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Consolidation Waves

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This paper explains why consolidation acquisitions occur in waves and it predicts the differing role each firm is likely to play in the consolidation game. We propose that whether a firm assumes the role of rival consolidator, target, or passive observer depends on the position of the firm relative to the entity that merges first. Our model predicts that an initial acquisition triggers a wave of follow-on acquisitions, where the process of asset accumulation by the consolidator is accelerated since the value of follow-on acquisitions is enhanced by the more concentrated industry structure. An initial consolidation can trigger a consolidating acquisition by a rival in a remote market segment, while some firms prefer to be a target and others remain passive observers that await the outcome of the consolidation process rather than merge amongst themselves. Fragmentation, demand uncertainty, and investment costs determine the timing of acquisitions.

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1. Introduction

Merger opportunities can be viewed as real options. Mergers are associated with substantial costs, like transaction fees for bankers and consultants, that forestall immediate merger activity. As with exercising an option, a merger becomes profitable when the surplus exceeds the investment outlay to compensate for the option premium. In the consolidation of an industry, value creation from mergers derives not only from interfirm synergies but also from potential intertemporal synergies with future acquisitions.

We embed an option valuation in an industrial organization model. The initial or platform acquisition generates and constrains future acquisition prospects along its path. A consolidator's new position within the industry also affects the potential paths and roles of other players, who may decide to become rival consolidators, to accept a position as a target, or to remain a passive observer.

The option game model presented here considers consolidation acquisitions within the "circular city" concept, but extends the analysis using more realistic demand following a stochastic process and sequential investment according to real option theory. The circular city concept specifies product differentiation and the relatedness of firms, expressed by the distance between them. The strategic position of a firm, then, depends on the location of the firm vis-à-vis other industry players. The price paid for an acquisition is endogenous and depends on the target value under alternative industry consolidation paths.

Consolidation can increase industry profits, as the merged firm limits competition and has additional market power to raise prices. Rival firms may therefore also benefit from the merger and may prefer to accept either the role of "target," or "passive observer." In our setting, the extent to which rival firms can increase profits depends on their location relative to the merged entity, (degree of relatedness). Nearby targets will generate higher value for the consolidated entity as other firms prefer to passively benefit from the reduction in competition delivered by the consolidator rather then merge amongst themselves. A rival consolidator may arise only in a distant market segment. As

a consequence, the initial consolidation may trigger a wave of acquisitions, where the increasing attractiveness of merging for the consolidator depends on fragmentation, demand uncertainty, and the cost involved in acquisitions.

The process of industry consolidation may suffer from a free-rider problem (e.g., Stigler, 1950), where in a standard Cournot framework a merger reduces the profits for the insiders, while only outsiders benefit (Salant, Switzer and Reynold, 1983). As a consequence, it has been claimed that firms are reluctant to merge.[1] Mergers are profitable under price competition where the response of rival firms to the merger is strategic complementarily, which induces product prices to increase. Deneckere and Davidson (1985) show how mergers of firms engaged in price competition under symmetric product differentiation[2] become more profitable when firm size increases. Levy and Reitzes (1992) consider mergers in the circular city setup of Salop (1979). The circular city enables product differentiation that aims to reduce the intensity of price competition (Economides, 1984). A firm in competition is directly affected by its close rivals, whereas firms at a larger distance only indirectly affect its product price. Because mergers benefit the closest outsiders more than insiders of the merger, the incentive to wait depends on their relative positions. Brito (2003) analyzes the conditions under which firms prefer to wait or to engage in a pre-emptive merger, as being an outsider at a larger distance is less preferred than being an insider.

Often, a first acquisition leads to a wave of acquisitions in which a fragmented industry consolidates. In our model, the rationale for the occurrence of waves differs from the reasons presented by Shleifer and Vishny (2003), and Gort (1962). These are the two main theories that explain the causes of merger waves. The *neoclassical theory* sees mergers as a response to industry shocks (Gort, 1962; Mitchell and Mulherrin, 1996). Lambrecht (2004), and Morellec and Zhdanov (2005) model the timing and terms of a merger decision as a real option and find that the division of the surplus between acquirer

[1] Perry and Porter (1985) extend this analysis and find that mergers are profitable when firms differ in size and a particular production factor is scarce. In a more general setting, Farrel and Shapiro (1990) show that mergers that do not create synergies always raise product prices.

[2] Reitzes and Levy (1995) show that a merger is always profitable in Hotelling's model.

and target influences the timing of the transaction. Lambrecht (2004) shows that merger waves occur procyclically when they are motivated by economies of scale. The *behavioral theory* claims that stock market valuations drive merger waves (Shleifer and Vishny, 2003; Rhodes-Kropf and Viswanathan, 2004). Empirical evidence shows that misvaluation drives waves (Rhodes-Kropf, Robinson and Viswanathan, 2005), but that shocks to the industry precede these waves (Harford, 2005).

The key contribution of this paper is to provide an explanation for merger waves and the evolution of consolidating industries. In addition, based on their position we predict which firms take the roles of consolidator, target, or passive observer. While the consolidator continues its sequence of acquisitions, most firms prefer not to merge amongst themselves. We provide an alternative explanation for industry consolidation acquisition waves that are due to the more advantaged position of merged entities. In our model, direct acquisitions are made in response to an increase in demand; industry concentration then enables firms to reduce competition and this triggers a wave of follow-on acquisitions. A merger wave unfolds because the first acquisition enhances the rationale for the next. We show how industry consolidation depends on the degree of fragmentation of the market. The surplus from an acquisition increases when fewer firms are present in the industry, and when positive externalities from merging make further consolidation even more attractive.

For instance, the steel industry is characterized by many firms with plants at different locations around the world producing steel of varying quality and facing fluctuating demand. Furthermore, steel is a heavy product and transportation costs are substantial, giving a competitive edge to local steel producers over foreign exporters. Nevertheless, local steel prices are indirectly affected by global supply and demand. The increase in prices caused by a recovery in the world economy facilitated a round of consolidation. In the US, International Steel Group acquired LTV, Acme Steel and Bethlehem Steel, and US Steel Corporation bought National Steel. Mittal bought many steel producers in Eastern Europe delivering a lower quality bulk product. Arcelor resulted from the combination of several nations' steel industries. Frequently, mergers of

rivals have been applauded[3] as they increase the profitability of the overall industry by reducing price competition. Early industry consolidation was characterized by a local build-up in size, as firms with nearby plants delivering similar quality products merged. Some firms are frequently in the role of the acquirer (e.g., Mittal), whereas other firms are bound to be targets (e.g., Eastern European firms). Additionally, many firms wait out the consolidation process and do not engage in merger and acquisition activity. Other examples in which firms play differing roles during an industry consolidation are evident in the automotive, airline, banking, mining, and mobile telecommunications industries.

This paper is organized as follows. In Section 2 we present the model. Section 3 models when a firm prefers to merge in the case where a single acquisition can be made. Section 4 describes industry consolidation using a nine-firm industry structure and the roles of different firms. The first acquisition makes later acquisitions more attractive and an acquisition wave begins to reinforce itself. Section 5 sets forth the conclusion.

2. Model Assumptions and Consolidation Gains

Our model assumes the following:

Assumption 1. Price setting and acquisition decisions are made with the objective of shareholder value maximization.

Assumption 2. Firms and investors have complete information regarding all parameters in the model. Agents do not coordinate decisions with each other.

Assumption 1 rules out agency considerations and "empire building." Assumption 2 rules out acquisitions induced by misvaluation of firms in the financial markets (Shleifer and Vishny, 2003). Also, target firms do not collude in raising acquisition prices.

Assumption 3. A Bertrand oligopoly of n firms serves a "circular" market, where consumers are uniformly distributed on a circle with perimeter 1. Each consumer has a

[3] Guy Dollé, CEO of Arcelor approved of Mittal's consolidation strategy and US Steel Corporation favored the formation of International Steel Group.

most-preferred location (or "brand" specification) denoted by its location on the circle, $x_c \in [0,1]$. Products are delivered to the market with brand specifications x_i at price p_i by firm i. The total costs for a consumer at location x_c buying product x_i is given by

$$C(x_i, x_c) = p_i + \lambda \mid x_c - x_i \mid, \tag{1}$$

where λ denotes transportation costs. Each consumer buys a single item of the product that delivers the lowest total costs.

