# Stabilising Merger Waves: An Agent-Based Networked Model of Market Stability

### Camillia Zedan

Seth Bullock

Institute for Complex Systems Simulation University of Southampton, UK Email: c.zedan@soton.ac.uk Institute for Complex Systems Simulation University of Southampton, UK Email: sgb@ecs.soton.ac.uk

### Antonella Ianni

School of Social Sciences University of Southampton, UK Email: a.ianni@soton.ac.uk

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#### Abstract

The world's markets are increasingly interconnected, imposing additional challenges for both regulators and market participants. This paper considers the effect of inter-market dependencies on the spread of endogenously generated merger waves. Though merger activity can generate efficiency gains, it disrupts market competition and can lead to negative effects for consumers. The conditions under which disruptive merger activity can spread to otherwise stable markets are identified. It is also shown which inter-market dependency configurations are more likely to lead to situations in which the stability of some markets can be disrupted by merger activity in others.<sup>1</sup>

*Keywords*— Cournot competition, agent-based simulation, endogenous mergers, emergent behaviour, merger waves.

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# 1 Introduction

The world's markets are increasingly interconnected. Since 2000, despite the financial crisis, global trade has almost tripled in value (WTO, 2013) and foreign direct investment has increased by more than 25% (WB, 2013). This presents a number of difficulties for regulators, whose aim it is to encourage competition and maintain consumer welfare. Consequently, regulation of competition at the national level alone has become inadequate (McGowan and Cini, 1999). An increasing number of regulatory bodies are working together to develop competition policy principles to rule on cases in which the consequences of activity in one country might significantly impact other countries (see ICN, 2013).

Of particular interest to regulators are the consequences of mergers. Though merger activity can generate efficiency gains, it disrupts market competition and can lead to negative effects for consumers. Mergers have also been found to increase systemic risk (Mishkin, 1999): the risk that a failure in one part of a system can spread to the whole system. When two firms merge, the resultant merged firm is often a larger, more significant market player with more dependents and more market power. Consequently, its failure will have a larger impact on the surrounding markets. In 2010 the US Congress passed the Dodd-Frank Act, which explicitly requires that all proposed mergers are evaluated not just by their potential effect on competition, but by their 'systemic footprint' as well (Tarullo, 2011).

Understanding the extended impact of merger activity is made complicated by dynamic dependencies between markets, such as supply chains. Firms dependent on a merging firm, such as suppliers or distributers, are likely to be affected by merger decisions, in addition to direct competitors. For example, changes to demand have been found to cause merger waves: unpredictable periods of increased merger activity (Harford, 2005). Similarly, Ahern and Harford (2013) finds that dependencies between markets can act as pathways for merger waves to spread.

In this paper, we investigate the effect of inter-market dependencies on the spread of endogenously generated merger waves. This is done by constructing an agent-based simulation model of endogenous horizontal merging in connected markets. Merger waves are then generated by applying shocks to supply and demand, corresponding to the neoclassical and behavioural theories of merger wave causes (Harford, 2005). We then identify the conditions under which waves can spread to markets that would have otherwise remained stable. We also identify which inter-market dependency configurations are more susceptible to disruption than others, and discuss the potential for such agent-based models to provide regulators with methods of protecting against destabilising behaviour.

# 2 Model

Following representations in the literature (eg Qiu and Zhou, 2005; Neary, 2007; Horn and Persson, 2001), in our model, a market is composed of a number of agents who engage in a repeated two-stage game: in the first stage, agents are given an opportunity to merge, and in the second stage, they compete to produce a homogeneous good. Markets are connected through supply chains: the goods produced by firms in one market supply the production of firms in downstream markets.

Each timestep, for each market: (1) all firms in a market evaluate whether or not they wish to merge; (2) of the firms that wish to merge, one is chosen at random to perform a merger; (3) all firms establish an ideal production quantity (as in a Cournot competition); (4) all firms attempt to source goods from firms in supplier markets; (5) all firms produce.

In addition to this, two firms with randomly assigned costs attempt to enter the market and at most two are randomly removed. This encourages a turnover of market participants and prevents 'lockout', the situation in which certain entrants become unable to successfully produce in a market (see Zedan et al., 2013).

Since the goods produced in one market supply another, an ordering is applied on how markets are updated.

### A Market

A market M is a set of firms, where |M| = m. Each firm i is randomly assigned a production cost  $c_i$  from within a range  $[c_{\min}, c_{\max}]$ .

Endogenous merging is modelled as a two-stage game (as in Neary (2007), Qiu and Zhou (2005) and Zedan et al. (2013)): in the first stage, firms decide whether or not to merge, and in the second stage, firms engage in a Cournot quantity competition. The second stage incentivises the first. Therefore, we consider the second stage first.

#### Stage 2: Competition

In the second stage, all firms in a market engage in a Cournot quantity competition. That is, all firms produce an identical good, at constant marginal cost and no fixed cost, facing a linear inverse demand curve:

$$P = \alpha - Q$$

where P is the market price,  $\alpha$  is the market size and Q is total output of all firms in the market.

Therefore, the profit-maximising quantity  $q_i^M$  for firm *i* to produce in market *M* is given by:

$$q_i^M = \frac{\alpha + \sum\limits_{j \in M} c_j}{m+1} - c_i \tag{1}$$

We can also define the profit as:

$$\pi_i^M = (P \cdot s_i^M) - (c_i \cdot q_i^M) \tag{2}$$

where  $\pi_i^M$  is the profit for firm *i* in market M,  $s_i^M$  is the quantity of goods sold by *i*, *P* is the price at which they were sold,  $q_i^M$  is the quantity produced and  $c_i$  is *i*'s cost of production.

