate whether or not a merger was agreed to by both parties, with 1 meaning it was. The size of the buyout offer solves:

$$\max_{\tau_{ij}} \left(V^B(\Omega \mid m_{ij} = 1, \sigma_j) - \tau_{ij} - V^B(\Omega \mid m_{ij} = 0) \right)^{\rho_b} \left(\tau_{ij} - V^S(\Omega \mid m_{ij} = 0) \right)^{\rho_s} \tag{3}$$

where ρ_b and ρ_s represent buyer and seller bargaining power parameters. The result is a payment equal to

$$\tau_{ij} = \rho_b V^S(\Omega \,|m_{ij} = 0) + \rho_s[V^B(\Omega \,|m_{ij} = 1, \sigma_j) - V^B(\Omega \,|m_{ij} = 0)] \tag{4}$$

Because $\rho_s = 1 - \rho_b$ by definition, this can equivalently be written as

$$\tau_{ij} = V^S(\Omega \,|m_{ij} = 0) + \rho_s[V^B(\Omega \,|m_{ij} = 1, \sigma_j) - V^B(\Omega \,|m_{ij} = 0) - V^S(\Omega \,|m_{ij} = 0)] \tag{5}$$

The first term is the reservation value of the seller and the second term is the share of the surplus from the buyer that is paid out.

2.3 Antitrust Policy

I consider specifications with and without antitrust policy. In specifications with antitrust policy, all mergers are reviewed by an antitrust authority who determines whether or not to allow the merger to proceed. The antitrust authority has full information, observing the state $s = \{\Omega, i, j, \sigma_{ij}\}$ where i and j are the identities of the merging firms.

Conditional on observing s, the antitrust authority evaluates the post-merger state of the world against the alternative. Denote these Ω_M and Ω_{NM} for the state where the merger proceeds and where the merger is blocked, respectively. When active, the authority calculates consumer surplus under both alternatives and decides its policy according to the rule:

$$a_{it} = \begin{cases} reject & \text{if } CS(\Omega_{NM}) > CS(\Omega_M) \\ approve & \text{if } CS(\Omega_{NM}) \leq CS(\Omega_M) \end{cases} \tag{6}$$

where $CS(\cdot)$ represents static consumer surplus calculated by integrating over the demand system described in equation 1.

2.4 Potential Entrants

In each period, a single firm may enter the market. The potential entrant lives for a single period and must pay an entry cost to join the industry, becoming an incumbent and competing in the product market in the following period. Potential entrants face the same

investment cost function as incumbents, but where greenfield costs begin at ω_{max}, allowing entrants to innovate up to any possible ω level if they were to receive a favorable cost draw. The timing of the model is such that potential entrants make their entry and investment decision at the beginning of the period, simultaneous with existing firms making their exit and investment decisions.

2.5 Timing

1. Incumbent firms observe investment costs and potential entrants observe entry costs.
2. Incumbents choose whether or not to exit, their investment level if continuing, and entrants decide to enter or not and at what quality level. Their product qualities adjust as a result.
3. Firms enter the merger stage:
    (a) Some firm i is selected and observes merger synergies σ_{ij} for all other firms.
    (b) Firm i selects its most profitable potential partner, and if the total surplus from the merger is positive, the two firms agree to merge.
    (c) If no merger is agreed to in step (b), the merger stage repeats until all firms have had a chance to propose mergers or an agreement occurs.
4. If a merger agreement was reached and the antitrust authority is active, it evaluates the proposed merger and approves or rejects. If the merger is approved, firm i's product updates to $\omega_B + \sigma_{ij}\omega_S$ and pays τ_{ij} to firm j.
5. Firms compete and earn profits $\pi(\Omega\ )$

3 Equilibrium and Computation

3.1 Firm Policies

In this section I formally describe firm policies over entry, exit, investment and mergers as well as the antitrust authorities merger review policy. I describe the conditions for a symmetric, Markov perfect equilibrium and the computational algorithm for finding it.

Incumbent exit and investment policies: At the beginning of a period, each incumbent draws a set of investment costs equal in number to their product quality ω, which takes an integer value. For simplicity, I will describe the policies of one representative firm. Firm i with product quality ω_i takes ω_i draws uniformly from the distribution $[\underline{c}, \overline{c}]$. In addition they draw a greenfield cost from the distribution $[\overline{c}, c_g]$.

