UNIVERSITY OF SOUTHAMPTON
Faculty of Physical Sciences and Engineering
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Competition, Cascades and Connectivity: The Effect of Mergers on the Global Economy

by Camillia Zedan

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ABSTRACT

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There is an increasing trend towards global financial consolidation. Empirical evidence has shown that though consolidation can increase market efficiency, it can also increase systemic risk. Therefore, understanding the effects of company mergers on the global economy is an increasingly pertinent issue.

The research presented in this thesis aims to explore the effects that mergers can have on interconnected markets. It will also suggest potentially stabilising market conditions that can reduce the risks associated with competitive production.

An agent-based model of endogenous merger formation in a simulated market is developed. The dynamics of the model are investigated, and the conditions are identified under which market competition is sufficiently disrupted to prompt extended periods during which mergers are desirable. The model is used to demonstrate how merger waves can be created through industry shocks and firm overconfidence.

This single-market model is then extended to one of multiple markets connected through supply chains. The conditions under which merger waves can spread along these pathways are found. The effect of introducing inter-market dependencies on market behaviour is also investigated.

Finally, the model is developed into a closed system in which agents react to changes in demand by varying their production quantities. Although this is found to increase the average market profitability, it has a significant effect on market behaviour.[1]

[1]This work was supported by an EPSRC Doctoral Training Centre grant (EP/G03690X/1).

For my family.

Contents

List of Figures

List of Tables

Declaration of Authorship

I, CAMILLIA ZEDAN, declare that the thesis entitled

COMPETITION, CASCADES AND CONNECTIVITY:
THE EFFECT OF MERGERS ON THE GLOBAL ECONOMY

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
- parts of this work have been published as: Zedan et al. (2013a), Zedan et al. (2011b), Zedan et al. (2011a), Zedan et al. (2012a), Zedan (2012), Zedan et al. (2012b), Zedan et al. (2013c), Zedan et al. (2013d) and Zedan et al. (2013b)

Signed

Date

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I am also grateful to the Institute of Complex Systems Simulation for providing a strong research base, uniting a diverse range of backgrounds and interests in the EPSRC Centre for Doctoral Training[2]. In particular, Nicki Lewin has been an exceptional source of support. I would also like to acknowledge the members of my cohort and research group, and thank them for their continued discussions and useful debates.

[2]This work was supported by an EPSRC Doctoral Training Centre grant (EP/G03690X/1).

Nomenclature

P	market price
α	market size (demand)
α_0	the minimum α that keeps all firms in a given market in production
$\alpha_{\max}$	the maximum α for which mergers are profitable in a given market
$\alpha^M_{i,j}$	the maximum α required for a merger between firm i and j to be profitable
Q_A	total quantity output by market A
c_i	marginal cost of firm i
M	a market (set of firms)
m	the number of firms in a market
q_i	Cournot-Nash equilibrium quantity level produced by firm i
π_i	Cournot-Nash equilibrium profit for firm i
$E(\alpha^S_{i,t+1}\|\phi)$	firm i's expected demand in market in market S
$F(\alpha)$	fixed demand (a market's initial α)
$A(\alpha^S)$	the actual demand placed on market S

Preface

Throughout its development, the research in this thesis has been presented and peer-reviewed at both national and international levels.

The majority of the work presented in *Chapter 3* was published in Zedan et al. (2013a). *Part I* was presented and discussed at Zedan et al. (2011b) and Zedan et al. (2011a). The work in *Chapter 5* was presented at Zedan et al. (2012a), Zedan (2012),Zedan et al. (2012b), and *Chapter 6* at Zedan et al. (2013c), Zedan et al. (2013d) and Zedan et al. (2013b).

Chapter 1

Introduction

In response to the damage caused by the recent global economic crisis, the UK government announced plans to restructure the way in which the financial markets are regulated (Treasury, 2010). It is believed that suitable regulation could enable the early detection and possible prevention of future crises by, for example, encouraging market stability or reducing systemic risk (Review, 2009). Overall, this move has highlighted the importance of understanding how complex economic systems form, interact and evolve over time.

In 2002[1], the Competition Commission, an independent public body, was made responsible for regulating mergers, markets and industries with the aim of '...ensuring healthy competition between companies in the UK for the benefit of companies, customers and the economy' (CC, 2013). This was done in an attempt to address the problem of market failure[2]: the situation in which a free market is not economically efficient.

Competitive markets are considered beneficial because they have the potential to promote fair prices for consumers, encourage firms to innovate, and increase efficiency by putting downward pressure on costs. Therefore, increases in competition should lead to increases in economic welfare.

Mergers are among the most direct causes of changes to competition in a market. Therefore, their careful regulation is important. However, the effect of regulation at the firm or market level is not always predictable or desirable (Gual, 2007). Due to the complex interdependencies that connect companies and markets, a seemingly small policy change or ruling in one market could negatively affect competitors, consumers (Norback and Persson, 2007) and other markets (Ahern and Harford, 2013).

[1]Though established in 1999, the Competition Commission was not given remedial powers until the Enterprise Act (2002). Up until this time, its role was limited to providing the government with recommendations.

[2]In Bator (1958), Bator determines that markets become efficient if they remain competitive.

The trend towards global financial integration is increasing the strength and number of market interdependencies and, according to Stephanou (2009), leading to a 'shrinking role of the state in financial systems' as cross-border ownership increases. In the past fifteen years, emerging market cross border mergers and acquisitions (M&A) have nearly quadrupled in number and increased more than five-fold in value. Over the past 40 years, global outward foreign direct investment has gone from roughly \$14bn to over \$1tr (WB, 2013)[3]. Research has found that though consolidation can lead to an increase in market efficiency, it also increases systemic risk (Mishkin, 1999; De Nicolo and Kwast, 2002). Therefore, understanding the causes and effects of mergers has become increasingly important in the regulation of an increasingly global market.

Understanding the potential effects of mergers enables firms to better evaluate the risk associated with developing inter- and intra-market dependencies (Pergler and Lamarre, 2009). It could also potentially lead to better long-term regulation by providing policy makers with regulatory mechanisms that are less likely to cause disruptive chain effects. Modelling the origin of these effects could also be used later for the testing of new regulations.

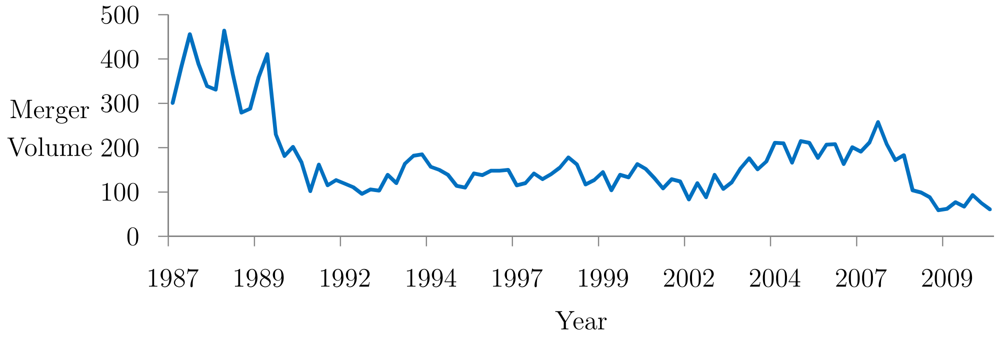
Markets are affected by the phenomenon of merger waves. It is well documented that merger activity follows a wave-like pattern; that is, a period of high merger activity is followed by a period of low merger activity (Town, 1992; Lipton, 2006; Gugler et al., 2008). However, econometric studies have shown that the precise behaviour of these waves is highly dependent on both the country and market in question (Resende, 1996; Maksimovic et al., 2011). For example, Figure 1.1 shows merger activity in the UK between 1987 and 2010[4]. As can be seen, both outward and inward M&A follow a sinusoidal wave pattern. However, UK domestic M&A appears to follow a two-phase regime-switching pattern in which high merger activity steps to low merger activity rather than transitioning more gently between the two (Gartner and Halbheer, 2009; Resende, 2008).

Research has shown that much wave behaviour is significantly different from a random walk (Gartner and Halbheer, 2009). 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*.