To ensure all operating firms are producing non-negative quantites at initialisation, the market size,  $\alpha$ , must follow:

$$\alpha > \alpha_0 \equiv (m+1)c_m - \sum_{i=1}^m c_i \tag{3}$$

where  $c_m$  is the largest production cost in the market.

Additionally, following Qiu and Zhou (2005), an upper bound of  $\alpha$  is also defined for which a merger i + j (where m > 2 and  $c_i < c_j$ ) is profitable:

$$\alpha \le \frac{(m+1)}{(m-1)^2 - 2} ((m^2 - 1)c_j - 2mc_i) - \sum_{k=1}^m c_k \equiv \alpha_{i,j}^M$$
(4)

If, at time  $t, \alpha_{i,j}^M \ge \alpha_0$  for some i, j such that  $i \ne j$ , there is at least one profitable merger in the system.

- When α > α<sup>M</sup><sub>i,j</sub> ∀i, j such that i ≠ j, the market size is too large to make any strategic merger profitable.
- When  $\alpha < \alpha_0$ , there is not a minimum amount of demand to keep all firms producing.

Therefore, we define  $\alpha_{\max}$  and  $\alpha_{\min}$  as the maximum and minimum values of  $\alpha$  for which mergers are profitable.

$$\alpha_{\max} = \max(\alpha_{i,j}^M) \quad \forall i, j \ i \neq j \tag{5}$$

Consequently, a market may be in one of three states based on  $\alpha$  (see Figure 1):

- 1. Stable (no mergers are desirable and all agents are producing goods);
- 2. Unstable:
  - (a) Mergers are desirable and all agents are producing goods;
  - (b) Mergers are desirable and not all agents are producing goods.



Figure 1: Abstract borders of market size values that incentivise merging and production.

### Stage 1: Merging

In the first stage of the game, firms must decide whether or not to merge based on the payoff they expect to receive in the second stage.

Any firm in the market can act as an acquirer or be a target of a merger offer. Whenever a merger takes place, one firm ceases to operate (the target of the merger). Therefore, the number of operating firms m is then reduced by one unit. As a result, market competition is reduced and all post-merger operating firms benefit (an instance of the free-riding effect, see Clougherty and Duso (2008)). This benefit increases with the efficiency of the target of the merger; the lower the production cost of a firm, the greater its efficiency. However, efficient targets also demand higher

acquisition prices. Consequently, the net effect of a merger depends upon the cost configuration of acquirer and acquiree.

Let us consider the merger process in more detail. An acquirer chooses whether to propose a merger to a given target firm at a given price, or to pass. A target chooses whether to accept or decline the offer.

As a target's opportunity cost of accepting a merger's offer is its current profit, the optimal acquisition strategy, when there are m active firms in the market, is to offer target j the acquisition price of  $\pi_j^M$ . At this stage, firms assume they will be able to source all goods required for production and sell all produce. Therefore, let the expected profit for firm i in market M be  $\pi_i^M = (q_i^M)^2$ .

Acquirer *i*'s expected profit from proposing to acquire *j*, at price  $\pi_j^M$ , in a market with *m* active firms is denoted by  $\pi_{i+\{j\}}^{M-\{j\}} - \pi_j^M$  and, in equilibrium, target *j* accepts the offer of  $\pi_j^M$ .

As a result, a merger is profitable if it generates positive surplus, i.e., if the post-merger profit of operating firms net of their pre-merger profit is positive:

$$\pi_{i+\{j\}}^{M-\{j\}} - \pi_i^M - \pi_j^M > 0 \tag{6}$$

A firm may have a strategic incentive to wait and free-ride on other firms merging, as, by doing this, it may enjoy the benefit of decreased competition without having to pay the acquisition cost.

## Supply Chains

Having determined whether or not to merge and how many goods they wish to produce in the competition stage, firms then need to source and later sell their goods. Exogenously defined supply chains determine which markets supply other markets.

Dependent on the configuration of markets, a market may act as both a supplier market and/or a distributor market. Supplier markets sell their goods to distributor markets, that use those goods in their own production. We assume a one-to-one ratio for production: one unit of supply good is required in order to produce one unit of good for any given market.

Of additional consideration is the extent to which markets at the same level are producing *comple*mentary or substitutable goods. For example, consider a structure in which markets A and B both supply market C. If the goods produced by markets A and B are complementary, in order for market C to produce one unit of good it would require one unit from *both* markets A and B (i.e., two units of good in total). Conversely, if the goods produced by markets A and B are substitutable, in order for market C to produce one unit of good, it would require one unit from *either* market A or market B. Clearly, these different types of dependency relation will have different effects on the extent to which multi-market structures are vulnerable to changes in other markets.

Consider a simple multi-market structure with three markets: a supplier market S, an intermediate market I, and a distributor market D.

#### Sourcing and Selling Goods

#### Consider market I.

Having determined how many goods they wish to produce (i.e.,  $q_i^I$ ), firms in I must source this many goods from supplier firms in market S. If they manage to source this amount, they produce their optimum amount. Otherwise, each firm produces as much as they can with the resources available.

Firms in I are indifferent to which firms they obtain goods from in S. However, firms in I will visit the minimum number of suppliers in order to obtain all their goods.

If a firm is unable to obtain *any* goods, it is forced to exit the market. Similarly, if a firm is unable to sell *any* goods, it is forced to exit the market.

### **Timestep Evaluation**

The simple three market chain model consists of a supplier market S, a middle market I, and a distributor market D.