Let $\overline{V}(\omega_i, \omega_{-i})$ represent the interim value of being in state ω_i while your rivals have states ω_{-i} after entry, exit, and investment have taken place but before the merger stage. After observing its set of cost draws $\tilde{c_i}$, firm i chooses its exit policy $\chi^{EX} \in \{0, 1\}$ and, if not exiting, the amount of investment to undertake $x_i \in \{0, ..., \overline{\omega}_{max}\}$. Simultaneously, the industry-wide depreciation shock $\eta \in \{0, 1\}$ is realized, taking value 1 with probability δ. This depreciation is equivalent to an increase in the quality of the outside option. After investing at level x_i, a firm's state updates to $\omega_i = \omega_i + x_i - \eta$. The firm therefore solves:

$$\max_{x_i}\{-FC - C(\tilde{c_i}, x_i) + \beta \quad {}_{\eta} \quad {}_{\omega_{-i}} V(\omega_i + x_i - \eta, \omega_{-i})p(\eta)h(\omega_{-i}|\omega_{-i})\} \tag{7}$$

Where $h(\cdot|\cdot)$ represents beliefs over rival firms investment outcomes, including potential entry and exit. Let x_i^* represent the solution to this problem. The firm exits and $\chi^{EX} = 1$ if

$$\{-C(\tilde{c_i}, x_i^*) + \beta \quad {}_{\eta} \quad {}_{\omega_{-i}} V(\omega_i + x_i^* - \eta, \omega_{-i})p(\eta)h(\omega_{-i}|\omega_{-i})\} < FC.$$

The investment level x_i^* is determined by equating the marginal cost of an additional unit of investment to the increase in the expected value upon reaching the merger stage.

The potential entrant's problem is very similar to that of an incumbent. It draws $\overline{\omega}_{max}$ investment cost draws from the distribution $[\underline{c}, \overline{c}]$. It then decides whether or not to enter based on the expected value of pursuing the optimal level of investment. Consequently, the product quality of the entrant is endogenous and can take any value in $\{1, ..., \overline{\omega}_{max}\}$.

Mergers: When deciding whether or not to propose a merger with another firm, firm i must evaluate a set of potential future outcomes. Denote as $V(\omega_i, \omega_{-i})$ the value of being in state ω_i with rivals in states ω_{-i} at the beginning of a period, before cost shocks have been observed. To take expectations over the future state if firm i does not propose a merger, they must consider the probability that there is a merger between other firms, which occurs with probability ${}_{k} \quad {}_{j} \int_{\sigma_{jk}} Q(m_{jk}|\Omega)$ where m_{jk} represents a merger between firms k and j. This probability represents the joint probability that firms k or j are next to

propose a merger as well as the distribution of potential synergy values over each pair that is reached in equilibrium. If they antitrust authority is active, they must also consider the its decision rule χ^{AA} when considering proposing a merger. Because the antitrust authority faces a deterministic decision, in equilibrium firms will never propose mergers which are subsequently rejected.

If firm i is the proposing firm, they observe synergy values σ_{ij} for all firms in the market, including a new entrant if entry occurred earlier in the period. They then choose

$$\max \Big\{ \max_{j} \{ \chi^{AA}(\Omega, i, j, \sigma_{ij}) \Big[-\tau_{ij}(\omega_i, \omega_{-i}, \sigma_{ij}) + \pi(\omega_i + \sigma_{ij}\omega_j, \omega_{-i}|m_{ij}) + \beta V(\omega_i + \sigma_{ij}\omega_j, \omega_{-i}|m_{ij}) \Big] \}, \\ {}_{k} \quad {}_{j} \int_{\sigma jk} Q(m_{jk}|\Omega) \chi^{AA}(\Omega, j, k, \sigma jk) \Big[\pi(\omega_i, \omega_{-i}|m_{jk}, \sigma_{jk}) + \beta V(\omega_i, \omega_{-i}|m_{jk}, \sigma_{jk}) \Big] d\sigma \Big\} \tag{8}$$

The first term inside the max operator is the firm's choice of merger partner. For each potential partner, conditional on the observed σ_{ij}, they evaluate the size of the buyout payment and post-merger profits and continuation value. The second term is the expected value of not proposing a merger and potentially seeing rival firms merge in the same period.