To soften price competition, firms try to differentiate their products[4]. The circular city is useful in our context, as it ranks rival firms according to the degree of (dis)similarity of their products; and some rivals make products that might be closer substitutes than others. It thereby defines the strategic situation vis-à-vis direct and indirect rivals in the industry. A firm competes directly only with its two neighboring rivals. Other firms affect its price strategy only indirectly, via the competition of its neighbors. When transportation costs are high, a firm must revise its price strategy substantially to attract consumers that are located closer to rival firms. Location determines the intensity of competition.

Assumption 4. We assume no marginal costs. Firms are located equidistantly on the circle, with a distance $d = 1/n$ between firms.

Assumption 5. An acquisition is an irreversible investment and associated with costs *I*. Uncertainty in the stand-alone equity value of firm *i*, $E_i(\theta, n)$ (for $i = 1..n$) is determined by stochastic demand, θ, representing the density of consumers along the circle and the number of firms, n. The option value from either acquiring or being acquired is given by

[4] Consumers with a preference for a certain variety are willing to pay a higher price and the firm is not forced to lower its price, as rival firms deliver a different kind of product. In the linear city model (Hotelling, 1929), product attributes are heterogeneous, whereas in the circular city, product characteristics are symmetric. Therefore no location is a priori superior, whereas in the linear city, firms prefer to locate their plant in the center. A second advantage of the circular city model over the linear city model is that all firms have more than one direct rival.

$O_i(\theta, n)$. Total firm value equals the stand-alone value (assets in place) plus the acquisition option value:

$$V_i(\theta, n) = E_i(\theta, n) + O_i(\theta, n). \quad (1)$$

When marginal costs are absent, there is no mill price undercutting and assumption 4 will be sufficient for the existence of a pure Nash equilibrium[5]. Firms do not choose initial locations and they cannot be altered. As noted, the initial competitive position of each firm is identical in that all rivals are located at the same distance.

A firm's market value and the intensity of price competition depend directly on the distance to its close rivals. An acquisition opportunity can be seen as similar to an option. The exercise price presents the costs of a merger and the underlying value equals the surplus. The surplus equals the value of the newly merged entity, deducted by the standalone value of the acquirer and the price of the target. Examples of the costs involved include fees for investment bankers and consultants, and costs associated with combining two firms. These costs of an acquisition have a similar function as in Lambrecht (2004) in that they deter firms from an immediate merger.

Assumption 6. The size of the market is presented by the density parameter, θ, and follows a geometric Brownian motion:

$$d\theta_t = \mu\theta_t dt + \sigma\theta_t dW_t, \quad (2)$$

where $\mu < r$, and $\sigma > 0$. W_t follows a Brownian motion and r denotes the risk free interest rate.

[5] For a proof, see Economides, 1984.

Fluctuations in the stochastic market demand do not affect consumers' preference for product varieties[6]. Rather, the density of consumers along the circle increases, but the circle's perimeter is invariable and the locations of firms remain the same.

2.A. Stand-Alone Firm Value

We derive the stand-alone value of a firm without the option value to acquire, or the option premium of being a target. Firms can influence value only by using their pricing strategy to capture new consumers, because all consumers in the market buy exactly 1 single item of the product. A consumer at location x' is indifferent between choosing a product from firm i at location x_i and firm $i+1$ at location $x_{i+1} = x_i + d$ that offer prices p_i and p_{i+1}, respectively[7].

$$x' = x_i + \frac{p_{i+1} - p_i + \lambda d}{2\lambda}. \tag{3}$$

Demand for firm i depends only on the firm's price and the prices of its direct neighbors at location x_{i-1} and x_{i+1}.

$$D(p_i, p_{i+1}, p_{i-1}) = \theta_t \frac{p_{i-1} + p_{i+1} - 2p_i + 2\lambda d}{2\lambda}. \tag{4}$$

In a symmetrical structure, the instantaneous profit flow for firm i, $\pi_i(\theta_t)$ when all firms are located equidistantly on the circle is given by:

$$\pi_i(\theta_t) = \theta_t \lambda d^2. \tag{5}$$

The stand-alone value of the firm, $V_i(\theta_t)$, equals the profit stream discounted as an annuity with discount rate δ,

[6] The costs of buying the optimal matching product do not increase when the market grows. A change in market demand has a similar effect for all firms.

[7] Assuming no mill-price undercutting.

$$V_i(\theta_t) = \theta_t \frac{\lambda d^2}{\delta}. \tag{6}$$

2.B. The Value Creation from an Acquisition

When a consolidator acquires a neighbor, the newly merged entity delivers its products at two different locations (or with two different product characteristics) and can immediately optimally raise its prices in order to maximize its profits. The value creation from the acquisition depends on the position of the two locations of the new multi-plant firm with respect to each other and to rival firms. Most nearby firms in the industry also benefit due to the increase in market share and the higher price resulting from reduced competition (Levy and Reitzes, 1992; and Brito, 2003).

When Firm 1 and Firm 2 merge, the combined entity, Firm *m*, sets higher prices p_1 and p_2 for the products delivered at its two locations x_1 and x_2. Rival firms raise prices, p_i, according to the distance of their location from the merged entity[8]. Prices are given by

$$p_m = p_1 = p_2 = c + \lambda d\big(1 + z(-1)\big), \tag{7}$$

and

$$p_i = c + \lambda d\big(1 + z(j)\big) \text{ for } i \geq 3, \tag{8}$$

where $z(j) = \dfrac{a^{-j} - a^{j} - a^{n-3-j} + a^{3+j-n}}{\sqrt{3}(4 - a^{2-n} - a^{n-2})}$, and where j = min(i-3, n-i). j denotes the number of firms between firm i and the merged entity, firm m, and $a = 2 + \sqrt{3}$.

Eq. 8 shows that prices increase for all firms in the new market structure where the highest increase accrues to the two neighbors of the merged entity and the lowest increase accrues to the firm located at the greatest distance from the merged firm as $z(j)$

[8] For a proof of the analysis in this section, see Appendix A and Brito (2003).

declines in j[9]. The merged firm, raising prices more than its direct rivals, is able to compensate for the loss in consumers with the increase in profits made on the consumers located between its two plants. Nevertheless, close rivals' profits increase to an even greater extent than that of the merging firms, whereas rivals located further away have a smaller increase in profitability. Profits are given by

$$\pi_m(\theta_t) = \theta_t \lambda d^2 \left(1 + z(-1)\right)^2, \tag{9}$$

and

$$\pi_i(\theta_t) = \theta_t(\lambda d^2)\left(1 + z(j)\right)^2 \text{ for } i \geq 3. \tag{10}$$

Note that when the firm does not acquire its neighbor, the competition between firm locations does not alter in nature and industry profits do not change[10].

3. The Option to Acquire a Single Firm

Suppose that an increase in profits and thereby the extent of value creation from the acquisition depend on the evolution of market demand. Similar to exercising an option, a certain level of market demand exists above which it is optimal to acquire a neighbor. This threshold level depends on the price of the target and the fixed costs involved with the transaction.

When the terms of the acquisition are such that all profits realized in merging the operations accrue to the sellers, the rationale to execute the acquisition is absent for the acquirer (Grossman and Hart, 1982). Hence, the maximum acquisition price is given by the target's value, together with the synergies to be realized and deducted by the

[9] The price converges to *td* at a greater distance from the merged entity.

[10] When the multi-plant firm raises its prices, competition from both sides of a single location takes away more consumers than can be offset by the increase in the profits made on the remaining ones. The value of the merged firm will equal twice the stand-alone value of the firm, whereas costs associated with the merger turn the acquisition into a negative undertaking. Only the firm with two plants located next to each other meets competition at one side of its location. Therefore, the firm will only acquire neighboring firms when market power is the single source of value.

transaction costs. Obviously, the minimum acquisition price is the current standalone value of the target.