Each timestep, the model runs through in the following sequence: (1) at most one firm in S merges and all firms calculate  $q_i^S$ , (2) firms in S produce  $q_i^S$ , (3) at most one firm in I merges and all firms calculate  $q_i^I$ , (4) firms in I source goods from firms in S (and firms in S sell goods to market I), (5) firms in I produce their goods, (6) at most one firm in D merges and all calculate  $q_i^D$ , (7) firms in D source goods from firms in I (and firms in I sell goods to firms in market D), (8) firms in Dproduce their goods. Markets who have no supplier markets are assumed to have access to infinite supplies; markets with no distributor markets are assumed to be able to sell all their goods.

As already mentioned, each timestep, two entrants with costs randomly assigned from a given range enter each market and up to two firms are randomly removed. All firms then evaluate whether or not they want to merge. Of the firms who want to merge (if any), a firm is chosen at random to perform their most profitable merger action.

Any firms unable to source any goods, produce any goods or sell any goods, exit the market.

### Generating Merger Waves

Markets are affected by the phenomenon of merger waves. It is well documented that merger activity follows a wave-like pattern; that is, a period of high merger activity is followed by a period of low merger activity, and vice versa (Town, 1992; Lipton, 2006; Gugler et al., 2008). However, econometric studies have shown that the precise behaviour of these waves is both highly country and market dependent (Resende, 1996; Maksimovic et al., 2011).

In attempting to identify the causes of such merger waves, a number of interesting traits have been noted. For instance, the peaks of merger waves approximately coincide with the peaks of stock market booms (Gugler et al., 2008) and some waves can only be seen to affect a subset of markets (Ahern and Harford, 2013). Broadly speaking, the literature provides three potential theory groups for these surges in merger activity: *neoclassical, behavioural* and *random*.

Neoclassical theories, such as the Q-Theory of Mergers (Jovanovic and Rousseau, 2002) and the Industry Shocks Theory (Harford, 2005), make use of standard neoclassical assumptions to explain waves. For instance, an industry might receive a shock such as the introduction of a new technology, which enables them to produce goods at a lower cost. This may then provide new merger opportunities, resulting in a flurry of merger activity. Aggregate merger waves are then caused when multiple, simultaneous shocks affect a number of industries.

Behavioural theories, such as the Managerial Discretion Theory (Shleifer and Vishny, 2003) and the Overvalued Shares Theory (Rhodes-Kropf et al., 2005), assume non-rational behavioural traits of market players. For instance, overconfidence in the market may lead to the overvaluation of stock. This may then encourage managers to make more merger bids than usual, either due to the increased perceived value of their own firm or a potential target's. There is some support also for the view that merger waves occur randomly. That is, that merger waves may be endogenously generated without any explicitly identifiable behavioural or technological shock (Shughart and Tollison, 1984). For example, a chance combination of particular market participants might create a setting in which a merger wave endogenously occurs.

Despite using similar and sometimes identical datasets, empirical investigations have found evidence to support each theory dependent on the filtering techniques applied (Resende, 1999, 2008, 1996; Harford, 2005; Gugler et al., 2008). Lipton (2006) concludes that discrepancies between the findings are caused by overfitting the models to the data: 'The overriding problem with these models is that none of them work very well outside the market or timeframe over which they were created'. He argues that this is because there is in fact no single factor that stimulates a wave, but instead a complex combination of economic, social and legal conditions that make mergers more appealing during certain periods. We argue that this complexity encourages a bottom-up, agent-based approach to modelling this problem in which the aggregate effect of individual merger decisions can be considered.

### Defining A Wave

In our model, since at most one merger may take place in each timestep, we will consider *merger desirability*: the number of firms in a market who, if given the opportunity, would choose to engage in a merger. Therefore, a merger wave in our model occurs when one or more firms want to merge for a number of consecutive timesteps.

### Demand Shocks

Shocks to demand may be generated by external control of the  $\alpha$  variable. For example, exogenously created increases in the market size may correspond to boom periods, and decreases may represent recessions.

### Supply Shocks

Shocks to supply may be generated by shifting the range of production costs during simulation. For example, suppose production costs are drawn from a range  $[c_{\min}, c_{\max}]$ , technological innovation might be represented by the reduction of production costs for firms above some cost value  $c_{\min} < c < c_{\max}$ .

Trivially, waves that are randomly generated by the model do not require specific stimulation.

# 3 Behaviour

In this section, we consider a variety of structures of multiple markets connected by supply chains as defined in the previous section. These are shown in Figure 2. Each box represents a market of competing firms. The arrows indicate the flow of goods from supplier market(s) to distributor market(s). Numbers in the graph show the order of play in a given timestep during the simulation. For example, in the tree market (Figure 2b), in each timestep: (1) firms in market A merge and produce, (2) market A's produce supplies both markets B and C simultaneously, (3) firms in market B merge and produce, (4) firms in market C merge and produce, (5) market B's produce supplies both markets D and E simultaneously, (6) firms in market D merge and produce, (7) firms in market E merge and produce. This is then repeated.



Figure 2: Multi-market micro-structures. Boxes contain markets of competing firms; arrows indicate the supply flow of goods between markets; numberings show the simulation order of play.

### Generating Merger Waves

### Random Waves

Let us first consider the random occurrence of merger waves.