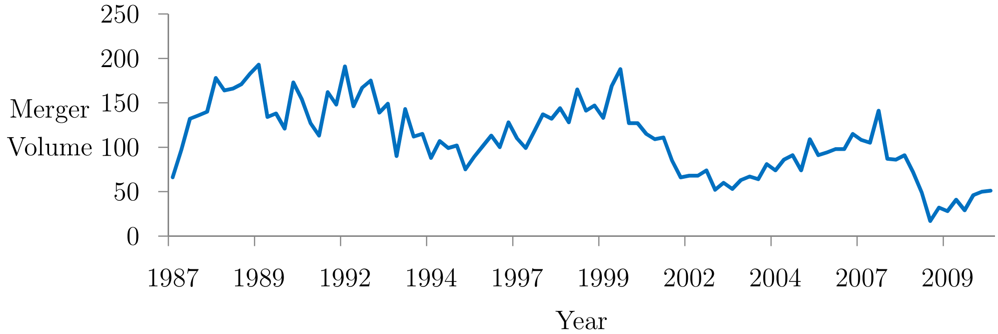
Neoclassical theories, such as the Q-Theory of Mergers (Jovanovic and Rousseau, 2002) and the Industry Shocks Theory (Harford, 2005), make use of standard neoclassical assumptions to explain waves. For instance, an industry might receive a shock such as

[3]These values are inflation adjusted in current US dollars.

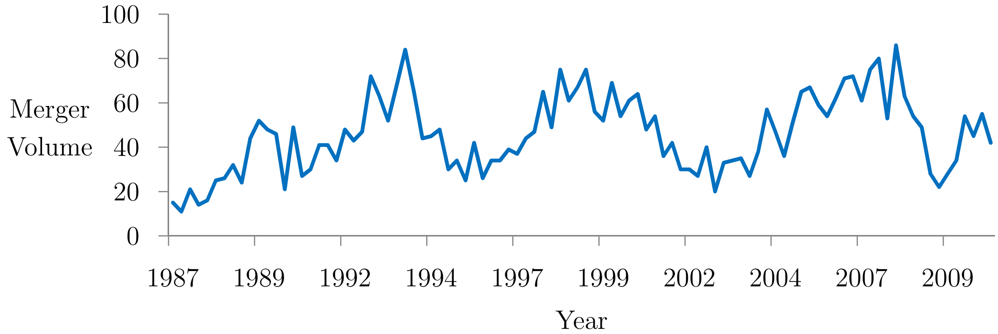
[4]The time series UK merger data was taken from datasets provided by the Office for National Statistics.



(A) Domestic UK M&A Activity



(B) Outward UK M&A Activity



(C) Inward UK M&A Activity

FIGURE 1.1: UK M&A activity. Merger volume is the number of acquisitions completed in a given quarter. Data is provided by the Office for National Statistics, www.ons.gov.uk.

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., 2005a), 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, an indirect policy change, and shift in market sentiment, might create a setting in which a merger wave endogenously occurs.

Despite using similar 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 model 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.

According to a 2007 study by the Hay Group (HayGroup, 2007), despite motives to the contrary, 91% of corporate mergers and acquisitions fall short of their objectives. Of the British companies considered, this rose to 97%. It was also found that on average mergers and acquisitions disrupt company operations for over two years, integration takes 19 months, and newly merged businesses are leaderless for two and a half months. Therefore, the effect of a single merger on a company is often considered unpredictable.

The extended impact of this unpredictability on a market is of particular interest to regulators such as the Competition Commission (CC, 2013), whose aim it is to promote market competition, efficiency and stability. Such regulation is made more difficult by the fact that markets do not exist in isolation; they are connected through a series of complex dependencies caused by e.g., supply chains, geographical proximities to other markets, and trade routes (see GDE (2011)). Therefore, dependent on factors such as the strength of the dependency and the importance of the firm, any destabilising consequences of merger activities could spread to connected markets (Ahern and Harford, 2013).

One way of gaining a greater understanding of the consequences of a potential merger is through the construction of dynamic simulation models. Such models have the potential to investigate why mergers take place, test how relevant merger behaviour can arise through different theoretical explanations, and suggest ways of protecting against the negative effects of phenomena such as merger waves.

This research aims to explore some of the consequences that merger activity can have on interconnected markets. This is achieved by developing a multi-market agent-based model of endogenous merger formation.

Chapters 2 provides an overview of the relevant literature and outlines the research concept; Chapters 3 and 4 investigate the causes of merger waves in a single market model of competition and endogenous merging; Chapters 5 and 6 connect multiple simulated markets through supply chains to study the extended effect of merger waves; Chapter 7 discusses the empirical relevance of the model, provides a discussion of future work, and concludes.

Chapter 2

Literature Review

The nature of interdisciplinary research is such that a variety of topics from several disciplines must be considered when reviewing relevant literature. The main challenge this presents is with regard to domain-specific terminology: different disciplines may refer to the same concept using different terms. For example, computer science refers to autonomous agents in a similar way to economics' game-theoretic players. Additionally, the relative novelty of developing computational simulations of economic phenomena means that there are few directly relevant interdisciplinary models that may act as suitable benchmarks.

Consequently, though the literature reviewed may appear to cover a diverse range of topics, each subject provides a relevant and useful background to the research question.

2.1 The Economy as a Complex System

In Roth (2002), Roth says that '...the economic environment evolves, but it is also designed.' It is designed by the policies and regulations that govern how economic agents, such as banks and businesses, may behave and interact. However, it also evolves, favouring those who can adapt better to an ever-changing environment. The economy is generally considered to be a *complex system* (Arthur, 1999; Beinhocker, 2007; Durlauf, 2012).

2.1.1 Complex Systems

Though there is no fixed definition, a complex system may be considered one composed of a number of elements which interact to exhibit some kind of emergent behaviour. Beinhocker (2007)'s economic interpretation considers macroeconomic phenomena as the emergent attributes of micro-level behaviour. Unlike more classical economic interpretations, the complex systems' view of the economy is dynamic and non-linear (Arthur, 2005), agents do not have perfect information or necessarily behave efficiently (Dawnay and Shah, 2005), and interactions between agents may be characterised by evolving networks (Ehrhardt et al., 2006).

An important implication of conceptualising the economy as a complex system is that system traits previously considered to be phenomena or noise, may now be investigated and better understood as consequences of aggregate interaction. Arthur (1999) suggests an extended importance of this methodology: '...it is bringing an awareness that policies succeed better by influencing the natural processes of formation of economic structures, than by forcing static outcomes.'

Despite its growing popularity, complexity science - the study of complex systems - is not without its critics. Some believe that there is a lack of robustness in complexity research or that it is too random and unrealistic, limiting its long term use (Horgan, 1995). However, in the last ten years, this view has been increasingly contested and replaced with a growing sentiment that '...complexity thinking can enrich the way in which economists conceptualize various phenomena...' (Durlauf, 2012). It is this unification of economics and complexity science that we employ in this thesis.

2.1.2 Agent-Based Computational Economics

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.

The EURACE project (EURACE, 2006) developed an extensive agent-based model of a complete economy used for policy analysis. Aiming to capture the main features of the European economy, the model was dynamically complete (i.e., specified all real and financial stocks and flows), implemented empirically documented behaviours (such as herd behaviour: the tendency for traders to copy each other's trading decisions without evidence to justify a given choice), and had an evolving social network structure. The simulation model was completed in 2009 and since then has been used to run what-if scenarios.

However, since the shock of the 2008 financial crisis, an increased focus has been placed on protecting against systemic risk: the risk that an instability in one market or group of markets can spread. The CRISIS project (CRISIS, 2011), due to be completed in 2014, aims to create a simulation model for economic policy making with a focus on addressing systemic instabilities. Like EURACE, the CRISIS model will be initially constructed around EU data. However, the long term aim is to produce a global agent-based economic simulation model that captures many of the complex, real-world attributes left out of traditional perfectly rational models, such as instances when markets fail to clear and herd behaviour.

The EURACE and CRISIS projects are demonstrating the extent to which agent-based models can be calibrated to the real world and provide realistic forecasts about the effects of policy changes. However, the consequences of producing such a detailed model involving complex interactions is that the role of individual components on the behaviour of the system becomes more difficult to discern. Section 2.4 provides a further discussion on the issues surrounding the validation of agent-based models.

Agent-based models have already begun to provide a better fit in understanding real-world economic systems than some classical models. One of their largest contributions has been the ability to recreate certain real-world phenomena without the need to rely on traditional unrealistic assumptions or centralised control mechanisms. For example, Gaffeo et al. (2012) demonstrates using a bottom-up approach that it is possible to obtain a full employment solution without the need of a Walrasian auctioneer, a centralised matching tool used in macroeconomic models to match suppliers with buyers. The agent-based model it presents also has the additional ability to demonstrate the conditions under which market failures can occur, something explicitly undefined when using a Walrasian auctioneer. Similarly, Ormerod et al. (2007) relax the economic assumption that agents are intelligent (i.e., capable of processing a large amount of information efficiently so they can perform maximising behaviour). They explore two socio-economic phenomena, the distribution of US economic recessions and the distribution of individual crimes, and demonstrate that both can be accounted for using agents with a low cognitive ability.