Equilibrium: I will consider Markov Perfect Equilibria (MPE) for this model. If $s \in \mathcal{S}$ represents some element of the state space, a MPE consists of:

- A subset $\mathcal{R} \subset \mathcal{S}$;
- Strategies χ^* for every $s \in \mathcal{R}$, where $\chi^* = (\chi^E, \chi^{EX}, m_{ij}, \tau_{ij}, x_i, xe_i)$ respectively governing entry, exit, mergers, buyout offers, and investment.
- Expected discounted values conditional on these strategies, $V^E(\Omega, ce_i), V(\omega_i, \omega_{-i})$, $V^M(\Omega, i, j, \sigma_j) \forall j$, and $V^I(\omega_i, \omega_{-i})$.

Such that:

1. The Markov process defined by any initial condition s_0 and the strategies χ^* has $\mathcal{R}$ as a recurrent class.
2. For every $s \in \mathcal{R}$, strategies are optimal given $V^E(\cdot)$, $V(\cdot)$, $V^M(\cdot)$, and $V^I(\cdot)$. That is, $\chi^*(\Omega)$ solves:

$$\max_{\chi^E} V^E(\Omega, ce_i), \max_{\chi^{EX}, x_i} V^I(\omega_i, \omega_{-i}), \max_{\chi^M, m_{ij}, \tau_{ij}} V^M(\Omega, i, j, \sigma_j)$$

3. Values are consistent on $\mathcal{R}$. For every Ω and Ω which are components of $s \in \mathcal{R}$:

$$V(\omega_i, \omega_{-i}) = \pi(\omega_i, \omega_{-i}) - FC + \quad {}_{i} \quad {}_{j} \int_{[0,1]} Q(m_{jk}|\Omega) V^I(\omega_i, \omega_{-i}|m_{ij}, \sigma_j) \mathrm{d}\sigma$$

$$V^I(\omega_i, \omega_{-i}) = \max\{0, \max_{x_i} -C(\omega_i, x_i) + \beta \quad {}_{\eta} \quad {}_{\omega_{-i}} \quad V(\omega_i + x_i - \eta, \omega_{-i}) p(\eta) h(\omega_{-i}|\omega_{-i})\}$$

$$V^E(\chi^{E*}, xe_i|\Omega, ce_i) = \max\{0, max_{xe_i} - C(\omega_{max}, xe_i) + \beta \quad {}_{\eta} \quad {}_{\omega_{-i}} \quad V(xe_i - \eta, \omega_{-i}) p(\eta) h(\omega_{-i}|\omega_{-i})\}$$

An MPE for this model can be shown to exist following Doraszelski and Satterthwaite (2010). For a discussion of potential multiplicity, see Doraszelski and Pakes (2008). Generally, there is no way to rule out the possibility of multiple equilibria, which poses a challenge for counterfactual policy analysis. Given that multiple equilibria have been found to exist in similar models without a merger stage, a more complex model also plausibly suffers from this problem. Borkovski et al. (2012) show multiplicity in a quality ladder model, although they conclude that "the differences between equilibria tend to be small and may matter little in practice." Here, I offer the standard disclaimer that in the course of solving the model large numbers of starting states and policies were tested and never produced meaningfully different outcomes. In addition, when computing the equilibrium with mergers, I tested initiating the policies and values using the results from the equilibrium without mergers, and vice versa. In both cases, the algorithm converged to the same equilibrium. Because, as described in more detail below, the computational algorithm used to compute equilibria uses reinforcement learning, it generates stable equilibria only, which are likely to be more relevant for practical purposes, and the counterfactual comparisons can be thought of as finding one equilibrium in which antitrust policy suddenly switches regimes.

To compute the model, I map the measure of product quality ω onto the integers $\{0, ..., 10\}$. There is no limit on the number of firms allowed in the market although under the parameters chosen there are never more than 4 firms active in equilibrium. Most prior work in this literature caps the number of active firms at 2 for computational reasons. This

limitation is potentially costly, as it necessarily restricts attention to mergers to monopoly, which are rarely allowed in practice and which always reduce consumer welfare in this model unlike mergers from 3 to 2 firms. A binding cap could be thought of as imposing an infinite entry cost at states with 2 firms in the industry, even if a third firm could profitably operate.