Consider a market of firms with the same production costs. The benefit of merging would solely be to reduce the market competition. In fact, for any two agents to merge, it must be that the payoff from merging is greater than the payoff from not merging:

$$\pi_{i}^{M-1} > \pi_{i}^{M}$$

$$\left(\frac{\alpha + \sum_{i=1}^{m-1} c_{i}}{m} - c_{i}\right)^{2} - \left(\frac{\alpha + \sum_{i=1}^{m} c_{i}}{m+1} - c_{i}\right) > \left(\frac{\alpha + \sum_{i=1}^{m} c_{i}}{m+1} - c_{i}\right)^{2}$$

$$(7)$$

In the case where  $c_i = c$  for all *i*, this becomes:

$$\left(\frac{\alpha + c(m-1)}{m} - c\right)^2 - \left(\frac{\alpha + cm}{m+1} - c\right) > \left(\frac{\alpha + cm}{m+1} - c\right)^2 \tag{8}$$

Figure 3 shows the payoff to a firm in such a market from merging or not merging. As can be seen, the payoff from merging is only more beneficial than not merging for very small m. The point at which this occurs depends on the market configuration. Therefore, in such markets with a large number of firms, the market is stable.



Figure 3: Payoff from merging vs. not merging for  $c_i = 10 \ \forall i$  and varying m



Figure 4: Waves of merger desirability. Parameters are:  $\alpha = \alpha_0 + 1$ , m = 5,  $c_{\min} = 1$  and  $c_{\max} = m$ .

Now, let us consider a market with firms given randomly assigned costs from within a given range. A simulation run for such a market is shown in Figure 4, which shows the total number of firms in a market and the number of firms who wish to merge. As can be seen, waves in merger desirability occur endogenously in the model. This type of wave activity occurs regardless of a market's position within a multi-market structure, and is a result of the cost configuration of firms within the market.

### **Demand Shocks**

Consider the effect of exogenously generated shifts in the market size  $\alpha$  on the occurrence of merger waves. This may correspond to behavioural theories of merger waves, such as market optimism. Alternatively, increases in market size correspond to boom periods, and decreases represent recessions.

Figure 5 shows the number of active firms and merger desirability, along with  $\alpha$  from a representative simulation run. The market size,  $\alpha$ , is exogenously made to oscillate about  $\alpha = \alpha_0 + 1$ .

As can be seen, merger waves can be generated by exogenous changes in market size, though do not necessarily occur during every oscillation of  $\alpha$ . Figure 6 aggregates merger data from 100 longduration (5000 timestep) runs of the model. Here, each dot records the *proportion* of firms that want to merge at a point during the sinusoidal wave phase of  $\alpha$  from a particular simulation. As can be seen, though merger waves may occur at any stage during the wave phase, a high proportion of merger activity takes place when demand is reduced, primarily during depression periods and early recovery (i.e., the troughs in market size). This is unsurprising when recalling Figure 1, which suggests that reductions in  $\alpha$  increase the likelihood of firms wanting to merge.



Figure 5: Waves of merger desirability with exogenously determined sinusoidal  $\alpha$ . Parameters are:  $\alpha$  follows a sine wave about  $\alpha_0 + 1$  with period = 250 timesteps and amplitude =  $\frac{\alpha_0+1}{2}$ , m = 10,  $c_{\min} = 1$  and  $c_{\max} = m$ .



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-α-value • Proportion of Firms Who Want To Merge

Figure 6: The degree of merger desirability shown as the proportion of firms who want to merge as a function of the phase of the exogenously determined sinusoidal  $\alpha$ . Parameters are:  $\alpha$  follows a sine wave about  $\alpha_0 + 1$  with period = 250 timesteps and amplitude =  $\frac{\alpha_0+1}{2}$ , m = 5,  $c_{\min} = 1$  and  $c_{\max} = m$ . Data is drawn from 100 runs of a 5000-timestep simulation.

Again, applying demand shocks to a specific market in this way will cause similar results regardless of the market's position within the multi-market model.

### Supply Shocks

Consider the effect of an exogenously generated supply shock caused by shifting the production costs,  $c_i$ , that new agents are assigned during simulation. Therefore, suppose firms are originally randomly assigned costs between 11 and 20. At 500 timesteps, market entrants are now assigned costs between 1 and 10, corresponding to some a technological innovation. Figure 7 shows simulation results from this shift.

Identifying waves caused exclusively by the supply shock is difficult because there is already a significant amount of merger activity in the market caused by the frequently changing cost distributions of firms. These are the result of the random removal and addition of firms in each timestep. If, however, this feature of the model is removed, the effect of the industry shock on the system becomes immediately identifiable (see Figure 8).



Figure 7: Waves of merger desirability with an exogenously generated cost shift at t = 500. Parameters are:  $\alpha = \alpha_0 + 1$ , m = 10. Initially,  $c_i$  is drawn at random from a uniform distribution between {11, 20}. After 500 timesteps,  $c_i$  is drawn from {1, 10}.



Figure 8: Waves of merger desirability with an exogenously generated cost shift at t = 500 with no random removal of agents. Parameters are:  $\alpha = \alpha_0 + 1, m = 10$ . Initially,  $c_i$  is drawn from {11,20}. After 500 timesteps,  $c_i$  is drawn from {1,10}.

As can be seen, supply shocks can also generate merger waves. Further investigation into the different types of wave generation in this model can be found in Zedan et al. (2013).

### The Spread of Merger Waves

Ahern and Harford (2013) finds that merger waves can spread along supply chains, originating in one market and then propagating throughout a network. Having now successfully simulated the generation of waves within a market, we consider whether the model's simple supply-chain mechanism enables waves to be incited in markets that would otherwise remain stable (i.e., not exhibit merger waves). We ask whether or not dependencies between markets enable activity in one market to incite mergers in an otherwise stable connected market.

As can be seen in Figure 1, for a market to be stable, the current value of  $\alpha$  must be greater than  $\alpha_{\max}$ , the maximum value of  $\alpha$  for which at least one merger is profitable.