We can further tighten the range for the acquisition price. Note that in the initial symmetric setting, the consolidator can choose between acquiring either its right or its left neighbor, achieving exactly the same value as a merged entity, and is therefore indifferent between them. The target is not passive in price negotiation, but will try to negotiate a premium above its standalone value that at least matches its value in the new market structure. The lower bound on the price for a target is given by its modified standalone value when the acquirer buys the firm on its other side. Hence, when a lower price is offered, the target firm prefers to remain independent.

The higher bound on price is determined by the acquirer. The higher bound is given by the price that would deliver the same profits to the acquirer as when he would buy the other neighbor. In the symmetric case of this first acquisition, where either target will deliver the same value creation, the lower bound equals the higher bound on price. As we will see later, price boundaries may diverge and a negotiation region arises when industry structure becomes asymmetric. For instance, when the total value creation of the acquisition of target A is higher than that of target B, target B can appropriate only the minimum price. Target A can negotiate a price between the minimum price and the price that would make the surplus to the acquirer equal to its surplus from acquiring target B at the minimum price.

Consistent with the empirical evidence, the target receives the greater portion of the value created. The close outsiders or the direct rivals of the newly merged firm gain more from the increase in market power than the two insiders of the merged entity; which is reflected in the negotiation process. The price for the target is therefore at least equal to the value of the close outsiders. In addition, the acquirer incurs the transaction costs I.

For simplicity, we assume that Firm 1 is the consolidator and its value includes the acquisition option value, $O_A(\theta_t)$. Its close neighbors are Firm 2 and n, and their value includes an option to be acquired, $O_N(\theta_t)$. Other firms benefit from the acquisition and their value includes option value $O_i(\theta_t)$.

Proposition 1. *The surplus from the acquisition for the acquirer is given by*

$$S_A(\theta_t) = \max\left(\frac{\theta_t \lambda d^2}{\delta}\left[\left(1+z(-1)\right)^2 - \left(1+z(0)\right)^2 - 1\right] - I, 0\right). \tag{11}$$

The surplus increases with θ_t, the number of firms, n, and transportation costs, t. The surplus decreases with the fees, I. The surplus from the acquisition of both close neighbors is given by

$$S_N(\theta_t) = \max\left(\frac{\theta_t \lambda d^2}{\delta}\left[\left(1+z(0)\right)^2 - 1\right], 0\right). \tag{12}$$

The surplus increases with θ_t, and transportation costs, λ. The surplus decreases the number of firms, n. The surplus from the acquisition for other industry players depends on the location of the target relative to the acquirer.

$$S_i(\theta_t) = \max\left(\frac{\theta_t \lambda d^2}{\delta}\left[\left(1+z(j)\right)^2 - 1\right], 0\right), \tag{13}$$

where j = min(i-3, n-i) for i ≥ 3, when firm 1 acquires firm 2, and where j = min(i-2, n-i-1) when firm 1 acquires firm n.

The surplus for the acquirer, $S_A(\theta)$, in Eq. 11 consists of three parts. *Part 1* represents the value of the merged entity in the new market structure, $\frac{\theta_t \lambda d^2}{\delta}\left(1+z(-1)\right)^2$. The second part is the price of the target and the pre-merger value of the consolidator, $\frac{\theta_t \lambda d^2}{\delta}\left[-\left(1+z(0)\right)^2 - 1\right]$, that must be exchanged to receive *part 1*. The third part is the fee, *I*. The surplus for the neighbors and other industry players consists of two parts. The

first part equals the value of the firm in the modified market structure, $\frac{\theta_t \lambda d^2}{\delta}(1+z(i))^2$, and the second part equals the value of the firm before the acquisition, $\frac{\theta_t \lambda d^2}{\delta}$.

All surpluses of firms in the industry increase in θ_t, which indicates that mergers occur procyclically (see Lambrecht, 2004). When market demand has grown, the gains from the transaction exceed the transaction costs. Furthermore, the surplus increases with the number of firms that are active within the industry. The acquisition price decreases to a larger extent than the value of the merged entity, when the number of industry participants increases, *n*.

Proposition 2. *When there is no threat of pre-emption, the value of the option to acquire a neighbor firm is given by*

$$O_A(\theta_t) = \left(\frac{\theta_t \lambda d^2}{\delta} \left[(1+z(-1))^2 - (1+z(0))^2 - 1 \right] - I \right) \left(\frac{\theta_t}{\overline{\theta}} \right)^{\gamma}. \tag{14}$$

The option value to be acquired for both close neighbors is given by

$$O_N(\theta_t) = \left(\frac{\theta_t \lambda d^2}{\delta} \left[(1+z(0))^2 - 1 \right] \right) \left(\frac{\theta_t}{\overline{\theta}} \right)^{\gamma}. \tag{15}$$

The option value of the other industry participants benefiting from the acquisition is given by

$$O_i(\theta_t) = \tfrac{1}{2} \left(\frac{\theta_t \lambda d^2}{\delta} \left[\tfrac{1}{2}(1+z(j))^2 + \tfrac{1}{2}(1+z(j+1))^2 - 1 \right] \right) \left(\frac{\theta_t}{\overline{\theta}} \right)^{\gamma} \text{ for } i \geq 3, \tag{16}$$

where j = min(i-3, n-i) for i ≥ 3, and

$\bar{\theta} = \frac{\gamma}{\gamma - 1} \frac{I\delta}{\lambda d^2 \left[\left(1 + z(-1)\right)^2 - \left(1 + z(0)\right)^2 - 1 \right]}$ *is the threshold at which the option will be exercised, and γ is the positive root of the characteristic equation.*

$$\gamma = \frac{-(\mu - \sigma^2/2) + \sqrt{(\mu - \sigma^2/2)^2 + 2r\sigma^2}}{\sigma^2} > 1.$$

The option value for each of the players consists of two parts. The first part denotes the surplus that will be attained when the option is exercised by the acquirer at the optimal threshold and resembles proposition 1. The second part, $\left(\frac{\theta_t}{\bar{\theta}}\right)^{\gamma}$, represents the discount factor that determines the present value of receiving the surplus at the optimal threshold. The optimal threshold depends on the ratio between the acquisition costs, *I* and the surplus for the acquirer, $S_A(\theta)$, and the factor that represents the uncertainty in demand, $\frac{\gamma}{\gamma - 1}$. An increase in demand uncertainty raises the threshold and thereby delays the acquisition. In contrast, an increase in the market growth, μ, advances the acquisition. Lower acquisition costs, *I*, as compared to the surplus, $S_A(\theta)$, advances the acquisition as well.

When the acquirer faces competition from other firms in making the first acquisition, the timing of the acquisition may be accelerated under the threat of competition, and may take place at a lower demand threshold. A firm may also prefer to abstain from making the acquisition, as it gains more when a rival acquires a firm. As noted, all firms within the industry benefit from the increase in market power, while the closest outsiders benefit even more than the consolidator. Choosing to be an acquirer is therefore not a dominant strategy, when it is known that a close neighbor wants to make an acquisition. Only when a rival acquirer is located further away does making the acquisition become a dominant strategy. When it is uncertain which player will become the actual acquirer, the decision to acquire or to wait and become either a target or a

passive observer depends on the degree of fragmentation or the number of firms in the industry[11].