The model is too complex to allow an analytic solution, instead, it is solved computationally using the stochastic algorithm of Pakes and McGuire (2001). The potential computational burden of the model described is enormous. The size of the state space grows exponentially in the number of firms and potential good qualities, and for each state, the integral over potential future states required to calculate the expected discounted value of different actions involves probability distributions over the random sequence of merger proposers, synergy values, exit and entry behavior, and the outcomes of investment. The computational burden of this high-dimensional integral and state space is the reason there has been little work done on this type of analysis to date. The stochastic algorithm method substantially reduces this burden.

This method solves the model asynchronously using the technique of reinforcement learning. The model is simulated for a very high number of periods, with firms' value functions being updated with the observed results of their actions. Over time, the average of a firm's experiences becomes equal to its true expected value. The method offers several advantages. The first is that equilibrium policy and value functions are only computed over a subset of the state space. This subset, $\mathcal{R} \subset \mathcal{S}$, is the recurrent class of the Markov process formed by equilibrium strategies. While the state space grows exponentially in the number of potential firms, its possible for $\mathcal{R}$ to grow linearly or even not grow at all.

The other advantage is that by simulating the model rather than solving it directly, it is not necessary to solve any high-dimensional integrals except once, in the limit. To briefly describe the algorithm; for each visit to a state, firms solve the optimal policy based on their estimate of the value function. Once they choose, pseudo-random numbers are drawn to determine the outcomes of their choices and update the state. The value function estimate at the original state is then updated to include the profit realized and value at the new state. The process then repeats at the new state. To improve performance, policy functions are randomly perturbed in a small share of periods which slowly declines to zero.[8] Periodically, a test of the equilibrium conditions is conducted, this test is described in detail in Fershtman

[8]This prevents the algorithm from getting "stuck" in non-equilibrium values. It is referred to in the machine learning literature as an epsilon-decreasing strategy.

and Pakes (2012). The algorithm performs well, converging to the same equilibrium outcome from very different initializations of value of policy functions.

4 Results

4.1 Mergers and Innovation Incentives

The model is solved for MPE numerically with initial parameter values taken primarily from Pakes and McGuire (1994) with merger fixed costs set at .5 and merging firms having equal bargaining power.[9] The full set of parameters can be seen in Table 1. The results that follow simulate the industry for 500,000 periods from the equilibrium's recurrent class of states. This is a sufficient number of simulation periods that the results displayed do not vary over simulations and so no standard deviations are presented alongside them.

Table 1: Base Parameterization

Parameter	Value
β	.925
$\overline{\omega}$	10
FC	.6
c_M	.5
ρ_b, ρ_s	.5
δ	.6
$\underline{c}$	.1
$\overline{c}$	15
y	15
M	10

Table 2 summarizes the key equilibrium outcomes in three different settings: one in which no mergers are allowed, one with no restrictions on mergers, and one in which mergers are allowed except that a simple antitrust policy blocks those that would create a monopoly. In the benchmark case without firm acquisitions, the industry forms a relatively stable duopoly with little entry or exit. The duopoly takes the form of a leader and a laggard on quality where the leading firm invests enough to typically maintain its position. I measure the rate of innovation as the share of periods in which investment advances the industry frontier past ω_{max}. In the no-merger duopoly outcome, there is little incentive for the industry leader to advance ω_{max}, and so innovation only occurs in .3% of periods.

[9] The empirical finance literature finds inconclusive results on the shares of a merger's surplus going to either party, but most work finds the shares roughly equal. See, for instance, Ahern (2012).

Figure 1: Distribution of Mergers when N=2

	1	2	3	4	5	6	7	8	9
1	0								
2	0	0							
3	0	0	0						
4	0	0	0	0					
5	0	0	0	0	0				
6	0	0	0	0	0	0			
7	0.001	0	0.000	0	0	0	0		
8	0.002	0.000	0.000	0.000	0	0	0	0	
9	0.503	0.009	0.006	0.002	0.002	0.011	0.002	0.461	0