Recall:

$$\alpha_{\max} = \max[\alpha_{i,j}^{M} = \frac{(m+1)}{(m-1)^2 - 2}((m^2 - 1)c_j - 2mc_i) - \sum_{k=1}^{m} c_k]$$

Therefore,  $\alpha_{i,j}^M$  is largest for firms i, j with the greatest difference in production costs.

When markets are connected, a stable market (i.e., a market stabilised with fixed  $\alpha$  and fixed production cost boundaries) may become destabilised by changes to the total number of firms, m. Figure 9 shows the relationship between the number of firms in a market (m) and the maximum  $\alpha_{i,j}^M$  for a fixed  $c_i \neq c_j$ . The specific values of the market are not important; the shape of the graph is consistent across all values.

When a market's  $\alpha$ -value is above the black dashed line (the maximum  $\alpha_{i,j}^M$ ), no mergers will take place.

The graph shows that, for  $m \ge 4$ , as m increases,  $\alpha_{\max}$  increases. Therefore, the likelihood of  $\alpha_{\max} > \alpha$  increases. In other words, members of a stable market may be incentivised to merge when a shock in a connected market significantly increases m above a particular threshold amount. This value depends on the market and the value of  $\alpha$ .

When m < 4, the graph behaves differently but symmetrically for  $c_i > c_j$  and  $c_j > c_i$ . Interestingly, we see that for m < 4, dependent on a market's  $\alpha$ -value, it is also possible that a shock that lowers



Figure 9: Relationship between the number of firms in a market (m) and the maximum  $\alpha_{i,j}^M$  for a fixed  $c_i \neq c_j$ , when  $c_i > c_j$  and when  $c_j > c_i$ .

m to these values may incentivise a merger wave.

Recall that distributor firms who cannot obtain any supplies are forced to exit the market, as are supplier firms who cannot sell any goods. Therefore, we can conclude that it is possible for the total number of firms in a market to change, inciting mergers, based on the supply and demand in connected markets. Trivially, a market's production quantity changes as firm number and cost distribution change.

We now consider this in more detail for each multi-market structure. For each structure, let  $Q_A$  be the total quantity of goods produced by market A,  $Q_B$  by market B and so on. Let the desired quantity of goods to be produced by firm i in market B be denoted by  $q_i^B$  and let the maximum quantity of goods desired by a single agent be  $q_{\text{max}}^B$ .

### 3.0.1 Chain

Consider the chain multi-market structure in Figure 10.

Given that the order in which firms in market B are selected to locate suppliers for their desired goods is random, and the fact that a firm will obtain the maximum possible number of supplies it needs before the next firm is selected to act, we can make the following statement.



In order to ensure the removal of at least one firm from market B:

$$Q_A \le Q_B - q_{\max}^B \tag{9}$$

In other words, we must assume that even if the firm producing  $q_{\text{max}}^B$  was chosen to locate its supplies last (i.e., all other firms had had an opportunity to source goods), this firm would be unable to source *any* goods. As a result, it would be forced to exit the market.

Figure 10: Chain

Note that there is no difference between substitutable or complementary goods. Trivially, this is because each market sources goods from only one other market.

Market B is wholly reliant on market A for supplies. Any change in the quantity produced by market A will have an effect on firms in market B. Similarly, market B is wholly reliant on market C for demand. Therefore, a merger-inducing shock in one market could spread to all others.

It is difficult to quantify the effect of changes in demand in market C on market B, since a supplier firm can survive selling any non-zero quantity of good, and supplies at a single firm are not exhausted before the next firm may sell goods. However, it may be assumed that the larger the number of firms in market C, the less likely it is for a firm to be forced to exit market B.

#### 3.0.2 Tree

Recall the tree multi-market structure in Figure 11.



Let us consider the general case with a single supplier market A and  $\{B, C, \dots N\}$  distributor markets.

In order to ensure the removal of at least one firm from market *B*:

$$Q_A \le Q_B - q_{\max}^B \tag{10}$$

In this configuration, we note that there is no difference betweenFigure 11: Treesubstitutable or complementary goods. However, there is a fixedlimited supply from A for all dependent markets.

It is clear that market B is not just vulnerable to behaviour in its supplier market A, but A's other distributor markets<sup>2</sup> { $C \cdots N$ }. The proportional size of the other distributor markets is also likely to affect how much supply is available to firms in market B, since firms are selected at random from all distributor markets to locate supplies in market A. Therefore, the smaller the number of firms in market B, or the greater the number of firms in competing markets, the less likely it is that firms will be able to locate their desired supplies. This, of course, depends on the quantity produced by market A.

Again, the goods sourcing mechanism makes it difficult to quantify the upstream effect of multiple suppliers on market A, since a supplier firm can survive selling any non-zero quantity of good, and supplies at a single firm are not exhausted before the next firm may sell goods. It may be assumed that the larger the number of firms and markets sourcing supplies from market A, the less likely it is for a supplier firm to be forced to exit the market. Therefore, this configuration is likely to result in a supplier market less vulnerable to perturbations in distributor markets.

In addition to changes to supply caused by distributor markets, the supplier market itself might become unstable. In this case, its unique position as the sole source of supplies leaves all distributor markets in a vulnerable position. A drop in production would affect all other markets, again due to the matching mechanism since no market is preferred above another.

Clearly, therefore, this configuration places distributor firms in a particularly vulnerable position by being heavily reliant on a single supplier. Based on their relative position in the multi-market structure, some markets are clearly more vulnerable to changes in other markets. The branching structure enables shocks to be more easily absorbed as they travel up supply chains. Whereas, where there are single suppliers, shocks to these markets can easily spread downstream through connected markets.