Firms have an incentive to become the acquirer in highly fragmented markets; the expected distance of a firm to the unknown consolidator is on average larger, as measured by the expected number of firms between them. The expected value of being an outsider is therefore lower than for being the acquirer, hence all firms prefer to be the acquirer. Firms prefer to make an acquisition when market demand reaches a threshold level such that the value of taking the role of acquirer equals the expected value of any other firm making the acquisition. In our model, a random selection mechanism (Nature) will determine who will acquire the first target. In the context of our model, the industry must be comprised of at least nine[12] firms to trigger the first acquisition (when the fee *I* equals 0). The number of required firms increases with *I*. With nine or more industry players, the expected value derived from taking the role of acquirer exceeds the expected value of waiting while a random rival makes the acquisition. The timing of the first acquisition will be advanced due to the threat of pre-emption. All firms prefer to acquire at the threshold level of demand, at which the expected value of making an acquisition equals the expected value of waiting. By taking the role of acquirer, firms can mitigate the disadvantages of a location at a greater distance from the consolidator and the merely marginal benefit derived from the rival's acquisition.

Firms prefer to wait in less fragmented markets. When an industry consists of fewer than nine firms (or more when the acquisition costs, *I*, increases), the value of waiting, while any of a firm's rivals acquires a target, exceeds the value of making the acquisition itself (independent of the level of demand). However, if all firms remain so passive, this would imply that no increase in market power would raise profits and that, therefore, a firm executing an acquisition would benefit compared with receiving nothing. In a mixed strategy equilibrium, each firm has a particular probability of acquiring

[11] For instance, Brito (2003) has shown that when 5 or fewer firms are present in an industry and the value creation is evenly shared between acquirer and target, the expected value of being an outsider exceeds the value of being an insider.

[12] The number of firms depends on the distance between firms, or the perimeter of the circle and the functional form of the transportation costs

another firm. There is no threat of pre-emption, as each firm prefers that a rival firm make the acquisition instead.

4. Industry Consolidation

In this section, we will discuss how the industry as a whole may respond to the first acquisition and to the increased market power of the combined entity.

4.A. Second Stage Industry Evolution Paths

For ease of exposition, we consider a market structure involving 9 firms. Figure 1 depicts the profits made as the industry evolves in different market structures. Panel A presents the first stage, where only two firms have merged and the rivals operate solitarily. As noted, close-in rivals of the merged firm have the highest plant profits and profits decrease for firms at greater distance from the merged entity.

Panels B–E show the possible industry structures and the associated profit stream for each firm or firm's plant when the second acquisition is made. The second acquisition in the industry may involve a follow-on acquisition by the merged firm, as represented in Panel B, or the rise of a second consolidating entity as shown in Panel C, D or E. In Panel B, the consolidator continuing its acquisition path delivers the highest overall industry profits, as compared with the other market structures. In Panel C, the two merged firms are located next to each other, and in Panel E the merged firms are located on opposite sides of the circle. In Panels C, D and E, the distance between the two consolidators increases and overall industry profits decline.

[Insert Figure 1]

4.A.1. Acquisition Prices and Surpluses of the Second Stage

The acquisition price depends on the strategic position of the target and the alternatives available to the bidder. Whereas the lower and upper boundaries on price are equal for the first acquisition in a symmetric industry structure, these bounds may diverge for the second acquisition when the industry structure becomes asymmetric. When the total

value creation scenario for an acquirer buying either its left or right neighbor differs, the more profitable target may demand a higher acquisition price.

Value creation and potential for target surplus are higher when the consolidated entities are located closer together. A target prefers to be acquired by a consolidator who is located between the target and the initial consolidated entity over being acquired by a rival at a greater distance from the initial consolidator. Similarly, the acquirer prefers to buy a target that lies between the existing consolidated entity and the firm, as this would again deliver the higher value creation and acquirer surplus. As a consequence, an acquirer preferred by a certain target prefers to buy a target at its other side. The acquirer's preferred target then has a greater ability to negotiate a favorable price within the lower and upper bounds of the price region. When this target demands the upper bound, the acquirer again becomes indifferent between its right and left neighbors.

For instance, Table 1 depicts value creation, minimum and maximum prices, and the corresponding surplus to the acquirer and the target for all possible combinations in the second stage. To illustrate the mechanisms of the lower and upper price boundaries, consider Firm 4 thinking about acquiring either Firm 5 (located at a larger distance from consolidator *m*) at price P_5 or Firm 3 (located closer to firm *m*) at price P_3. When Firm 3 is acquired, the value of Firm 5 equals $1.41\theta td^2$ and when Firm 5 is acquired, the value of Firm 3 equals $1.73\theta td^2$. Hence, Firm 4 prefers to acquire Firm 3, because the minimum price required by Firm 3 equals $1.73\theta td^2$ and the maximum is given by $1.84\theta td^2$, at which price the firm is indifferent about acquiring Firm 3 or Firm 5. Hence, the acquisition of Firm 5 is a dominated strategy and acquiring Firm 3 yields profits between $0.13\theta td^2$ and $0.24\theta td^2$. Firm 3 earns an amount between $0.40\theta td^2$ and $0.51\theta td^2$.

When the initial consolidator buys its neighbor, both prospective targets deliver the same value creation. The acquirer is indifferent between the two targets and the lower bound coincides with the higher bound on price, similar to the first acquisition in section 3. We observe in Table 1 that consolidator Firm *m* is in an advantaged position to acquire any of its new neighboring firms as a second acquisition. Firm 3 would deliver the same value creation, acquirer- and target-surplus as the alternative target, Firm 9. As

shown in Table 1 and Figure 1, Panel B, the price equals $1.72\theta td^2$. This acquisition delivers the highest surplus of all possible acquisitions within the industry and also delivers the highest positive externalities for rival firm value. The value creation for the acquirer equals $0.69\theta td^2$.

When an uneven number of firms operate within an industry, a second firm in addition to the initial consolidator exists which faces identical neighbors in terms of profits, such as Firm 6 in panel A. Firm 6 pays a higher premium over the current standalone value of the target relative to what Firm *m* would pay. A larger part of the value creation accrues to the target. The reduction of market share is smaller, as the interior plant does not face competition. Also, when a market structure is characterized by many firms, firms located at some distance from the already merged firm face identical (symmetrical) neighbors.

[Insert Table 1]

4.A.2. Consolidation Waves

Table 1 shows that the payoff from the second acquisition in the industry is higher for most combinations than from the first acquisition ($0.15\theta td^2 - I$). There is an increasing advantage of consolidation. The first acquisition is made when the surplus for the acquirer is high enough to justify the acquisition costs. Hence, the second acquisition with an even higher surplus is then certainly profitable at the same time. As a consequence, the consolidator will immediately buy the second add-on and would also prefer to buy a third, a fourth, and so on. Firms located at a large distance from the merged firm are in a position similar to the initial acquirer (with even higher surpluses). Hence, the first acquisition invites new acquisitions immediately and therefore results in a merger wave.

The consolidator may incorporate in the timing decision of its initial acquisition the likelihood of follow-on acquisitions. The consolidating firm may therefore advance the initial acquisition, if it intents to acquire several targets. Even when it is likely that a

rival firm makes the follow-on acquisition, the initial consolidator may advance its acquisition due to higher total industry profits.

The incentive to engage in a merger increases with each transaction made, because the intensity of competition in the product market declines faster with each merger and the wave thereby reinforces itself. The first target creates additional value, as it provokes a wave of acquisitions in which prices are raised, subsequently also benefiting the initial consolidator. Hence, waves occur procyclically, where one acquisition provokes the next. Our explanation for consolidation waves complements the current more general explanation for merger waves—that an industry shock or overvaluation of shares affects all firms within an industry in a similar manner.

4.B. Timing Under Competition in the First and Second Stages of Consolidation

In this section, we examine the strategies that the initial consolidator adopts to prevent nearby rivals from making acquisitions, while tolerating a rival consolidator in a remote market segment. Once the first acquisition has been completed, it is not only the consolidator who may be interested in making a follow-on acquisition. Aside from the consolidator, firms located far away from the merged firm are positioned to make acquisitions, while firms at an intermediate distance prefer to be passive observers. In addition, the price level - whether low or high - at which a target is acquired may influence other industry players. We assume that only two acquisitions can be made in an industry and that acquirers pay at the lower price bound for their targets.