Seller state

Figure 2: Distribution of Mergers when N=3

	1	2	3	4	5	6	7	8	9
1	0								
2	0.007	0							
3	0.038	0.007	0						
4	0.008	0.003	0.002	0					
5	0.013	0.004	0.000	0.000	0				
6	0.003	0.001	0.000	0.000	0.000	0			
7	0.025	0.003	0.000	0.000	0.000	0.000	0		
8	0.007	0.002	0.001	0.000	0.000	0.000	0.006	0	
9	0.236	0.029	0.026	0.017	0.031	0.013	0.488	0.029	0

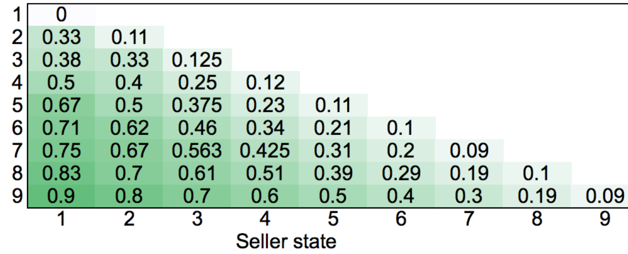
Seller state

When mergers are allowed with no restrictions, they occur frequently, in over one third of periods. Figures 1 and 2 show the distribution of mergers in equilibrium when the total number of firms active pre-merger, N, is 2 and 3, respectively. The vertical axis shows the state of the acquiring firm and the horizontal axis shows the state of the selling firm. Only states below the diagonal are represented because the larger firm is the acquirer by definition. When $N = 2$, the vast majority of mergers are between the leading firm and either a firm of state 1 or of state 8. When $N = 3$, these are again the most common merger states but there is a greater range of outcomes.

The most notable fact about the mergers that occur is that they are almost entirely harmful to consumers in the short run. Static consumer surplus is always decreased by a merger at $N = 2$ to create a monopoly. When $N = 3$, the short run welfare effects of a merger depend on the size of the firms involved, the third firm, and the synergy value σ. Table 3 shows the share of mergers that increase welfare for every buyer-seller pair. Of all the mergers that occur in equilibrium, only 18.8% are welfare increasing, the vast majority harm consumers in the short run.

The most important result is that when mergers are allowed the rate of entry increases substantially from only 6.5% of periods to roughly 49% of periods. It is notable that allowing

Figure 3: Share of Mergers increasing welfare when N=3



firms to acquire one another results in only slightly fewer firms in the market, on average, decreasing from 2.06 to 1.84 and increasing the share of periods with 3 firms active. The result of allowing mergers is an industry spending roughly 11% of the time with three firms and 27% as a monopoly.

Despite the fact that the vast majority of mergers reduce welfare in the short run, allowing mergers increases the average consumer surplus in the industry and the rate of innovation substantially. The share of periods with innovations increases from .3% to 85%. Interestingly, while there is more entry, average firm profits also increase when mergers are allowed, likely due to the increased share periods where one firm holds a monopoly. For the remainder of the results section, for simplicity I consider only the unlimited mergers and no mergers equilibria.

Beyond average market outcomes, we can observe firm policy functions directly to explore the effects of mergers on innovation. Figure 4 shows firm R&D policy functions plotted over quality level. These are calculated from simulations and weighted by states visited. For each equilibrium, we see an inverse-U shaped relationship between firm size/quality and investment. Firms invest the most at intermediate states and reduce investment when they reach the highest quality states. Two notable results emerge when comparing investment functions with and without mergers. First, at all quality states, investment is higher when mergers are allowed. Second, with fewer restrictions on mergers, total investment is higher and it peaks at a lower state.

Figure 5 shows that the rates of entry occurring for different numbers of incumbent firms. When there is only one incumbent in the market, entry occurs 86% of the time in the mergers equilibria. Entry occurs more rarely in the no-mergers equilibrium, regardless of number of incumbent firms.