Tesfatsion (2005, 2000) provides popular and comprehensive overviews motivating the ACE approach to modelling.

2.1.3 Agent-Based Modelling Techniques

Agent-based modelling (ABM) in computer science is a useful tool used by many disciplines to simulate the interaction of entities that are defined in similar ways. In ABM, an agent is an autonomous computer software system that is embedded in some environment, such as a community of other agents, which they can sense and act upon. They are social and so may communicate with other agents or a user. They are also reactive to communication or changes in the environment, and are goal-directed. Agents may maintain an internal set of beliefs and desires, make inferences about the state of their environment, or be capable of bargaining and argumentation (Russell and Norvig, 2010; Wooldridge, 2009).

This modelling approach offers much flexibility in how agents are designed, enabling modellers to question the effect of e.g., assumptions of rationality and intelligence on agent behaviour (eg Ormerod et al., 2007). Together with the computational ability to simulate large numbers of interacting agents, ABM enables the creation of highly complex economic models.

2.2 Markets and Mergers

A market may be defined as a set of firms that are grouped due to production, geographical or other similarities. For example, firms producing technology goods may be grouped into a market, as well as firms primarily operating within the UK.

Markets can change and evolve over time in response to changes in consumer demand. For example, since the release of Amazon's Kindle and other tablet devices, more publishers have responded by providing ebooks as well as traditional print. According to a study by The Publishers Association (PA, 2011), consumer ebook sales increased by 366% between 2010 and 2011 despite the combined total sales of digital and physical books falling by 2%. Therefore, understanding the behaviour of markets with such evolving boundaries requires the use of dynamic modelling techniques.

2.2.1 Competition

Firms within a market are in direct competition with each other. If we assume that they are rational, each firm acts to maximise its own profit. In reality, anti-competitive practices, such as collusion between firms, can result in price-fixing and other activities that negatively impact consumer welfare. In such cases, government intervention may be required.

Regulatory bodies such as the Competition Commission in the UK and the Federal Trade Commission in the US aim to promote market competition. This is largely done through attempts to control the distribution of market power across firms. Market power refers to the extent to which a firm may control the price of a good by deliberately affecting its demand or supply. In perfectly competitive markets, all firms have zero market power.

Market power may be affected by mergers between competitors, price fixing, exclusive dealing, dumping, etc. Regulation is therefore required to prevent this where necessary.

The importance placed on competitive markets stems from the beneficial effects that competition generates: competitive markets are considered to promote fair prices for consumers, encourage firms to innovate and increase efficiency by putting a downward pressure on costs. Therefore, increases in competition should lead to an increase in economic welfare.

However, not all anti-competitive practices such as monopolies and mergers are detrimental to consumer welfare. For example, firms with high market power may choose to not raise prices in case it encourages other firms to overcome entry barriers and greatly increase their competition.

Economic Models of Competition

There are many traditional economic models that examine market competition. The simplest of these are offered by Cournot, Bertrand and Stackelberg.

All models present a market in which firms compete whilst producing a homogeneous good. In Bertrand's model of competition, each firm must determine the price at which to sell their goods (i.e., it is a *price competition*). In Cournot's model, each firm must determine the quantity of goods it will produce (i.e., *quantity competition*). In Stackelberg's model, firms do not set their price or quantity simultaneously: one firm acts first to determine its price or production quantity, and then the next firm acts having observed the previous actions taken.

Such models assume that firms are profit-maximising. However, there have been many studies that question the validity of this assumption in understanding real-world markets. Blume and Easley (2008) provide an interesting overview of several studies examining the selection pressures on firms determining whether or not it is reasonable to assume that successful firms are profit-maximisers, and whether or not it matters. They conclude that more research needs to be done since different markets behave differently. There are a number of alternative theories to profit-maximisation. For example, firms eager to maintain a strong market position might lower prices, reducing profit but making it more difficult for new competitors to enter the market. Similarly, firms might increase wages in order to prevent industrial action, or reduce prices in order to improve customer relations.

Computational Models of Competition

One of the shortcomings of the game-theoretic models of competition mentioned above is their static management of time: models often only consider one simultaneous-play game. Even in the case of Stackelberg competition, time must be finite to enable firms to calculate their best response using backwards induction. This results in models that are unable to investigate the potential effects that continuous, dynamic behaviour might have on the system.

Agent-based computational modelling lends itself well to simulating interaction and decision-making models over time. Such models often draw on game theoretic techniques to determine agent decisions, which can adapt to changing situations. For example, Yeung et al. (1999) creates a multi-agent model of coalition formation using cooperative game theory. Agents form coalitions using the Shapley value to determine who they will collaborate with and on what terms. Agent-based modelling is then used to simulate the negotiations between participants.

In computer science, artificial intelligence and agent-based modelling are developing *intelligent agents* (see Wooldridge, 2009; Russell and Norvig, 2010). These agents are increasingly sophisticated with communication languages, reasoning algorithms and learning capabilities. They may use complex genetic algorithms, inspired by biological and evolutionary models, to learn about their competitors and adjust their game-play accordingly. For example, Matos et al. (1998) assigns agents different strategies and leaves them to compete and evolve in a given environment. The most successful strategies are dominant at the end of the simulation.

The Trading Agent Competition (TAC, 2013) is an annual global competition to design agents capable of competing in challenging simulation scenarios. There are a number of different games agents have the opportunity to compete in, such as Ad Auctions (TAC/AA, 2013) in which agents must combine data analysis and bidding tactics to bid for search-engine advertisement places. Such competitions can help generate new ways of designing competitive agents (Wellman et al., 2005, see). They also offer the opportunity to develop existing methods of modelling strategic interaction by providing large datasets, which can be used for investigation. For example, Jordan et al. (2007) and Niu et al. (2008) analyse the results from TAC tournaments to identify the traits of successful strategies and determine equilibria.

2.2.2 Mergers

A merger occurs when two firms decide to bring together their business operations (Sloman and Hinde, 2007). It is different from an acquisition or takeover (when one business acquires another), since they may not necessarily involve a mutual agreement between both firms. The acquiring firm might bid for shares in the other against the will of the target firm's directors; this is known as a hostile takeover. However, often mergers and acquisitions are used to mean the same thing. The research in this thesis models the takeover of one firm by another following a mutual agreement.

Sloman and Hinde (2007) define three major types of merger[1]:

1. *Horizontal mergers:*

   Two firms in the same industry at the same stage of the production process merge;

2. *Vertical mergers:*

   Two firms in the same industry at different stages in the production process merge;

3. *Conglomerate mergers:*

   Two firms in different industries merge.

In general, mergers aim to improve profit and productivity, and reduce a firm's costs. Sloman and Hinde (2007) identify seven major incentives to merge:

1. *Mergers for growth:*

   A merger can be much quicker than internal expansion at acquiring consumer demand and new capacity;

2. *Mergers for economies of scale:*

   There may be a reduction in the cost of overheads made by joining;

3. *Mergers for monopoly power:*

   Strategically, a merger can be used to reduce competition, gaining greater market power and larger profits;

4. *Mergers for increased market valuation:*

   A merger can benefit shareholders of both firms if it leads to an increase in the stock market valuation of the merged firm (though there is little evidence to suggest this works in reality);

5. *Mergers to reduce uncertainty:*

   Since the behaviour of rivals can be unpredictable, a merger, by reducing the number of rivals, can reduce uncertainty as well as the related cost of competing. Similarly, during times of rapid economic change, a firm may seek to protect itself by merging with others;

6. *Mergers due to opportunity:*

   Mergers may take place simply as a consequence of an unforseen opportunity that arises, which is why they are largely unplanned and virtually impossible to predict;

[1] Further types of merger include market extension mergers, product extension mergers, reverse mergers, triangular or subsidiary mergers, forward triangular or subsidiary mergers, and reverse triangular or subsidiary mergers.

7. *Mergers in defense:*

   A firm might decide to merge in order to prevent an unwanted takeover.

It must be noted that though the items presented in this list are often used in the official textbook literature as the major reasons for merging, it is by no means an exhaustive list, nor without opposition. For instance, Lipton (1979) among others argues that there are several techniques a firm can use to block the threat of a hostile takeover.