From Table 1, we observe that the merged Firm *m* prefers to act as a consolidator over being the target, while all other firms prefer to become a target. In contrast to single-plant firms, Firm *m* realizes a higher profit when it acquires a second target rather than when it remains a passive observer or becomes a target. If the industry is of sufficient size, large rivals may compete for making the second acquisition. We can distinguish among the situations described below.

4.B.1. Industry Consolidation Without Rival Consolidators

In the first situation, Firm *m* conducts both the first and the second acquisitions and no rival consolidator arises. In a symmetric setting around Firm *m*, the second target's price

equals $1.72\theta td^2$, as given in Table 1. When we consider a sequence of investments, the first target will base its price on the market structure and the alternative market structures that ultimately result. Therefore, the first target will also demand a price of $1.72\theta td^2$, which represents its value, when the acquirer buys the two firms on either side of itself. Hence, when Firm 1 acquires Firm 2 and 3, it creates a value equal to $0.46\theta td^2$, but it must incur twice the transaction costs of *I* for each acquisition. Analogous to proposition 2, the timing of the two transactions, when there is no threat of a rival firm acquiring the same or another target, is given by the threshold level, $\overline{\theta}_m$:

$$\overline{\theta}_m = \frac{\gamma}{\gamma - 1} \frac{\delta I}{0.23td^2}. \tag{17}$$

4.B.2. Industry Consolidation When Adjacent Rivals May Compete

In the second situation, we allow Firm 4 and Firm 8 to compete with Firm *m* in making the second acquisition in the industry consolidation[13]. Firm *m* must mix its strategy by randomly choosing whether to acquire Firm 3 or Firm 9 in order to deter Firm 4 and Firm 8 from joining this acquisition game.

To illustrate this equilibrium, suppose that it is known that Firm *m* aims at acquiring Firm 3. Then, Firm 8 prefers to acquire Firm 9 rather than to remain a passive observer, which would deliver a payoff of $0.09\theta td^2$[14]. Firm 8's payoff from an acquisition would equal $0.23\theta td^2 - I$, which exceeds the value from waiting as long as $0.14\theta td^2 > I$. When the stochastic demand variable has reached the trigger in Eq. 17, it is also optimal for Firm 8 to make this acquisition. When Firm *m* intends to acquire Firm 9, Firm 4 is in a similar position as Firm 8 and would also favor its acquisition of Firm 3. However, now consider the case where Firm *m* randomly chooses a target, both Firm 4 and 8 will prefer to wait, as their expected payoff of waiting then equals

[13] Firm 3 and Firm 9 always prefer to be a target when Firm *m* makes the acquisition.

[14] The payoff of remaining a passive observer equals the difference in the current value and the value when Firm *m* acquires target Firm 3, as shown in Figure 1, Panels A and B.

$\frac{1}{2} \times 0.09\theta td^2 + \frac{1}{2} 0.64\theta td^2 = 0.36\theta td^2$, which exceeds the payoff from acquiring either Firm 3 or Firm 9[15].

4.B.3. Industry Consolidation When the Adjacent and Opposite Rivals May Compete

In the third situation, we allow Firm 6 to compete for making the second acquisition. In this situation, randomly choosing a target is not sufficient for Firm *m* to deter competition for the second industry acquisition. Firm *m* can choose to pre-empt Firm 6 from acquiring a neighbor firm by advancing the acquisition timing, or Firm *m* can accommodate Firm 6 to compete at the optimal time from a real options perspective. When uncertainty or market growth is high, accommodation of competition in consolidation is preferred over premature investment.

Consider first Firm 6's strategy where Firm *m* and Firm 6 compete for making the second acquisition. When two or more acquirers aim at buying a target, a random selection mechanism assigns who will be the acquirer. The payoff for Firm 6 when he buys either target Firm 5 or 7 is determined by $0.16\theta td^2 - I$. The value of remaining a passive observer for Firm 6, while Firm *m* buys either Firm 3 or Firm 9, equals $0.05\theta td^2$. Therefore, Firm 6 wants to acquire a neighbor as long as $0.11\theta td^2 > I$. Firm *m*'s payoff from remaining passive while Firm 6 acquires a target equals $0.05\theta td^2$ and therefore Firm *m* prefers to make the acquisition as well ($0.69\theta td^2 > 0.05\theta td^2$).

When Firm *m* competes with Firm 6 in the second stage, the price of Firm *m*'s first target depends on three possible industry structures that may result after two acquisitions have been made within the industry. The price is then given by the target's expected alternative value $\frac{1}{2} \times 1.72\theta td^2 + \frac{1}{4} \times 1.37\theta td^2 + \frac{1}{4} \times 1.44\theta td^2 = 1.56\theta td^2$. The first term with probability ½ represents the alternative value of the first target when Firm *m* can buy the second target, and the second and third parts, each with probability ¼, represent the value of the target when Firm 6 buys either its left or its right neighbor. As a

[15] Note that when Firm 4 and Firm 8 pay the upper bound on price, the argument to wait becomes even stronger.

consequence, the expected payoff for Firm *m* from acquiring the first target and the second target with probability ½ is given by

$$\begin{aligned}&\tfrac{1}{2}(4.89\theta td^2-\theta td^2-1.56\theta td^2-1.72\theta td^2-2I)+\tfrac{1}{2}(2.53\theta td^2-\theta td^2-1.56\theta td^2-I)=\\&=0.30\theta td^2-1\tfrac{1}{2}I\end{aligned} \tag{18}$$

The first term presents the value of Firm *m* when succeeding in making two acquisitions. It consists of the entity value deducted by the pre-consolidation value of Firm 1, the acquisition price of Firm 2 and 3, and the fees, *I*. The second term gives the value when Firm *m* acquires only the first target. It consists of the entity value deducted by the pre-consolidation value of Firm 1, the acquisition price of the first target and any acquisition fees.

If Firm *m* can optimally time the first acquisition and competes immediately thereafter with Firm 6 for making the second industry acquisition, the demand trigger at which the first acquisition will be made is given by:

$$\overline{\theta}_c=\frac{\gamma}{\gamma-1}\frac{\delta I}{0.20td^2}. \tag{19}$$

Hence the option value for Firm *m* given this strategy is given by

$$\left(0.30\overline{\theta}_c td^2-1\tfrac{1}{2}I\right)\left(\frac{\theta_t}{\overline{\theta}_c}\right)^{\gamma} \tag{20}$$

Firm *m* also has a second strategy to pre-empt Firm 6 by advancing its acquisition at a lower level of market demand. Firm *m* may want to make its acquisition at a lower level of stochastic demand than the optimal trigger from Eq. 19 and thereby ensure that Firm 6 does not make the second industry acquisition. When Firm *m* buys the first and second targets as soon as stochastic market demand, θ_t, has reached trigger $\overline{\theta}_p=\frac{\delta I}{0.11td^2}$, Firm

6 will be indifferent in remaining a passive observer or an acquirer. Firm *m* still has a positive NPV from acquiring at this time:

$$NPV = 0.46\frac{I}{0.11td^2}td^2 - 2I = 2.18I\,, \tag{21}$$

which exceeds the payoff from being the first acquisition and lets Firm 6 buy the second acquisition. It is not credible for Firm *m* to commit to making only the first acquisition and not joining the competition with Firm 6 to making the second acquisition.

Whether Firm *m* opts for the early investment or for an optimally timed acquisition depends the root γ of the characteristic equation in Proposition 2. The value of pre-emption, as presented in Eq. 21, equals the value of optimally competing as shown in Eq 20, where $\gamma = 1.69$. For values of γ below 1.69, Firm *m* prefers to compete with Firm 6 and for values above 1.69, Firm *m* prefers to pre-empt its rival. The parameter γ incorporates uncertainty, σ, the risk free interest rate, *r*, and market demand growth, μ, as shown in proposition 2. Hence, when uncertainty decreases, the interest rate decreases, or when the difference between the interest rate and the growth rate increases, the strategy of pre-emption becomes more attractive. Then, the optimal demand level to acquire while inviting competition will decline.