Figure 4: Investment levels with and without mergers

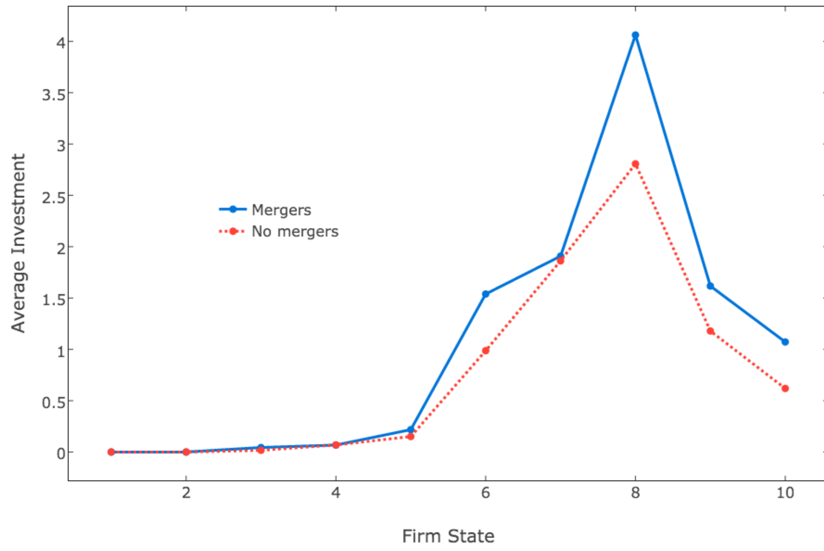


Figure 5: Entry Rates

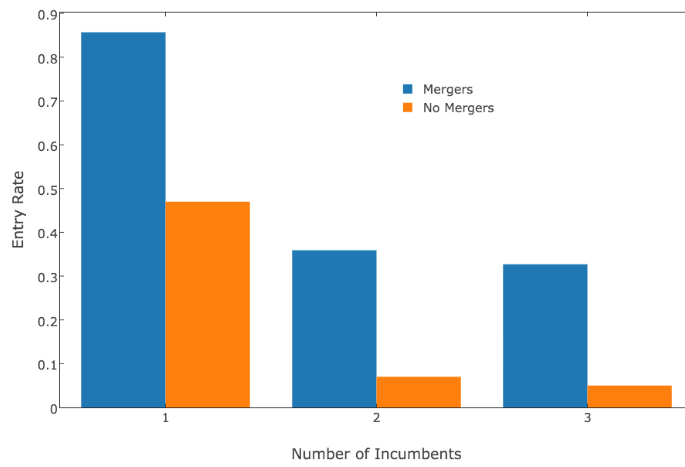


Table 2: Comparison of equilibrium with and without mergers

	No Mergers	Mergers	Mergers up to Duopoly
Firm Characteristics			
Mean number of firms	2.06	1.84	2.09
Mean firm quality	4.80	6.08	4.99
Share of periods with entry	6.50%	48.98%	25.74%
Share of periods with mergers		37.68%	16.59%
Investment			
Total investment	.80	1.29	1.15
Mean investment	.39	.70	.55
Rate of innovation	.003	.85	.55
Mean entrant investment	2.10	4.01	4.93
Mean investment by market leader	.79	1.09	1.07
Surplus			
Mean consumer surplus	5.89	11.26	9.67
Mean total profit	12.89	13.23	12.94
Firm Distribution			
Share of periods in Monopoly	.05	27.24%	.18%
Share of periods in Duopoly	93.49%	61.75%	90.66%
Share of periods with 3 firms	6.45%	11.01%	9.15%
Share of periods with 4 firms	5e-4%	.001%	.004%

It is clear from Figure 5 that the additional entry generated in the mergers equilibria is not merely replacement entry after a merger reduces the number of firms below the stable duopoly number. This is because with mergers allowed, the average number of firms in the market actually increases, the increase in entry takes place even when mergers to monopoly are not permitted, and entry occurs even when 2 or 3 incumbents are present, as shown in Figure 5. Entry rates are higher at every market state. While antitrust economists have long known that entry can mitigate the anticompetitive effects of mergers, and entry is discussed in the Horizontal Merger Guidelines for this reason, the argument for entry here is distinct. The value created by entry is not about reducing market power of large, post-merger incumbents, but instead the prospect of a future buyout is generating new, additional entry which is increasing competition and innovation while also increasing consumer surplus.

4.2 Antitrust Policy

This section describes the equilibrium outcome when the antitrust authority is active, blocking any merger which would decrease static consumer surplus. I compare it to the benchmark cases where all mergers are allowed and where none are which have already been described. Results are shown in Table 3. The primary result is that very few mergers are proposed and approved, occurring in less than 1% of periods. The set of mergers which is both profitable, welfare increasing, and reachable from the equilibrium path is very small. Almost all mergers have high synergies meaning $\frac{\sigma_{ij}}{\omega_j} > .5$. Because there is no uncertainty in merger review, in equilibrium no mergers are proposed which would be rejected, but of hypothetical mergers possible along the equilibrium path, 19% would be approved and the rest rejected.