In reality, it is often a combination of reasons that incentivises a merger to take place. However, since mergers can increase the market power of the firms involved, it can lead to less choice and higher prices for consumers. In order to maintain competition and protect consumers, regulation becomes necessary (see CC (2013) for more information).

According to a 2007 study by HayGroup (2007), 91% of corporate mergers and acquisitions fall short of their objectives. Of the British companies considered, this rose to 97%. It was also found that on average mergers and acquisitions disrupt company operations for over two years, integration takes 19 months, and newly merged businesses are leaderless for two and a half months. Therefore, the effects that a merger will have on the surrounding market can be unpredictable.

The impact of mergers and acquisitions on the firms directly involved has been studied in depth, since it often helps determine the success of a merger. For instance, a merger might affect:

1. *Employees:*

   A merger is likely to result in a reduction in the number of employees needed since, for example, there may be no need for two departments performing the same task;

2. *Top-level management:*

   A merger attempts to combine two different strategies and organisation cultures, which can create additional difficulties such as managerial arguments termed 'clash of the egos';

3. *Shareholders of the acquired firm:*

   Such shareholders may benefit the most since the acquiring firm is likely to have paid a little in excess of the true value of the firm;

4. *Shareholders of the acquiring firm:*

   Such shareholders are likely to be affected by the debt load they take on with the new firm, since they are likely to have paid in excess of the true value of the acquired firm.

2.2.3 Merger Waves

Figure 2.1 shows the number of mergers taking place each year in the UK. The literature distinguishes two types of merger activity (Resende, 2008): normal merger activity, when there is a period of approximately constant merger frequency (such as from the late 1970s to the early 1980s); and intense merger activity, when there is a sudden, unsustainable rise in merger frequency (such as from the late 1980s to the early 1990s). The periodic change in merger activity is known as a merger wave.

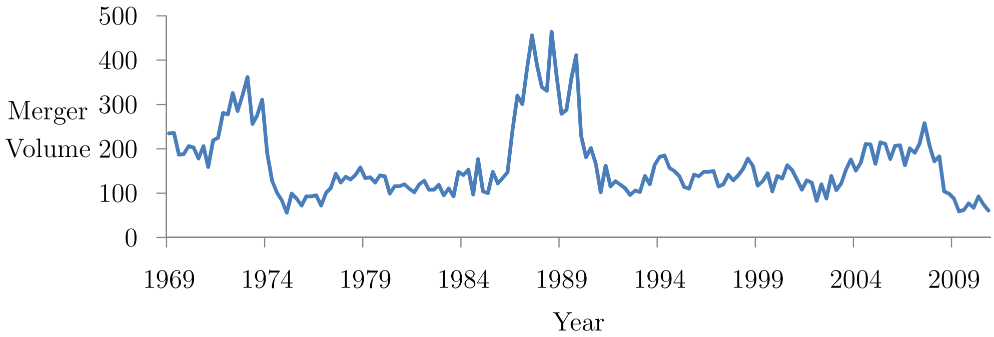


FIGURE 2.1: The number of mergers and acquisitions in the UK by UK companies per quarter (merger volume). Time series UK merger data was taken from datasets provided by the UK government's Office for National Statistics, www.ons.gov.uk.

The literature highlights three potential causes for a sudden surge in the number of mergers:

1. A particular merger in a market disrupts the existing market stability, increasing competition and providing opportunities for new mergers. The effects of this merger incite other mergers, which in turn can incite further mergers to take place. This cascade effect can continue until the market reaches a new equilibrium, in which it is able to support a smaller number of mergers without the disruptive effects of the earlier wave;
2. An external shock, such as a regulatory or technological change, disrupts the existing market stability, providing opportunities for new mergers in a similar way to before;
3. The wave is a random occurrence, generated by chance rather than by an explicit force on the market.

In the first case, the wave pattern would depend on the composition of market participants and their interdependencies. In the second case, the timing of the wave would depend on how long a sector or industry took to react to the shock, and its extent would depend on its relevance to the market. These causes may be termed *endogenous* and *exogenous* to the market.

The potential causes of merger waves have been studied in detail. Though models have been designed that demonstrate situations in which these waves can be brought about, the exact cause has yet to be identified. For example, Gartner and Halbheer (2009)'s Markov regime-switching model manages to identify several historical patterns in merger activity, but not the US 1980s merger wave. Similarly, Shughart and Tollison (1984) argue that merger waves could be random.

Lipton (2006) states that: '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 appealing. It is this complexity that encourages an agent-based approach to modelling this problem, such as the one proposed in this thesis.

There are currently two schools of thought on the causes of merger waves: *neoclassical* and *behavioural*.

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, industry-wide shocks provide merger opportunities that cause 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., 2005a), assume non-rational behavioural traits of market players. For instance, overconfidence in the market leads to overvaluation of stock, which encourages managers to make more merger bids at a certain time.

There is evidence both for and against these theories (see Table 2.6).

2.2.4 Models of Merger Waves

The literature on modelling mergers can be divided roughly into two categories: *empirical data models* and *abstract theory models*.

Empirical data models use historical data to construct econometric models of merger activity (see examples in Town (1992) and Gartner and Halbheer (2009)). These models tend to take a subset of historical data as a training set, which is then studied to identify any patterns. These patterns then form a model which can be used in forecasting to produce very immediate, accessible results. However, since they are focused on identifying a current trend, they are often incapable of offering insights into unpredictable market shifts. Similarly, since they rely heavily on historical datasets, they tend to require constant updating in order to maintain relevancy. For instance, models used to forecast years into the future might require estimations about how tax rates rates may change, when and by how much. Such values would then need to be updated over time.

Abstract theory models attempt to model merger activity at the level of firm interactions (see examples in Toxvaerd (2008) and Qiu and Zhou (2005)). These interactions are then contrasted against the real world and used to identify generic stylised facts, such as identifying some causal behaviour between two events. Since history can only provide one dataset, simulations of abstract theory models can offer a much larger sample of data from which to develop theories. Although this generated data is by no means equivalent to real sources, it is still useful in developing an understanding of a system and considering the potential effects of changes in policy design (Durlauf, 2012). However, since these models are often highly abstracted, they are sometimes considered unrealistic (Marks, 2012).

Particularly relevant to the development of this project are abstract theory models.

As already discussed, two types of merger wave trigger have been identified in the literature: endogenous and exogenous. Endogenous causes focus largely on the strategic interaction between agents within one market, such as competition. Exogenous causes of merger waves refer to a dependence on externally controlled factors. An agent can train to improve its endogenous performance but has little control of exogenous factors such as deregulation, globalisation or the introduction of new technology.

For example, the economy can be split into a number of industries. Within each of these industries, firms compete, strategically waiting for the 'right time' to target potential firms with which to merge. Endogenously, this 'right time' will depend on the firms and industry in question. However, exogenous shocks to the system, such as the aggregate effect of events in other markets, will also affect whether or not a merger or series of mergers suddenly become worthwhile. In reality, a combination of these factors play an important role in the stimulation of merger waves.

Most economic models of endogenous merging are designed as games with a finite number of stages in which firms merge and engage in competition.

Nilssen and Sorgard (1998) constructs a model to investigate the interdependence of merger decisions over time (i.e., the extent to which one merger might incite another). The model is a two stage game in which there are two possible mergers that can take place. In the first stage, the first group of firms decide whether or not to merge and, in the second, the second group decide. Different scenarios are analysed in which the decision to merge by either group affects the other. That is, there is some strategic interdependence of merger decision-making. The paper considers the profitability, strategic nature and welfare implications of these sequential mergers. Despite the model's abstractness, it highlights an important consequence of not considering mergers in isolation; current mergers may be (dis)incentivised by potential future mergers, and future mergers may depend on the past. In other words, whether or not a particular group of firms choose to merge can either incite or prevent a merger wave.

Horn and Persson (2001) similarly create a merger model to determine stable market structures in concentrated markets (i.e., those made up of a small number of firms). The model is a two stage game: in the first, firms decide whether or not to merge and in the second, they engage in a Cournot competition. Firms evaluate the ownership structure that would result from a potential series of mergers (i.e., firm strategy) and determine which is the most dominant structure. Horn and Persson show that communication between agents enables the most efficient industry structures to automatically arise. However, being specific to concentrated markets, certain attributes of real-world markets do not occur. For example, rival firms do not benefit from a reduction in competition when a merger takes place as found to be the case in the real-world: the 'free-riding' effect of mergers.