4.B.4. Industry Consolidation with Passive Observers

In the above situation, Firm 4, Firm 5, Firm 7 and Firm 8 prefer to remain passive. The expected payoff from waiting exceeds the payoff from making an acquisition independent of the strategy chosen by Firm *m*.

When Firm *m* and Firm 6 have an equal probability of making the second acquisition and randomly choose a right or left target, the expected payoff for Firm 4 and 8 is given by $0.29\theta td^2$ [16]. Because the expected payoff from remaining a passive observer

[16] The four possible industry structures deliver the following surplus to Firm 4 or Firm 8:
$\frac{1}{4}\times 0.63 + \frac{1}{4}\times 0.09 + \frac{1}{4}\times 0.35 + \frac{1}{4}\times 0.09 = 0.29$.

exceeds the payoff from acquiring ($0.23\theta td^2 - I$), Firm 4 and Firm 8 will remain passive observers.

Extending the above analysis by allowing Firm 5 and Firm 7 to compete for making an acquisition does not alter the results. When Firm *m* accommodates competition with Firm 6, Firm 5 and 7 do not want to enter the competition for making the second acquisition and when Firm *m* pre-empts Firm 6, it also pre-empts Firm 5 and Firm 7. The expected payoff[17] for Firm 5 and Firm 7 for remaining passive observers equals $0.22\theta td^2$, which exceeds the payoff of making the acquisition of Firm 4 or Firm 8 respectively, which equals $0.17\theta td^2 - I$.

When Firm *m* pre-empts Firm 6, both Firm 5 and Firm 7's value in remaining passive observers equals $0.09\theta td^2$. The value of making an acquisition is again given by $0.17\theta td^2 - I$. Hence, it is optimal for either of Firm 5 or Firm 7 to make an acquisition when $0.08\theta td^2 > I$. The level of stochastic demand at which Firm 5 or Firm 7 may want to compete with Firm *m* in making an acquisition is hence given by $\bar{\theta}_{p5,7} = \frac{I}{0.08td^2}$, which exceeds the level at which Firm 6 is deterred.

4.B.5. Industry Consolidation with Competition for the First Target

Finally, returning to the first stage of the consolidation, firms may also compete for being the initial consolidator. Firms face a trade-off in the value of trying to pre-empt and thereby advance the acquisition of the first target, or preferring to remain as passive observers and thereby profiting from rivals' efforts toward industry consolidation. In the consolidation game with 9 firms, the expected value of waiting equals $0.37\theta td^2 - \frac{1}{16}I$. In the consolidation game a firm can be in any of the eight different positions relative to the initial consolidator and hence the value of waiting equals the expected value of these 8 firm values. When the firm is exactly opposite from the entity composed of a single

[17] The value of Firm 5 or Firm 7 in the alternative market structure with either Firm *m* making the acquisition, or Firm 6 making an acquisition is given by $\frac{1}{2}\times 0.34 + \frac{1}{4}\times 0.15 + \frac{1}{4}\times 0.03 = 0.22\theta td^2$

acquisition, which happens with probability ⅛, it succeeds with probability ½ in acquiring a target, which explains the expected costs being equal to $\frac{1}{16}I$.

In an industry of 9 firms in which two acquisitions will be made, all firms prefer that a rival firm makes the first acquisition, as the expected payoff from waiting and benefiting from the consolidation started by a rival exceeds the payoff from being the first consolidator. However, when all firms wait, consolidation does not commence and the payoff would remain at zero. In a mixed strategy equilibrium, each firm will invest with a certain probability at the optimal time for the first acquisition, when the stochastic demand, θ_t, reaches either the pre-emption trigger or the allowing competition trigger.

4.C. Implications and Extensions

Consolidation reduces the intensity of competition within an industry. In a market with product differentiation, a merger benefits both insiders and outsiders. The merged firm is able to raise prices benefiting rival firms as well. The merged firm has locked in some consumers and now enjoys a small monopoly in a certain market segment. Rivals will raise their prices in response to the merged firm's price increases.

The value of the first acquisition can be considered as a real option. The initial platform acquisition creates the opportunity to continue the consolidation of the industry. A real option valuation incorporates the intertemporal synergies of a consolidation strategy and will determine the timing and pricing of the first and the follow-on acquisitions.

In our framework, we find that each firm has a specific role in industry consolidation. A consolidator, having acquired a first target, is better able to acquire a follow-on target. Closely related rival firms prefer to remain passive or to be a target and do not engage in acquisitions. Only at the opposite market segment do firms not sufficiently benefit, and such a firm may want to become an acquirer. When market uncertainty is low, market growth is low compared to the interest rate and the initial consolidator can pre-empt this opponent.

In particular, firms prefer to wait and to benefit from the consolidation commenced by a close rival; and there is no competition for being the initial consolidator

nor is there an incentive to pre-empt, when market fragmentation is low. However, when the first acquisition has been carried out, the second acquisition will be made immediately thereafter. The increasing advantage of consolidation will result in a merger wave where each acquisition makes a follow-on acquisition more attractive.

The value of consolidation increases with the number of potential acquisitions. Allowing for more than two acquisitions, the value creation of the consolidator increases to a larger extent than the prices to be paid for targets. In addition, firms located at a greater distance from the first merged entity now have a preference for being the passive observer or potential target. For instance, Firm 6 would prefer to remain passive if we allow for 3 acquisitions. The consolidator will ultimately acquire these firms for a high price, or they will become a close neighbor of the consolidator.

It becomes more attractive to be the first to acquire a target when more acquisitions will be undertaken. As noted, the value of the pre-emption strategy increases with each acquisition. In addition, while firms prefer to remain passive in a nine firm industry setting in which two acquisitions will be made, the value of the consolidation increases and competition may arise for initial consolidator status when more industry acquisitions are allowed.

The threat of pre-emption may increase with the number of players within the industry. When there is more fragmentation, the value of waiting decreases. The increase in market power is concentrated at the other side of the market. Once the first acquisition has been undertaken, more firms at a relatively greater distance will decide to make the second acquisition. Those firms are characterized by less asymmetric neighbors and they are able to extract a larger part of the value creation. In addition, increased expected distance between a firm and the merged entity makes the alternative of passively observing industry evolution less attractive.

5. Conclusion

In an industry evolving toward a new market structure, we expect that in each market segment a consolidator rolls up its close competitors. Those competitors prefer to passively observe the outcome as a potential target rather than engaging in acquisitions

themselves. Firms located further away may also act as consolidator as they will neither be a target nor benefit from the increase in market power. The timing of the consolidation strategy depends on the value of waiting and hoping that a close rival starts the consolidation relative to the value of being a consolidator.

The first acquisition provokes further consolidation, as later acquisitions are more profitable and hence merger waves arise endogenously. We have shown that mergers do not occur solely due to an industry shock—in our case an increase in demand—but also due to a self reinforcing effect, as industry competition declines in an accelerated fashion.

The timing of the initial acquisition depends on the number of firms in the industry, demand growth and uncertainty, and the level of market demand. Acquisitions, and hence consolidation waves, occur pro-cyclically. Highly fragmented industries are more competitive and a consolidation wave may occur relatively early. The role of consolidator is more valuable than that of a passive observer in highly fragmented industries. In industries with fewer firms, firms may benefit more from simply passively awaiting the consolidation started by a rival. The timing then depends on the consolidator, who prefers to make the acquisition itself and may gain then maybe less than rivals, but more than when no consolidation occurs at all.

The first acquisition redefines the position of ex-ante symmetric firms. Although the reduced competition benefits all firms, close rivals benefit more than firms located at a greater distance. Although the merged entity benefits less than close rivals, it has taken control of a strategic advantage in the form of a good strategic position to implement follow-on acquisitions. Firms in a remote market segment are in a similar position as the initial consolidator and are likely to make an acquisition as a first link in a chain of consolidation acquisitions. Firms that are located in a related market segment as the initial consolidator prefer to remain passive or to become a target in a later phase of the consolidation. The large asymmetry between these firms' two neighboring firms means that most of the value creation will accrue to the target. Benefiting indirectly from a rival's acquisition is then preferred over the smaller acquirer's surplus.