Average consumer welfare is only slightly higher than in the equilibrium with no mergers at all and innovation is essentially unchanged. The industry is essentially in a very stable duopoly with one leader and one laggard. The leading firm invests more in this equilibrium than in one without mergers, but less than when mergers are unrestricted. Innovation is therefore quite rare.

4.3 Contestability and Disruptability

In this section I explore what industry characteristics are driving the above results. I consider two related characteristics. First, I examine the role of "contestability" in the sense of Shapiro (2010), meaning the degree to which firms who successfully innovate can capture higher market share as a result. This is represented by the parameter ϕ in the consumers utility function, the dispersion of the random component of utility. When this parameter is high, preferences exhibit less heterogeneity, consumers agree more on which product offers the highest utility and firms with higher ω capture a higher market share. When ϕ is low, preferences are more horizontally differentiated.

When contestability is high, a successful innovation translates into a large increase in market share and profits. Thus this could be thought of as representing low consumer switching costs, brand loyalty, or the ease of distribution.[10] In industries with high contestability, the benchmark rate of innovation will naturally be higher, but the relative effects of hor-

[10]The scale of the dispersion parameter represents taste heterogeneity or unobserved product features, which are not dynamic in in the way switching costs are, but they do have similar implications for changes in market share resulting from innovation, although not for dynamic pricing policies which are not allowed here.

Table 3: Comparison of equilibrium with and without mergers

	No Mergers	Mergers	Optimal Antitrust Policy
Firm Characteristics			
Mean number of firms	2.06	1.84	2.00
Mean firm quality	4.80	6.08	4.99
Share of periods with entry	6.50%	48.98%	.08%
Share of periods with mergers		37.68%	.04%
Investment			
Total investment	.80	1.29	1.00
Mean investment	.39	.70	.50
Rate of innovation	.003	.85	.003
Mean entrant investment	2.10	4.01	5.04
Mean investment by market leader	.79	1.09	1.00
Surplus			
Mean consumer surplus	5.89	11.26	5.93
Mean total profit	12.89	13.23	13.09
Firm Distribution			
Share of periods in Monopoly	.05	27.24%	1e-5%
Share of periods in Duopoly	93.49%	61.75%	99.91%
Share of periods with 3 firms	6.45%	11.01%	.001%
Share of periods with 4 firms	5e-4%	.001%	3e-6%

izontal mergers is potentially ambiguous. To resolve this, I compare equilibria with and without horizontal mergers in industries with varying levels of contestability. The results are shown in Table 4.

As contestability rises the effects of horizontal mergers change dramatically. When $\phi = .8$, there is no difference in rate of innovation or consumer welfare between the mergers equilibrium and the no-mergers equilibrium. When contestability increases to $\phi = 1.33$, the rate of innovation and rate of consumer welfare are substantially higher in the mergers equilibrium and the no-mergers equilibrium. This result is somewhat counterintuitive, because when switching costs or loyalty are lower, a higher share of the gains from innovation come from business stealing. Merging firms should internalize this incentive and invest less. Indeed, they do, investment by leading firms falls when contestability increases, relative to the no-mergers case. But this effect is outweighed by a large increase in entry and innovation by new entrants. The reason is that when contestability is high, monopoly is relatively more valuable. The result is that the equilibrium buyout offer τ at the modal merger state is 2.4

Table 4: Higher Contestability Increases Innovation Disparity

	$\phi\ = .1.33$		$\phi\ = 1$		$\phi\ = .87$		$\phi\ = .8$	
	NM	M	NM	M	NM	M	NM	M
Rate of Innovation	.07	1.83	.003	.85	.01	.09	0	0
Consumer Surplus	4.26	16	5.89	11.26	5.94	6.86	6.35	6.35

Each column shows the rates of innovation and long run average consumer surplus with mergers and with no mergers.

times high when $\phi = 1.33$ than when $\tau = .8$.