### 3.0.3 Inverted Tree

Recall the inverted tree multi-market world in Figure 12.

Let us consider the general case with  $\{A, B, \dots N\}$  supplier markets suppling a single distributor market C.

In the case of complementary goods in supplier markets, in order to ensure the removal of at least one firm from market C:

 $<sup>^{2}</sup>$ Recall: firms in markets who share their supplier markets source supplies simultanously.

$$\min\{Q_A, Q_B, \cdots Q_N\} \le Q_C - q_{\max}^C \tag{11}$$

Of course, since firms source supplies in a random order, it is very likely that under these conditions more than one firm will be removed from C. However, to account for the case when the agent with  $q_{\max}^C$  is selected last to locate suppliers, this condition is necessary to ensure disruption in the connected market C.



Similarly, in the case of substitutable goods in supplier markets:

$$\sum \{Q_A, Q_B, \cdots Q_N\} \le Q_C - q_{\max}^C \tag{12}$$

From this we can clearly see that market C is more vulnerable to perturbations in production in any supplier market when goods are complementary rather than substituable. Since it is the total supply of goods considered in the substituable case, if one market consistently underperforms, the others might be able to

Figure 12: Inverted Tree

fill the demand. However, even if all but one supplier market significantly overproduces with complementary goods, any drop is enough to affect market C.

This is also the case for supplier markets. Suppose market A is unable to produce the amount to prevent firms leaving market C. When goods are complementary, the loss of at least one firm from market C might result in a supplier in B being forced out of the market. Whereas, the loss of one firm when goods are substitutable is less keenly felt by both the distributor market and other suppliers.

As the number of supplier firms increases, distributor market C is just as vulnerable to fluctuations in supplier markets when goods are complementary, though there are more markets that must sustain a minimum production quantity. However, when goods are substitutable, there is little change.

For supplier markets, there is a trade-off to be considered; when goods are complementary, they are vulnerable to fluctuations in production in other markets. However, when goods are substitutable, an increase in the number of markets given fixed demand in market C means that markets are likely to suffer a reduction in production since it must be shared with other suppliers.

There is a clear difference in the behaviour of the inverted tree multi-market structure when considering substitutable and complementary goods. When substitutable goods are considered, based on their position in the world, some markets are able to act as shock absorbers and prevent the spread of destabilising behaviour throughout the network. However, when considering complementary goods, their ability to dampen destabilising behaviour is reduced.

#### 3.0.4 Lattice, Loop and Star



Figure 13: Loop

The lattice structure itself is made up of two components: a loop and a star. As already discussed, dependent on their position within the micro-structure network, a market might be more vulnerable to destabilisations in other markets or able to absorb it.

Consider the loop structure in Figure 13. The top half of the loop behaves as in the tree structure, and the bottom half as in the inverse tree (see below).

To remove at least one firm from market B (or any similar market at that level):

$$Q_A \le Q_B - q_{\max}^B \tag{13}$$

To remove at least one firm from market D, the following must hold in the case of complementary goods:

$$\min\{Q_B, Q_C, \cdots Q_N\} \le Q_D - q_{\max}^D \tag{14}$$

And, in the case of substitutable goods:

$$\sum \{Q_B, Q_C, \cdots Q_N\} \le Q_D - q_{\max}^D \tag{15}$$

Consider the star structure in Figure 14. The behaviour of the loop is now reversed: the top half of the star behaves as in the inverse tree and the bottom half as in the tree (see below).



To remove at least one firm from market C, the following must hold in the case of complementary goods:

$$\min\{Q_A, Q_B, \cdots Q_N\} \le Q_C - q_{\max}^C \tag{16}$$

In the case of substitutable goods:

Figure 14: Star

$$\sum \{Q_A, Q_B, \cdots Q_N\} \le Q_C - q_{\max}^C \tag{17}$$

And, in order to remove at least one firm from market D (or any similar market at that level):

$$Q_C \le Q_D - q_{\max}^D \tag{18}$$

Now consider the lattice structure in Figure 15. In the example given, the edges of the lattice structure are loops (markets  $\{A, C, D, F\}$  and  $\{B, D, E, G\}$ ). However, the structure may also be modelled with star structures at the edge in a similar gridlike way (e.g., three top level supplier markets, two intermediate markets and three bottom level distributor markets).



Figure 15: Lattice

As in the loop and star configurations that make up the lattice, the behaviour of markets in the lattice structures follows the rules of either a tree or inverted tree, dependent on the number of supplier and distributor markets it is connected to. Therefore, the susceptibility to changes in supply again depends very much on a market's position in the supply chain network. By extension, markets behave very differently when complementary rather than substitutable goods are used; markets are much more

sensitive to changes in supply when goods are complementary.

### The Vulnerability of Markets

We have highlighted the importance that a market's location in a multi-market structure has on its susceptibility to changes in neighbouring markets. Figures 16 and 17 show the extent to which



the removal of a market affect other markets within a network when considering substitutable and complementary goods.

Figure 16: The importance of each market in the structure to other markets when firms produce substitutable goods. The removal of a single red market will cause all markets to cease production; the removal of a pink market will cause at least one other market to cease production; the removal of a white market will not necessarily cause any other market to cease production.

As can be seen, the overall network is more vulnerable to shocks where markets are wholly reliant on a single supplier or distributor market for goods or demand. By extension, when firms produce complementary goods, markets become much more dependent on suppliers.

Interestingly, in the case of substitutable goods, the lattice structure, which is a hybrid combining the loop and star, is able to reduce the impact to the whole network of failure in any one market.