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Appendix

A. Proof of Section 2.2

Demand for Firm *m* when setting prices p_1 and p_2 is given by

$$D(p_1, p_2, p_n, p_3) = \frac{p_n + p_2 - 2p_1 + 2td}{2t} + \frac{p_3 + p_1 - 2p_2 + 2td}{2t}. \quad \text{(A.1)}$$

Its profit is given by

$$\pi(p_1, p_2, p_n, p_3) = p_1 \frac{p_n + p_2 - 2p_1 + 2td}{2t} + p_2 \frac{p_3 + p_1 - 2p_2 + 2td}{2t}. \quad \text{(A.2)}$$

The first order conditions for Firm *m* are given by

$$\frac{\partial D(p_1, p_2, p_n, p_3)}{\partial p_1} = \frac{p_n + 2p_2 - 4p_1 + 2td}{2t} \quad \text{(A.3)}$$

$$\frac{\partial D(p_1, p_2, p_n, p_3)}{\partial p_2} = \frac{p_3 + 2p_1 - 4p_2 + 2td}{2t}. \quad \text{(A.4)}$$

The first order condition for other firms *i* are given by

$$\frac{\partial D(p_1, p_2, p_n, p_3)}{\partial p_i} = \frac{p_{i+1} + p_{i-1} - 4p_1 + 2td}{2t}. \quad \text{(A.5)}$$

Hence, we must solve the following system of equations for all prices to solve the game.

$$\begin{bmatrix} -4 & 2 & 0 & 0 & \dots & 0 & 1 \\ 2 & -4 & 1 & 0 & \dots & 0 & 0 \\ 0 & 1 & -4 & 1 & 0\dots & 0 & 0 \\ \vdots & & & & & & \vdots \\ 1 & 0 & 0 & 0 & \dots 0 & 1 & -4 \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ \vdots \\ p_n \end{bmatrix} = \begin{bmatrix} -2td \\ -2td \\ -2td \\ \vdots \\ -2td \end{bmatrix}$$

Each row l_i can be rewritten as a combination of later rows.

$$l_1 - \sum_{j=1}^{n-2} u_j l_{n-j} \text{ and } l_2 - \sum_{j=1}^{n-3} u_j l_{j+3} - u_{n-2} l_1 ,$$

where $u_i = \dfrac{a^i - a^{-i}}{2\sqrt{3}}$ and $a = 2 + \sqrt{3}$.

Hence, the first two rows of the matrix are given by

$$-(4 + 2u_{n-2})p_1 + (2 + 4u_{n-2} - u_{n-3})p_2 = -2td + \sum_{j=1}^{n-2} u_j (2td) \qquad \text{(A.6)}$$

$$(2 + 4u_{n-2} - u_{n-3})p_1 - (4 + 2u_{n-2})p_2 = -2td + \sum_{j=1}^{n-2} u_j (2td) \qquad \text{(A.7)}$$

Using a symmetry argument for Firm m, p_1 equals p_2.

$$(-2 + 2u_{n-2} - u_{n-3})p_m = -2td + \sum_{j=1}^{n-2} u_j (2td)$$

$$p_m = \frac{(-2td)(1 - \sum_{j=1}^{n-2} u_j)}{(-2 + 2u_{n-2} - u_{n-3})} \quad \text{or}$$

$$p_m = (td)\left(1 + \frac{2\sqrt{3} - a^{n-2} + a^{2-n}}{\sqrt{3}(4 - a^{2-n} - a^{n-2})}\right). \quad \text{(A.8)}$$

While the prices of the neighboring firms can be found recursively by

$$p_i = (td)\left(1 + z(j)\right) \text{ for } j = \min(\text{i-3, n-i}) \text{ for } i \geq 3, \quad \text{(A.9)}$$

and $z(j) = \dfrac{a^{-j} - a^{j} - a^{n-3-j} + a^{3+j-n}}{\sqrt{3}(4 - a^{2-n} - a^{n-2})}$,

profits for Firm *m* are then given by

$$\pi_m = td^2\left(1 + \frac{2\sqrt{3} - a^{n-2} + a^{2-n}}{\sqrt{3}(4 - a^{2-n} - a^{n-2})}\right)^2. \quad \text{(A.10)}$$

For rival firms,

$$\pi_i = td^2\left(1 + z(j)\right)^2 \text{ for } j = \min(\text{i-3, n-i}) \text{ for } i \geq 3. \quad \text{(A.11)}$$

B. Proof of Propositions

Proof of Proposition 1.

The surplus for the acquirer follows directly from deducting the price of the target, the current stand alone value of the acquirer, and the investment fee from the value of the merged entity. The surplus for the target is given by the difference in price and current standalone value, and the surplus for the neighbors is given by the difference between the value after the merger and the current standalone value.

The acquirer's surplus increases linearly in θ_t and transportation costs *t*, and decreases linearly in *I*. When the number of firms increases from n to n + 1, the

difference in the increase in value of the merged entity and its price depends crucially on the numerator, which is the only term for which the equations for value and price differ. For n = 3, the value of the numerator equals 0 for both value and price. When the number of firms increases by 1, the numerator of value decreases by

$$-(1+\sqrt{3})a^{n-2}+(1-\sqrt{3})a^{2-n},$$

and the numerator of price decreases by

$$(1-\sqrt{3})a^{n-2}-(1+\sqrt{3})a^{2-n}.$$

The difference between the above equations is always negative

$$-(2)a^{n-2}+(2)a^{2-n}<0 \text{ for n >3.} \tag{A.12}$$

Hence, because the denominator is negative, the difference in value of the merged entity and price of the target increases with the number of firms *n*.

The surplus of the close neighbors decreases with the number of firms, *n*,

$$\pi_m = td^2\left(1+\frac{-a^{n-3}+a^{3-n}}{\sqrt{3}(4-a^{2-n}-a^{n-2})}\right)^2. \tag{A.13}$$

When the number of firms increases, the denominator decreases by more than the numerator. Note that the numerator equals the denominator for n = 2.

The difference in the numerator is given by

$$(1-1\sqrt{3})a^{n-2}+(-1-1\sqrt{3})a^{2-n}.$$

The difference in the denominator is
$(-\sqrt{3}-3)a^{n-2})+((3-\sqrt{3})a^{2-n}$.

When the difference in the denominator is less than twice the difference in the numerator, the surplus decreases, or

$$(\sqrt{3}-5)a^{n-2})+((5+\sqrt{3})a^{2-n}<0 \text{ for } n>2. \quad \text{(A.14)}$$

Therefore, the surplus decreases with the number of firms.

Proof of Proposition 2

Let $R_i(\theta, n)$ denote the value of each agent's option. Using standard arguments (Dixit and Pindyck, 1994), R must solve the following differential equation

$$0=\tfrac{1}{2}\sigma^2\theta^2 R_{\theta\theta}+\mu\theta R_\theta - rR\,. \quad \text{(A.15)}$$

Equation 1 must be solved subject to appropriate boundary conditions. The boundary conditions for the acquirer are given by

$$R[\bar{\theta}]=\frac{\theta_t td^2}{\delta}\left[(1+z(-1))^2-(1+z(0))^2-1\right]-I\,, \quad \text{(A.16)}$$

and the smoothpasting condition

$$R_\theta[\bar{\theta}]=\frac{td^2}{\delta}\left[(1+z(-1))^2-(1+z(0))^2-1\right]. \quad \text{(A.17)}$$

Closed-form solutions for $R_A(\theta, n)$ and the trigger θ^* are easily obtained.

$$R_A(\theta_t) = \begin{cases} \left(\frac{\theta_t td^2}{\delta} \left[(1+z(-1))^2 - (1+z(0))^2 - 1 \right] - I \right) \left(\frac{\theta_t}{\bar{\theta}} \right)^{\gamma} & \text{for} \theta < \bar{\theta} \\ \frac{\theta_t td^2}{\delta} \left[(1+z(-1))^2 - (1+z(0))^2 - 1 \right] - I & \text{for} \theta \geq \bar{\theta} \end{cases}, \quad \text{(A.18)}$$

where

$$\bar{\theta} = \frac{\gamma}{\gamma - 1} \frac{\delta I}{td^2 \left[(1+z(-1))^2 - (1+z(0))^2 - 1 \right]},$$

and

$$\gamma = \frac{-(\mu - \sigma^2/2) + \sqrt{(\mu - \sigma^2/2)^2 + 2r\sigma^2}}{\sigma^2} > 1,$$

where $\mu < r$ to ensure convergence.