Lambrecht (2004) develops a merging model which tests the effect of uncertainty on merger behaviour. In the model, mergers are motivated by economies of scale. There is a sunk cost of merging, therefore, firms have to trade-off the benefit of merging against the cost. However, since the benefit of merging is stochastically linked to the level of demand in a market, firms must also strategically decide *when* to merge (i.e., firms decide the optimal time when a merger will be profitable). Two contract mechanisms are considered (merger and takeover) based on how the merger gains are divided, which influences the timing of the merger. In friendly mergers, both firms decide on the merger timing to maximise the total net present value of the merger, then determine a sharing rule. In hostile takeovers, the target pre-commits to the minimum terms for relinquishing control and the acquirer then decides on the timing given those terms.

The paper finds that, consistent with empirical evidence, merger activity closely follows demand. Perhaps unsurprisingly, when merger costs are larger and there is higher uncertainty in demand, firms delay mergers. Increased market power increases a firm's incentive to merge and speeds up merger activity. In friendly mergers, both firms determine a sharing rule such that a merger takes place at a globally efficient threshold. In hostile takeovers, targets demand a larger ownership share (which increases in times of uncertainty, when the bidder to target size ratio is larger, etc.), which delays potential mergers and reduces the probability of the merger happening.

The model successfully combines endogenous merger decision-making with an additional exogenous dependency on market values. However, the focus is on single merger agreements between two firms; though a dynamic time element is present in the formulating of merger agreements, the individual or aggregate effect of mergers on other firms is not considered.

Qiu and Zhou (2005) presents a model of endogenous mergers to study how firms merge as a dynamic process. The merger process is modelled as a two-stage game: agents choose whether or not to merge and then the remaining firms engage in a Cournot competition. When two firms merge, the resultant firm takes on the lower of the two firms production costs. Agents make their decision based on a utility function that evaluates a merger's potential profitability in the next round. It is found that mergers only occur if firms have different marginal costs or the industry has experienced a shock that reduces demand. Despite the model's abstractness, it is able to capture several real-world merger attributes such as the aforementioned free-riding effect. However, as in many other models, acquiring firms do not compete over potential targets and the game finitely ends after the initial two stages. This again prevents the dynamic effects of mergers from being studied.

A more general version of the model presented in Qiu and Zhou (2005) is that proposed by Neary (2007). In this model, firms may have one of two costs of production (either high or low) and engage in mergers just as in Qiu and Zhou (2005). In addition to this, two types of merger are identified: myopic and strategic, where strategic mergers are 'forward-looking'. In agreement with previous models, Neary (2007) finds that the proportion of production cost differences between firms incentivises merging. Specifically, Neary finds that a high proportion of possible mergers are of low-cost firms acquiring high-cost firms in order to reduce competition. Investigation into agent welfare suggests that the net effect of merging is positive.

Another interesting model is presented in Toxvaerd (2008), which combines both endogenous and exogenous causes of merger waves. Each timestep, an agent evaluates the utility of a potential merger based on the endogenous competition with other agents over target firms and an exogenously defined 'economic fundamental' variable that influences merger profitability. It then decides whether to raid (i.e., propose a merger with a target firm) or wait. Two models are presented. In the first, where there is complete information, it is found that in all subgame perfect equilibria all acquiring firms raid target firms simultaneously. This is interpreted as a merger wave. However, since in this model it is impossible to predict when the merger wave would occur, a second model is proposed in which agents receive imperfect information about the exogenous economic fundamental variable. This results in a unique perfect Bayesian equilibrium in monotone strategies that enables the timing of a merger wave to be predicted and analysed. The results of this model are interesting because it plausibly combines several theories about merger waves and is consistent with some of the key traits in real-world merger activity. The findings are also fairly intuitive. For example, it is found that the higher the number of raiders, the scarcer the targets become in future periods, and so the less an agent values waiting. However, the model suffers limitations in the rigid framework it imposes, not just because of its assumptions. For example, after having raided, an agent becomes inactive and is no longer able to participate in further mergers.

Gorton et al. (2009) presents a model in which two types of mergers may occur: profitable acquisitions and defensive mergers. The model argues for the theory that when mergers occur, the managers of the acquired firm lose power. Therefore, managers prefer to make acquisitions rather than be acquired. Profitable acquistions are when mergers occur because they increase the value of both firms. However, defensive mergers are unprofitable acquisitions that occur because managers don't want to become a target and so increase their size (i.e., *eat or be eaten*). When two firms merge, the resultant firm takes on some of the value of the acquired firm. This value is dependent on a state of the world variable, which defines whether a merger increases value or decreases it. They also demonstrate how 'merger waves' might arise. Firms are ranked and allowed to act in order of size. Conditions are found using backwards induction across two timesteps, based on the game being in one of two states: a bad state in which all mergers destroy value, and a good state.

Gorton et al. (2009) finds that defensive mergers take place when managers do not want to be acquired, which can prompt defensive merger waves. When managers have no preference, only profitable acquistions are made. It is also found that the size distribution of firms in the industry is very important for merger dynamics; industries in which firms are of a similar size are prone to defensive mergers if managers prefer to remain independent. Despite supporting a number of real-world findings, such as that on average acquirers lose money and mergers often occur in waves, the model has several shortcomings. For example, there is a strict hierarchy imposed on the order in which agents can act: firms can only propose mergers with firms smaller than themselves. This reduces the types of mergers that are possible. Similarly, a firm may make at most one acquisition. Also, the definition of merger wave in a two-timestep model might be difficult to understand. This is true of several of the models.

Though a relatively new field, there has been some agent-based computational investigation into modelling mergers. These studies attempt to address the shortcomings of some game theoretic models in identifying dynamic effects that occur over time. For instance, models that cannot be solved analytically, may be simulated. Equilibria can then be identified using dynamic programming methods.

Gowrisankaran (1999) develops a dynamic model of mergers in which decisions to merge, invest, and enter or exit the market are endogenously made. In a similar framework to previous models, firms may merge and then produce in a Cournot competition. In between these stages, an exit may take place from the market, and following the game investment and entry is permitted. Gowrisankaran finds that having mergers in the industry changes the probabilities of exit and entry (i.e., when mergers occur, the entry rate increases and the exit rate drops). This is because mergers in the model act as a way of transferring the capacity from weak firms to stronger firms. However, it is also found that mergers reduce innovation by incumbent firms, since mergers allow firms to substitute external investment with internal investment. Firms are found to merge in order to decrease competition and increase production capacity.

Gowrisankaran (1999) highlights how the dynamic approach to modelling economic problems has resulted in often surprising effects that were not evident in static models. An example given is that of the assumption that higher entry costs imply a lower entry rate to the market, which is not found to be true using the model.

However, it is also made clear that design considerations, such as using a Cournot competition to model firm interaction, can strongly influence simulation outcomes. This is true of most models. Therefore, throughout the modelling process in this thesis, we attempt to carefully differentiate between the effects of design choices and fundamental behavioural trends in the model.

2.2.5 Connected Markets

A variety of complex dependencies can connect markets and market participants. Among the most obvious are supply chains. Supply chains are often modelled using networks: nodes represent firms or markets responsible for sourcing, producing and distributing goods; links between nodes represent the flow of goods (see Min and Zhou (2002) for a discussion).

Supply chains, like markets, evolve and change dynamically over time. Therefore, manufacturers can often make large efficiency savings by managing and restructuring their supply chains. However, evaluating the effectiveness of all possible updates can be time consuming. Therefore, of key interest to modellers are quick ways of optimising supply chain formation and maintenance.

Swarminathan et al. (1998) argues that agent-based simulation models can act as quick, impartial 'decision support tools' for manufacturers to evaluate a number of potential changes to their supply chain[2]. They propose a framework for such models to act as a baseline for developing company-specific simulation models.

Efficient supply chain formation remains a relevant area of research in agent-based modelling, owing in no small amount to the dynamic, evolving nature of markets. They have already proved successful: Procter & Gamble Co. managed to save $300 million per year by using agent-based, what-if modelling to transform their supply chain into an efficient supply network (Anthes, 2003). However, there is a symbiosis between supply chains and markets; changes in a market will affect how supply chains evolve, and similarly supply chain behaviour can affect market operations.

Therefore, the extended impact of merger activity is made more complicated by the dynamic dependencies, such as supply chains, between markets. In addition to direct competitors, firms dependent on a merging firm, such as suppliers or distributers, are likely to be affected by merger decisions. For example, changes to demand have been

[2] Recall that a key trait of agent-based models is their ability to simulate 'what-if' scenarios.

found to cause merger waves (Harford, 2005). Similarly, Ahern and Harford (2013) finds that dependencies between markets can act as pathways for merger waves to spread. 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.