Figure 17: The importance of each market in the structure to other markets when firms produce complementary goods. The removal of a single red market will cause all markets to cease production; the removal of a pink market will cause at least one other market to cease production; the removal of a white market will not necessarily cause any other market to cease production.

### **Increasing Stability**

We have demonstrated so far how merger waves may be simulated, and shown how they can spread between markets. Given their effect on competition, it is important to consider ways of reducing the impact and spread of waves. In particular, we now ask what can be done from a regulatory point of view.

First, let us review our findings:

• Merger waves can arise randomly within a market, or be generated by shocks to demand or supply;

- Merger waves can spread between markets along supply chain dependencies;
- Dependent on the dependency configuration between markets, some markets may be more vulnerable to changes in activity in other markets.

#### **Understanding Merger Waves**

Of key concern to regulators are the possible effects of mergers on competition. We know that in our model mergers reduce competition in a market, benefitting rivals. They also offer a potential increase in efficiency to the acquiring firm.

Figure 18 shows scatter graphs of agent lifetimes and production costs from a long-run single market simulation. Each point on the graph represents a single agent, with red dots identifying firms who have exited the market through a merger. As can be seen, merger targets are exclusively the highand low-cost firms. This is not surprising, since motivations for merging are technological (i.e., a reduction in production cost) and competitive (i.e., a removal of a rival from the market).

However, as the number of firms in a market decreases, the relative importance of firms remaining in that market increases. Since markets favour lower production costs, it is more likely that firms of lower production cost make up the market. Therefore, should a lower cost firm exit the market (e.g., through failure to source, produce or sell goods, or via random removal), the effect that such a loss has on the remaining participants is larger than the effect of the removal of a higher cost firm. This effect extends to dependent suppliers and distributors as well: fewer goods are required from a supplier market and similarly produced for a distributor market. Therefore, the loss of a low-cost firm could result in the loss of firms in supplier and distributor markets. This is the systemic impact of a firm's exit.

This raises the question: should the loss of a large firm (i.e., one with a low production cost in our model which is thereby capable of producing a higher quantity of goods) be permitted to fail (i.e., exit the market), given its increased importance in the supply chain? The 'too big to fail' topic is one of ongoing interest (see Mishkin, 2005). Current market regulation already attempts to control for this situation by preventing mergers that would result in monopolies.







Figure 18: Production cost and agent lifetime categorised by firms who exit the market through mergers (bottom) and those who are forced to leave through an inability to produce (top). Costs are drawn at random from a uniform distribution between 3 and 5,  $\alpha$  is initialised to  $\alpha_0$  and m = 10.

### The Spread of Waves

In our model, the spread of merger waves is done through a reduction or increase in the number of firms in a market. Therefore, an otherwise stable market may be subject to merger waves due to behaviour in supplier or distributor markets.

A consequence of this is that the firms in one market may become controlled by the behaviour of another market. Therefore, a sudden drop in supplies could result in a market monopoly if all but one firm was unable to source goods. Therefore, of interest to regulators are ways of reducing the dependence of firms on other firms. Our model has shown that having multiple supplier markets producing substitutable goods is the best way of reducing dependencies on supplier markets. Recall how bottleneck markets were capable of 'absorbing' shocks from both upstream and downstream markets. However, this is not necessarily beneficial for firms in the supplier markets themselves, since they are effectively in competition with firms supplying the same market. Additionally, the overhead of sourcing goods from multiple firms or markets may make it an unattractive option to firms. Therefore, in order to reduce the reliance on a particular market or group of markets, some incentive (e.g., a reduction in the cost of goods) might be given to firms to source goods from multiple markets where possible.

Our model also suggests that markets with a large number of participants are less capable of responding to reduction in supplies than those with a small number of participants. To understand this, consider two markets A and B, both producing Q goods. Suppose market A has a firms and B has b firms such that a > b. If A and B both find themselves supplied Q - x goods, firms in A each expect to produce a smaller amount than firms in B. Therefore, it is more likely for a firm in A to be unable to source any good than a firm in B. Consequently, it is more likely for market A to receive a loss in firm number (i.e., market B is better able to 'absorb' the effect of a reduction in supplies).

This suggests that markets with a smaller number of firms are less vulnerable to drops in supply.

#### The Vulnerability of Markets

Undoubtedly, some markets are more vulnerable to waves and their effects than others. For instance, key markets, such as those that act as bottlenecks, must be carefully regulated since shocks in those markets are much more likely to affect a number of other markets. Similarly, markets with a large number of participants are more susceptible to reductions in supply or demand.

However, bottleneck markets are also less likely to be susceptible to shocks in demand and supply generated in *other* markets, since they have increased demand and supply risks that are distributed across the markets they source goods from or sell to. Therefore, although shocks generated in these markets are likely to have a more significant effect, shocks received externally are less likely to spread. Therefore, shocks generated in these markets must be very carefully controlled against.

# 4 Conclusion

This paper sets out to investigate the effect of inter-market dependencies on the spread of merger waves. This was done by constructing an agent-based simulation model of endogenous horizontal merging in connected markets. We demonstrated how merger waves could arise randomly in the market, or be generated through exogenously applied shocks to demand and supply. We considered a number of multi-market configurations and examined the susceptibility of markets to shocks generated in other markets.

We also provided a discussion of the potential for such models to suggest ways of protecting against the destabilising effects of merger waves. Our research suggested that firms with multiple suppliers or distributors were less susceptible to changes in these markets. However, any shocks generated in these markets were more likely to spread to other markets. We also found that the more concentrated a market (i.e., the fewer the number of market participants), the less susceptible it was to reductions in supply.