The boundary condition for the target and close neighbor is given by

$$R[\bar{\theta}] = \frac{\theta_t td^2}{\delta} \left[(1+z(0))^2 - 1 \right]. \quad \text{(A.19)}$$

The smoothpasting condition is not required. Hence the option value is given by

$$R_N(\theta_t) = \begin{cases} \left(\frac{\theta_t td^2}{\delta} \left[(1+z(0))^2 - 1 \right] \right) \left(\frac{\theta_t}{\bar{\theta}} \right)^{\gamma} & \text{for} \theta < \bar{\theta} \\ \frac{\theta_t td^2}{\delta} \left[(1+z(0))^2 - 1 \right] & \text{for} \theta \geq \bar{\theta} \end{cases}. \quad \text{(A.20)}$$

For other rival firms, the position of the target determines their distance from the newly merged entity. With probability ½, the distance is given by the number of firms between the firm itself and the acquirer, and with probability ½ the distance is the same number of firms mines one. The boundary condition is then given by

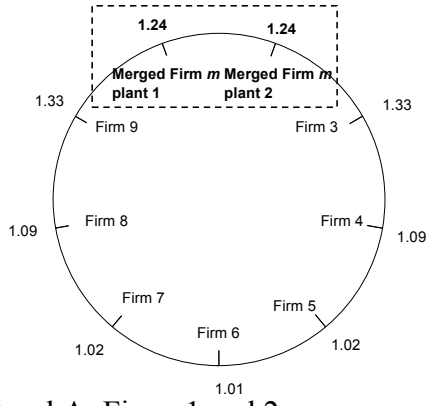
$$R[\bar{\theta}] = \tfrac{1}{2}\frac{\theta_t t d^2}{\delta}\left[(1+z(j))^2 - 1\right] + \tfrac{1}{2}\frac{\theta_t t d^2}{\delta}\left[(1+z(j+1))^2 - 1\right], \qquad \text{(A.21)}$$

where j = min(i-3, n-i) for $i \geq 3$.

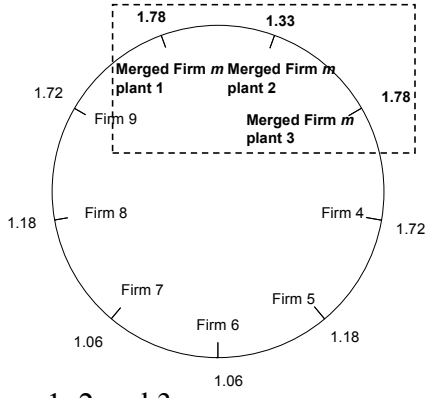
$$R_N(\theta_t) = \begin{cases} \left(\frac{\theta_t t d^2}{\delta}\left[\frac{1}{2}(1+z(j))^2 + \frac{1}{2}(1+z(j+1))^2 - 1\right]\right)\left(\frac{\theta_t}{\bar{\theta}}\right)^{\gamma} & \text{for}\theta < \bar{\theta} \\ \frac{\theta_t t d^2}{\delta}\left[(1+z(j))^2 - 1\right] & \text{for}\theta \geq \bar{\theta} \\ \frac{\theta_t t d^2}{\delta}\left[(1+z(j+1))^2 - 1\right] & \text{for}\theta \geq \bar{\theta} \end{cases} . \qquad \text{(A.22)}$$

When the trigger $\bar{\theta}$ has been reached, the location of the target becomes known and a jump in value of the firm occurs of size $\frac{\theta_t t d^2}{\delta}\left[\frac{1}{2}(1+z(j))^2 - \frac{1}{2}(1+z(j+1))^2\right]$ either upwards or downwards.

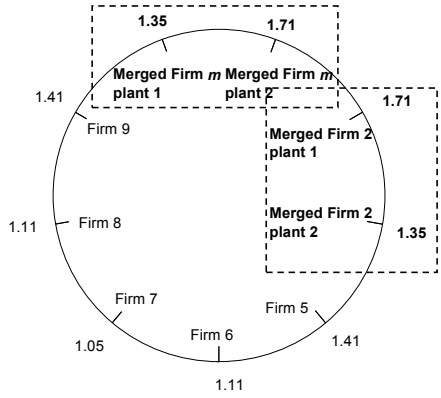
Figure 1. Profits in the Circular City Model with Merged Entities.



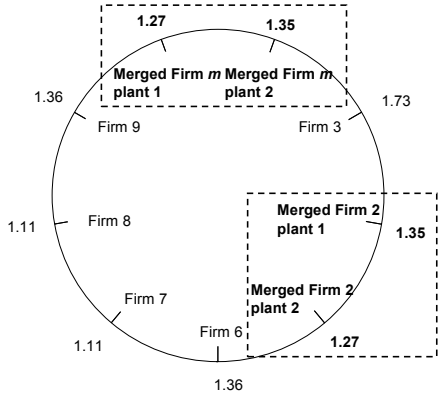
Panel A: Firms 1 and 2 merge



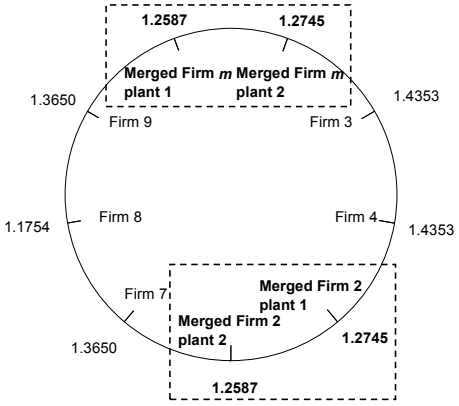
Panel B: Firms 1, 2 and 3 merge



Panel C: Firms 1 and 2 merge and Firms 3 and 4 merge



Panel D: Firms 1 and 2 merge and Firms 4 and 5 merge



Panel E: Firms 1 and 2 merge and Firms 5 and 6 merge

The circles in each panel present the nine firm plants and their respective profits in different industry settings where some firms may have merged and consequently set prices at their locations jointly. The parameters chosen are t =1, d = 1 and θ_t =1.

Table 1. Value Creation, Price and Acquirer and Target Surplus in the Second Stage

Acquirer	*Target*	*Merged Firm value*	*Value Creation*	*Price or Price Range*	*Acquirer Surplus*	*Target Surplus*
1 (m)	2 (m)	2.49	0.49	1.34	0.15	0.34
m	3	4.89	1.07	1.72	0.69	0.38
m	9	4.89	1.07	1.72	0.69	0.38
3	m	4.89	1.07	3.06	0.50	0.56
3	4	3.06	0.64	1.72	0.01	0.63
4	**3**	**3.06**	**0.64**	**1.73 - 1.84**	**0.13 - 0.24**	**0.40 - 0.51**
4	**5**	**2.63**	**0.52**	**1.41**	**0.13**	**0.39**
5	4	2.63	0.52	1.44 - 1.45	0.15 - 0.17	0.35 - 0.37
5	6	2.53	0.50	1.36	0.15	0.35
6	5	2.53	0.50	1.37	0.16	0.34

This table shows, for each possible combination of acquirer and target, the total value of the new firm, the value creation by merging the two entities, range of acquisition price and the associated surplus for the acquirer and the target in the second stage of the consolidation. Firm *m* is the combination of Firms 1 and 2 that merged in the first stage.