This spread of waves is of particular concern to regulators, since mergers have 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).

2.3 Empirical Evidence

Before developing a theoretical model for the analysis of the complex intra- and inter-market effects of merger behaviour, it is important to consider the trends identified in empirical studies. For instance, when Microsoft made a $43.7billion bid for Yahoo in February 2000, Microsoft's share price fell by nearly 9% and Yahoo's jumped by nearly 53%. This response to a merger announcement is not unusual.

2.3.1 The Consequences of Mergers

This section summarises some key effects of market mergers from a selection of empirical research. It is by no means an exhaustive account of all available research in this area, but is meant to illustrate some key findings. As is clear, there are often contradictory conclusions drawn based on the dataset, timeframe or technique applied. For further studies on the effects of mergers see Rhoades (1998), Gugler et al. (2003) and Agrawal and Jaffee (2000). The summary is split into five areas of study that are common in this area: the effect of mergers on profitability and productivity, the effect on rival firms, and trends in the characteristics of both acquiring and target firms. It is important to remember that, although studies are grouped into categories based on their overall findings, they often find individual cases that act as exceptions to the trend they are proposing.

2.3.1.1 Profitability

Most mergers are undertaken with the view that they will positively affect the profitability, either in the short or long term, of the acquiring company (e.g., through efficiency gains). As is indicated in Table 2.1, whether or not this is actually the case has been long debated.

Profitability		
Negative	Neutral	Positive
Merged firms are less profitable than non-merged firms in the same industry.	*There is no significant difference.*	*Merged firms are more profitable than non-merged firms in the same industry.*
Asquith (1983), Magenheim and Mueller (1988), Ravenscraft and Scherer (1989), Dafny (2005), Malmendier et al. (2011), Malmendier et al. (2012)	Mandelker (1974), Malatesta (1983), Kleinert and Klodt (1983), Bradley and Jarrell (1988), Franks et al. (1991)	Akhavein et al. (1997), Gugler et al. (2003), Mantravadi and Reddy (2008)
Merged firms receive a negative effect to share price in comparison to non-merged firms in the same industry.	*There is no significant effect.*	*Merged firms receive a positive effect to share price in comparison to non-merged firms in the same industry.*
Malatesta (1983), Agrawal et al. (1992), Firth (1980), Mueller (1985), Loderer and Martin (1992), Higson and Elliot (1998)		

Table 2.1: The profitability effect of mergers.

For instance, Malmendier et al. (2011), Magenheim and Mueller (1988) and Dafny (2005) all find that merged firms are significantly less profitable than firms that do not merge in the same industry, whilst Gugler et al. (2003), Mantravadi and Reddy (2008) and Akhavein et al. (1997) find that they are more profitable. Additionally, Malatesta (1983), Bradley and Jarrell (1988) and Kleinert and Klodt (1983) declare that merging does not significantly affect profitability at all. Interestingly, Bradley and Jarrell (1988) use the same data as Magenheim and Mueller (1988), yet reach a different conclusion because they use different models. Additionally, Bendeck and Waller (2007) find that target firms earn positive returns following a merger anouncement.

However, when share price alone is considered as a performance metric, there is a clear trend in findings. The share price of merged firms in these studies is often negatively affected by a merger announcement. There are a number of theories about why this might be. One such theory concerns market misvaluation: when a firm makes an acquisition it is because it believes its shares are currently overvalued by the market and is using its shares as a cheap way of acquiring other firms. The market then responds by lowering the share price to a more accurate valuation of the acquiring company (see Rhodes-Kropf et al. (2005b) for more).

These studies consider a number of different industries and time-frames. However, it is clear that the overall relationship between merging and profitability remains an open question. For more information on this, Agrawal and Jaffee (2000) provides a useful summary.

2.3.1.2 Productivity

Productivity is the amount of output produced per unit of input. The input may be labour and capital, and the output may be the good being produced. Therefore, certain mergers may be undertaken with an aim of increasing the productivity of the merging firms.

Productivity		
Negative	Neutral	Positive
Merged firms are less productive than non-merged firms in the same industry.	*There is no significant difference.*	*Merged firms are more productive than non-merged firms in the same industry.*
Lichtenberg and Siegel (1987), Rezitis (2008), Mullin et al. (1995)	Bernad et al. (2010)	Haynes and Thompson (1999)

Table 2.2: The productivity effect of mergers.

The studies in Table 2.2 suggest that there is no definite effect of a merger on the productivity of the merged firms with relation to firms in the same industry. Different conclusions may be drawn when considering different datasets. In fact, Bernad et al. (2010) find that only approximately half of the mergers considered increased productivity. They also highlight the inconvenient tendency in the literature to draw conclusions based only on short-term changes in productivity, rather than allowing for different post-merger integration times. Such differences in timescales and industries make it difficult to come to a definite conclusion on the post-merger productivity of firms.

2.3.1.3 Effect on Rivals

As already discussed in the previous chapter, of key interest to competition regulators is the effect of a merger on rival firms. Mergers that might significantly negatively disrupt competition are prohibited. Therefore, there are a number of studies on what the effects of successful mergers on rivals are (see Table 2.3). Note that Mullin et al. (1995) find both positive and negative results: mergers result in a loss in market power for rival firms (and subsequent negative effect on consumers), but often increase in productivity.

Effect on Rivals		
Negative	Neutral	Positive
Mergers have a negative effect on rivals.	*There is no significant difference.*	*Mergers have a positive effect on rivals.*
Mullin et al. (1995)		Eckbo (1983), Clougherty and Duso (2008), Mullin et al. (1995), Bendeck and Waller (2007), Dafny (2005), Akhigbe et al. (2000), Filbien and Kooli (2011)

Table 2.3: The effect of mergers on rival firms.

As the table shows, there is a great deal of evidence supporting the idea that mergers benefit rival firms. In the literature, this is known as the 'free-riding' effect of a merger and is largely attributed to a reduction in competition by the effective removal of a firm. This is contrary to the intuition that the increase in size, efficiency, etc., of merging firms give them an advantage over non-merging firms (also found by Akhigbe et al. (2000) and in the case of concentrated markets in Filbien and Kooli (2011)). Additionally, Dafny (2005) finds that the effect of a merger is greatest on rivals most similar to the acquiring firm.

2.3.1.4 Acquiring Firms

The characteristics of the acquiring firm are likely to have an effect on merger consequences. For example, deals involving larger acquiring firms tend to take longer to be completed (Moeller et al., 2004).

Table 2.4 provides a summary of studies into the relationship between the size of an acquiring firm and the effect of the merger. Negative effects, for example, may be a reduction in shareholder value or productivity. As can be seen, there is no clear effect that acquiring firm size has on the consequences of a merger.

Acquiring Firms		
Negative	Neutral	Positive
The larger the acquiring firm, the more negative the effect of the merger.	*There is no significant difference.*	*The larger the acquiring firm, the more positive the effect of the merger.*
Moeller et al. (2004), Kleinert and Klodt (1983), Rau and Vermealen (1998)	Agrawal et al. (1992), Rhoades (1998)	Asquith et al. (1983), Malatesta (1983), Alexandridis et al. (2013)

Table 2.4: The characteristics of acquiring firms.

However, Sorensen (2000) finds that acquiring firms tend to be larger and more profitable than their targets. This is perhaps unsurprising since smaller, less successful firms may not find the acquisition of other companies feasible. Additionally, Bendeck and Waller (2007) finds that all bidding banks (i.e., including acquiring firms) sustain negative returns following a merger announcement.

An extensive study of this topic is given in Moeller et al. (2004).

2.3.1.5 Merger Targets

The size of the target firm in relation to the acquiring firm is also an important consideration. Alexandridis et al. (2013) claims that some negative trends in merger outcomes are the effect of large target sizes. Table 2.5 provides a summary of studies into this relationship. Just as before, negative effects may be a reduction in shareholder value or productivity.

Target Firms		
Negative	Neutral	Positive
The larger the target firm, the more negative the effect of the merger.	*There is no significant difference.*	*The larger the target firm, the more positive the effect of the merger.*
Alexandridis et al. (2013), Loderer and Martin (1992)		Tuch and O'Sullivan (2007), Jarrell and Poulsen (1989)

Table 2.5: The characteristics of target firms.

As can be seen, a general case is not easy to define. Alexandridis et al. (2013) find that the larger the target firm, the lower the offer made by the acquiring firm. As a consequence, acquirers were less likely to overpay for larger targets. However, acquisitions of larger firms destroy more value for acquiring shareholders.