While contestability is a feature of consumer demand, I consider a related industry characteristic that is a feature of firm capacity to innovate. In the baseline model, firms are able to innovate to achieve any level of ω in any period. Indeed, in rare circumstances when a firm receives a set of very low investment costs, we do observe large changes in ω in a single period. This investment technology follows Mermelstein et al. (2014) and is important because it is "merger neutral" in the sense that it avoids mergers which mechanically reduce the industry's technological possibility set and hence investment. While important, it may not be realistic for all industries. In some industries, it is impossible regardless of investment costs to dramatically increase the quality of a product quickly.

I refer to this industry feature as "disruptability" and examine the results after varying the amount of product innovation firms are capable of from the baseline of no limit down to a limit of one incremental unit per period. Let $\tilde{I}$ represent this cap, such that $\omega\ \ - \omega \leq \tilde{I}$, or equivalently $c_i = \infty$ for $\omega_i > \omega\ \ - \omega$. In the baseline case with no cap on innovation $\tilde{I} = \overline{\omega}_{max}$.

Results are presented in Table 5. We see that, as disruptability falls and firms can only advance by 1 in each period, the previous results are reversed. There is essentially no innovation and long run consumer welfare is lower with horizontal mergers than without. For middle levels of disruptability, mergers produce slightly higher levels of innovation and welfare. Finally, when there is no cap on innovation, the previous result is seen again, mergers create the incentive for much higher innovation and long run consumer welfare. The discontinuous jump in welfare and innovation when comparing the rightmost two columns in Table 5 suggest much of the effect is driven by infrequent but very large innovations by new entrants and small firms. It may be that firms who enter the industry at a small level, prompted to do so by the prospect of a buyout when it otherwise would not have

Table 5: Higher Disruptability Increases Innovation Disparity

	$\tilde{I}=1$		$\tilde{I}=3$		$\tilde{I}=5$		$\tilde{I}=7$		No Cap	
	NM	M	NM	M	NM	M	NM	M	NM	M
Rate of Innovation	0	0	.002	.01	.003	.05	.003	.05	.003	.45
Consumer Surplus	4.8	3.8	5.8	6.1	5.8	6.1	5.8	6.1	5.9	8.9

Each column shows the rates of innovation and long run average consumer surplus with mergers and with no mergers.

been profitable to enter, occasionally see very low cost draws giving them an opportunity to generate a very large innovation.

Combined, the results on contestability and disruptability give some guidance to antitrust policymakers as to when there is potential long run benefit of allowing mergers that are harmful to consumers in the short run. This is most likely to occur in dynamic industries where consumers have low switching costs or brand loyalty and when innovation is occasionally rapid and disruptive. When consumers face switching costs or most innovation is of the incremental variety, the short run harm to consumers from anticompetitive mergers is likely to be the dominant force.

While the nature of innovation in an industry is a feature of underlying technology and thus out of the scope of policy, it may be observable and therefore a useful factor for a merger authority to consider. Contestability, however, is potentially under the influence of policymakers, who can seek a more contestable market by restricting the use of long-term contracts, bundling requirements, and other practices that raise switching costs. In innovative industries this the of policy may be more effective in promoting consumer welfare and innovation than strict merger review.

5 Conclusion

The relationship between horizontal mergers and innovation is increasingly important but poorly understood. To examine it requires simultaneously modeling endogenous entry and investment behavior and endogenous mergers. In addition, firms must have a broad ability to innovate, the long-run rate of innovation must be made endogenous, and the mergers technology must allow for a flexible and rich pattern of mergers.

This paper shows that in a model with these features, traditional horizontal mergers

policy based on static welfare analysis may be counterproductive in the long run. While the vast majority of equilibrium mergers fail such a test, the long term result when they are allowed is substantially higher innovation and consumer welfare. The prospect of a windfall gain from a buyout offer by the leading firm generates additional entry that otherwise would not occur. This is distinct from the replacement entry post-merger discussed in the Horizontal Merger Guidelines. In addition, firms find it profitable to invest to improve their prospects as a merger partner and some of the new entrants generate substantial innovations and become the leading firm in the market.

This pattern is most likely when the product market is more "contestable" in the sense that consumer switching costs or brand loyalties are low. It is also more likely when the industry is more "disruptable" meaning large and rapid innovations are possible. In industries with these features, antitrust policymakers should place more weight on the long run gains from the incentives provided by merger prospects and less weight on the immediate harm done to consumers by these mergers.

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