The model presented in this paper is intended as a prototype, an instance of how agent-based modelling can be used to model real-world behaviours and suggest ways of promoting certain favourable outcomes. It is suggested as future work that the model is calibrated to a particular industry and validated against empirical results.

As computational power has increased, the development of numerical solutions to complex economic problems has become more popular. In the last twenty years, the field of agent-based computational economics (ACE) has emerged, which models economic processes as dynamic systems of interacting agents. It has been argued that agents are the best way to model complex systems (Farmer and Foley, 2009; Arthur, 2005).

Traditional economic models often require the user to assume that households, firms and governments are perfectly rational, that the economy always settles into a balanced equilibrium, and that institutional structures and dependencies can be abstracted away. Large-scale ACE models, such as EURACE (EURACE, 2006) and CRISIS (CRISIS, 2011), attempt to reduce these assumptions by building bottom-up, agent-based models that can be used for policy making.

Although there are some existing models of merging that consider multiple markets, these focus on vertical merger waves (e.g., Hombert et al. (2009)) rather than the spread of horizontal waves between markets. They also do not take into account the dynamic nature of merger decisions; models of merging are often represented as one shot, two-stage games (eg Qiu and Zhou, 2005; Neary, 2007). It is hoped that this model acts as a suitable pathway to encourage future work into the investigation of dynamic economic and agent-based modelling that can be used for policy making.

# References

- K. R. Ahern and J. Harford. The importance of industry links in merger waves. *Journal of Finance, forthcoming*, 2013.
- W. B. Arthur. Out-of-equilibrium economics and agent-based modelling. Working Paper 2005-09-037, Santa Fe Institute, 2005.
- J A. Clougherty and T. Duso. The impact of horizontal mergers on rivals: Gains to being left outside the merger. *Journal of Management Studies*, 46(8):1365–1395, 2008.
- CRISIS. Complexity Research Initiative for Systemic InstabilitieS, 2011. http://www.crisis-economics.eu/.
- EURACE. The EURACE Project, 2006. http://www.eurace.org/.
- J. D. Farmer and D. Foley. The economy needs agent-based modelling. Nature, 460:685-686, 2009.
- K. Gugler, D. C. Mueller, and M. Weichselbaumer. The determinants of merger waves: An international perspective. Discussion Paper 08-076, Zentrum for Europische Wirtschaftsforschung, 2008.
- J. Harford. What drives merger waves? Journal of Financial Economics, 77(3):529-560, 2005.
- J. Hombert, J. Pouyet, and N. Schutz. Anticompetitive Vertical Mergers Waves. Working Paper 55, Department of Economics, Paris School of Economics, 2009.
- H. Horn and L. Persson. Endogenous mergers in concentrated markets. International Journal of Industrial Organization, 19(8):1213–1244, 2001.
- ICN. The competition network, 2013. http://www.internationalcompetitionnetwork.org.
- B. Jovanovic and P. L. Rousseau. The Q-theory of mergers. Working Paper 8740, National Bureau of Economic Research, Inc, 2002.
- M. Lipton. Merger waves in the 19th, 20th and 21st centuries. The Davies Lecture, Osgoode Hall Law School, York University. September, 2006, 2006.
- V. Maksimovic, G. Phillips, and L. Yang. Private and public merger waves. Working paper, University of Maryland, NBER and UCLA, 2011.
- L. McGowan and M. Cini. Discretion and politicization in EU competition policy: The case

of merger control. Governance: An Internationl Journal of Policy and Administration, 12(2): 175–200, 1999.

- F S. Mishkin. Financial consolidation: Dangers and opportunities. Journal of Banking & Finance, 23(2-4):675−691, 1999.
- F S. Mishkin. How big a problem is too big to fail? *Journal of Economic Literature*, 44:988–1004, 2005.
- J P. Neary. Cross-border mergers as instruments of comparative advantage. Review of Economic Studies, 74(4):1229–1257, 2007.
- L. D. Qiu and W. Zhou. Merger waves: A model of endogenous mergers. RAND Journal of Economics, 38(1):214–226, 2005.
- M. Resende. Mergers and acquisitions in the UK: A disaggregated analysis. Applied Economics Letters, 3(10):637–40, 1996.
- M. Resende. Wave behaviour of mergers and acquisitions in the UK: A sectoral study. Oxford Bulletin of Economics and Statistics, 61(1):85–94, 1999.
- M. Resende. Mergers and acquisitions waves in the UK: A markov-switching approach. Applied Financial Economics, 18(13):1067–1074, 2008.
- M. Rhodes-Kropf, D. T. Robinson, and S. Viswanathan. Valuation waves and merger activity: The empirical evidence. *Journal of Financial Economics*, 77(3):561–603, 2005.
- A. Shleifer and R W. Vishny. Stock market driven acquisitions. Journal of Financial Economics, 70(3):295–311, 2003.
- W F. Shughart and R D. Tollison. The random character of merger activity. *Journal of Economics*, 15(4):200–209, 1984.
- D K. Tarullo. Industrial organization and systemic risk: An agenda for further research. Conference on the Regulation of Systemic Risk, Federal Reserve Board, 2011.
- R. J. Town. Merger waves and the structure of merger and acquisition time-series. Journal of Applied Econometrics, 7(S1):S83–S100, 1992.
- WB. The world bank, 2013. http://data.worldbank.org.
- WTO. The world trade organisation, 2013. http://stat.wto.org.

C. Zedan, A. Ianni, and S. Bullock. Competition and cascades in markets: An agent-based model of endogenous mergers. *Intelligent Systems in Accounting, Finance and Management*, 20(1): 39–51, 2013.