Overall, larger target firms are often considered the cause of increased integration costs. However, such firms are also found to offer greater efficiency increases and potential increases in market power.

2.3.2 The Causes of Merger Waves

In attempting to identify the causes of 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). Also, studies have shown that there are different patterns of merger activity for listed and unlisted companies, and for certain sectors and markets during particular waves (Resende, 1996).

	Neoclassical	**Behavioural**	**Harford (2005)'s Findings**
Cause of industry wave	Regulatory or economic shock accompanied by capital liquidity	Overvaluation and dispersion of valuation within industry	Regulatory and economic shocks accompanied by capital liquidity
Cause of aggregate wave	Multiple simultaneous industry waves clustering because of macro liquidity factor	Overvaluation and dispersion in the aggregate	Multiple simultaneous industry waves clustering because of macro liquidity factors
Cause of partial-firm acquisitions	Increase during wave; could be made by stock bidders	Do not increase during wave; are not made by stock bidders	Increase during waves and are made by stock bidders
Pre-wave returns and market-to-book ratios	High if capital liquidity is tied to asset valuation	High	High
Dispersion in pre-wave returns	No prediction	High	Normal
Post-wave returns	No prediction	Low	Normal
Measures of tight credit	Low if capital liquidity is important	No prediction	Low
Post-merger operating performance	Better than without a merger	Worse in waves	Similar/better in waves

Table 2.6: Summary of predictions of neoclassical and behavioural theories of merger waves, taken from Harford (2005). The final column gives findings from Harford (2005)'s investigation.

Gugler et al. (2008) use empirical merger data to evaluate the neoclassical and behavioural theories of merger waves. They do this by discriminating between different types of merger. Firms are divided into listed or unlisted. If, as neoclassical theories suggest, fundamental economic shocks are responsible for merger activities, both types of firm would be equally affected by a wave. Similarly, if, as behavioural theories suggest, unlisted firms cannot be overvalued by the stock market, the two types of firm would be affected differently. It is found that waves are almost exclusively confined to listed firms, supporting the behavioural theories.

However, Harford (2005) finds evidence to support the neoclassical theories that shocks cause industry merger waves (see Table 2.6).

It is interesting to note that empirical investigations into merger waves tend to use similar datasets, applying different filtering and econometric analysis techniques (see Resende (1999), Resende (2008), and Resende (1996)). As demonstrated in the above cases, different methods of filtering and analysing the data can lead to different conclusions.

2.3.3 The Effects of Regulating Markets

> With national markets fast becoming European and even global in character, control of industrial activity at the national level is clearly inadequate (McGowan and Cini, 1999).

As already touched upon, the aim of regulating markets is to encourage competition and maintain consumer welfare. In an attempt to respond to an increasingly global market, a number of regulatory institutions have been developed to rule on cases that fall beyond a single country's juristiction (i.e., where the consequences of a decision might significantly impact another country). For example, in 1997 a merger was proposed between Boeing and McDonnell-Douglas, two American airline manufacturers (McGowan and Cini, 1999). Although the American Federal Trade Commission approved the merger, the EU Competition Commission opposed it: the merger would have created a company with a 70% share of the world's aerospace market, and the intention of Boeing to make purchasers sign a 20 year exclusivity deal would have excluded potential competitors such as Airbus. Given the EU's reaction, any Boeing flying into EU airspace could have been impounded and Boeing would have been excluded from the EU market. After a long running debate, Boeing eventually agreed to remove the exclusivity clause and make a number of changes to its merger agreement to be acceptable to the EU.

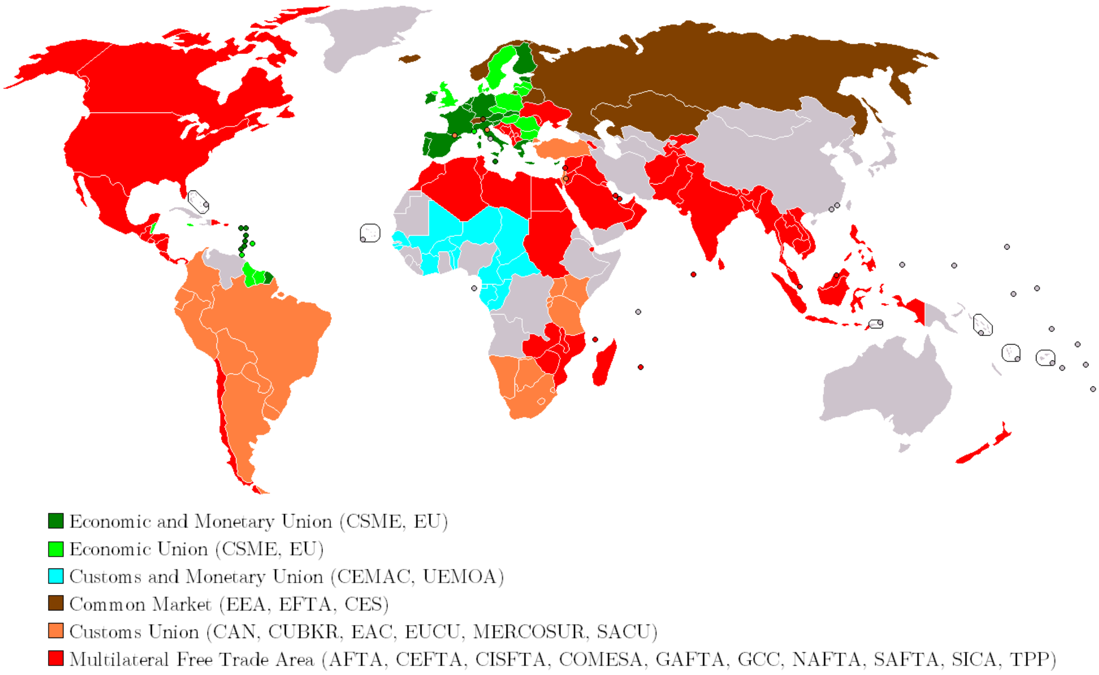


FIGURE 2.2: The current level of global economic integration (Various, 2013).

As illustrated by Figure 2.2, the extent of international economic integration varies by region. The degree of integration ranges from preferential trading areas, which give preferential trade access to certain products from particular countries, to complete economic integration, which removes any control of economic policy from individual countries or units.

The regulation of UK mergers may take place on two levels: EU and UK.

The European Commission's Merger Regulation (ECMR) is applied when a merger has a 'community dimension'. That is, when a proposed merger would have an effect at a global or international level. For example, ECMR is imposed when the combined worldwide turnover of the merging parties is greater than €5000m.

In cases that do not require ECMR, the UK law follows the Enterprise Act 2002, which aims to prevent mergers that would cause a 'substantial lessening of competition' in any affected market. The law is then enforced by the Competition Commission (CC) and the Office of Fair Trading (OFT). The OFT first chooses whether or not to allow the merger or pass it onto the CC for in-depth investigation.

Perhaps unsurprisingly, the relationship between EU and national regulation caused some disagreement when it was first introduced. The 'German Clause' (Article 9) was a last-minute addition to the ECMR, which allows national authorities to request that a case be repatriated under certain circumstances. Similarly, the 'Dutch Clause' (Article 23(3)) is the reverse, allowing member states to ask the European Commission to take on a national case. McGowan and Cini (1999) provides an engaging overview of how EU competition policy was created and evolved until 2000. They highlight the often *ad hoc* way in which policies are introduced and adjusted to respond to changing reactions.

However, as a consequence of this, the way in which policy is introduced and adapted can call into question its motives and effectiveness. For example, in 1992, the European Commission was accused of engaging in 'industrial engineering' when the Swiss firm Nestlé wanted to merge with France's Perrier. The merger would have created a duopoly in the French mineral water market but it was conditionally approved provided Nestlé gave up 20% of the market to an independent buyer. Similarly, in 2000, the European Commission prohibited a merger between Volvo and Scania, determining that it would have an adverse effect in Sweden. This triggered debate over whether EU policy was preventing companies in small countries from competing globally. However, the EU dismissed this, arguing that cross-border mergers provided expansion opportunities (as later shown by the mergers between Volvo and Renault, and Scania and Volkswagen (Horn and Stennek, 2007)).

Quantitatively estimating the effects of mergers on competition remains a key way of determining the success of a merger bid. However, the case-by-case nature of regulating merger bids highlights the flexibility in current merger guidelines. This is a consequence of evolving market boundaries, which require policy to be fair across countries. Therefore, flexibility is likely to remain a key trait of future regulation. As such, simulation models capable of identifying threshold triggers provide a useful tool in understanding the effects of regulatory changes.

2.4 Validating Agent-Based Models

'Fully concretised models are impossible to build in a complex world.' (Windrum et al., 2007). That is, it is impossible for modellers to capture every real-world nuance. Therefore, dependent on its purpose, a model must abstract away the behaviours and mechanisms that do not appear relevant to the phenomenon they are trying to investigate. For example, in time-series econometrics, a *signal* is used to capture the mechanisms of interest and *noise* accounts for other random factors. Unsurprisingly, such abstractions can make validation difficult.

According to Kleijnen (1995), validation is the process of asking 'is the conceptual simulation model...an accurate representation of the system under study?' Answering this question depends, therefore, on the type of model, how it has been designed, and what methods and datasets are available to test its accuracy.

Windrum et al. (2007) identify six stages that can present problems when validating agent-based models:

1. *Constructing Empirically-Based Models:*
   There are conflicting views on how models should be constructed. For example, should the simplest models be preferred over the most descriptive? An approach gaining popularity is *participatory modelling* in which stakeholders, such as people working in the industry, actively take part during the modelling process (Chu et al., 2012).

2. *Over-Parameterisation in Agent-Based Models:*
   A common problem in attempting to construct an accurate model is that of over-parameterisation; when a model is designed with too many variables. This can make causal relationships between parameters difficult to identify, since there are too many interdependencies between variables. According to Windrum et al. (2007), this can even produce a system that is 'little better than a random walk'.

3. *The Implications of Counterfactuals:*
   Windrum et al. (2007) suggest that 'by exploring a sufficiently large number of points in the space of initial conditions and parameter values...one can gain a deeper understanding of the behaviour of [a model].' Real-world data only provides one stream of events. Therefore, how can simulated results of counterfactual situations be evaluated? This is a particular problem when evaluating models designed specifically for 'what-if' analyses.

4. *Developing Sufficiently Strong Empirical Tests:*
   Being able to reproduce similar real-world behaviours does not necessarily mean that a given model is able to explain them. Therefore, it can be difficult determining how useful an empirical test is.

5. *The Availability, Quality and Bias of Datasets:*
   Given their reliance on real-world data, where the quality or availability of a dataset is called into question, evaluating the model against specific outcomes may be difficult.

In general, some calibration of a model to real-world empirical findings is often required in the validation process. For predictive models, this may involve calibrating model parameters based on historic data and testing them for future accuracy. For models that seek to explain phenomena, such as the model developed in this thesis, this may involve identifying stylised facts in previous empirical studies and observing that they also occur in the model.

Validating agent-based models remains an ongoing research problem. More discussions can be found in Marks (2012), Windrum et al. (2007) and Bianchi et al. (2007).

2.5 Summary

This chapter has outlined why agent-based models have become a popular tool for constructing dynamic simulations of economic phenomena, although issues surrounding their validation remain. It has also provided a detailed overview to the ongoing phenomenon of mergers waves: the theories surrounding their generation, their real world behaviour, how mergers are regulated, and how waves are modelled in the literature.

This research aims to make the following contributions:

1. To demonstrate how agent-based modelling can be used to create dynamic models of merging, capable of simulating merger wave phenomena;

2. To test the theories of merger wave causes;

3. To develop a better understanding of the role of dependencies between markets.

First, it will test the theories surrounding the causes of merger waves (Part I). This will be done by developing an agent-based model of a market in which firms endogenously merge and compete. The model will then be subjected to shocks designed to represent either behavioural or neoclassical merger wave triggers.

Then, it will examine the effect that inter-market dependencies have on the spread of merger waves (Part II). This will be done by connecting multiple market instances using supply chains. The model will then be tested to see if waves are clustered by industry and dependencies between markets act as pathways for mergers to spread.

The next chapter presents an agent-based model of competition and endogenous merging, which is then used to test the causes of merger waves.

Part I

A Single Market Model

As already highlighted in Chapter 2, there are many ways to model competitive markets. However, models of endogenous merging are often structured as a two-stage game. In the first stage, firms decide whether or not they want to merge. In the second stage, firms engage in some kind of competition. The decision to merge in the first stage is incentivised by the payoff a firm will receive in the competitive second stage.

The aim of Part I is to test the theories surrounding the causes of merger waves using agent-based modelling techniques. Given the popularity of the two-stage game format, we will adopt this approach, utilising two existing static models by Neary (2007) and Qiu and Zhou (2005), which differ slightly in their focus and conceptualisation of market firms. In Neary (2007), there are only two types of firms: those with a high or low production cost. In Qiu and Zhou (2005), firms may be assigned any production cost value within a given range.

Chapter 3 will develop a dynamic repeated-play game based on Neary (2007) and explore the concept of waves of merger desirability. It will also examine the effect of shocks on the behaviour of the market and the generation of waves.

Chapter 4 will expand our model to include an increased heterogeneity in firm production costs (as in Qiu and Zhou (2005)), and explore its effect on the behaviour of the market.

Considering dynamic implementations of both models will enable us to develop a useful understanding of the fundamental concepts of the merger game. It will also provide a step towards identifying how significant certain design choices are in affecting the overall behaviour of the model, which is an important consideration when designing any model.

Chapter 3

Two Cost Firms

This chapter develops a dynamic, agent-based model of endogenous merging based on Neary (2007). The model is then used to explore merger behaviour and identify the causes of merger waves.

In Neary's model, firms are assigned either a high or low production cost, then engage in a two-stage game. In the first stage, firms are given the opportunity to merge; in the second, all firms engage in a Cournot competition[1]. The outcome of the second stage incentivises the merger behaviour in the first stage.

In our dynamic model, this two-stage game is repeated. We also investigate the effect that the type of agent has on the model's behaviour: i.e., the extent to which agents are myopic (considering only the next timestep) or strategic (considering future timesteps).

3.1 A Dynamic Model

In our repeated two-stage game, the second stage incentivises the first. Therefore, consider now the second stage in which a group of firms compete to produce goods.

Stage 2: Production

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

$$P = \alpha - Q$$

[1]Although we follow Neary (2007) in employing a Cournot competition, a Bertrand competition would be an alternative option.

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

As a result of these assumptions, in a Cournot equilibrium where c_i denotes the marginal cost of firm i, M is the set of firms operating in the market, and $m = |M|$, firms' profits are equal to the square of the output:

$$\pi_i^M = (q_i^M)^2 \qquad q_i^M = \frac{\alpha + \sum_{j \in M} c_j}{m+1} - c_i \tag{3.1}$$

where q_i^M and π_i^M are the (Cournot-Nash) equilibrium levels of quantity and profit respectively. In equilibrium no firm has any incentive to deviate (i.e., increase or decrease their production quantity), because doing so would reduce their profit and all firms seek to maximise their profits.

Since demand is linear, outputs are strategic substitutes in Cournot competition. This means that if the number of operating firms decreases due to a merger between any two firms, then the output and hence profit of all surviving firms increases. This strategic effect is known as the free-riding effect of mergers (Bernile et al., 2011).

As in Neary (2007), we assume that firms are of two types: n firms produce at marginal cost c and $n^* = m - n$, at marginal cost $c^* < c$. Thus, for $c_i \in \{c, c^*\}$, equilibrium quantities are:

$$q_i = \frac{\alpha + n^*c^* + nc}{n^* + n + 1} - c_i \tag{3.2}$$

We note that a necessary condition for operating firms to produce non-negative quantities of output is that the market is large enough, i.e., that the market size, α, is such that:

$$\alpha \geq \alpha_0 \equiv n^*c - n^*c^* + c \tag{3.3}$$

which corresponds to Assumption 1 in Qiu and Zhou (2005).

Following Neary (2007), this condition can be equivalently formulated in terms of cost parameters, as follows:

$$c \leq \zeta_0\alpha + (1 - \zeta_0)c^* \qquad \zeta_0 = \frac{1}{n^* + 1} \leq 1 \tag{3.4}$$

showing that, in any Cournot equilibrium, profitability requires the marginal cost of less efficient firms, c, to be less than a weighted average of the size of the market, α, and the cost parameter of efficient firms, c^*, where the weights depend on the number of operating efficient firms.

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 (above).

Any firm in the market can act as an acquirer or be a target of a merger offer. Whenever a merger takes place, the target of the merger ceases to operate and leaves the game. Therefore, the number of operating firms m is then reduced by one. As a result, market competition is reduced and all post-merger operating firms benefit (an instance of the aforementioned free-riding effect). The remaining merged firm takes on the lowest production cost of the acquirer and target. Therefore, the benefit of merging can be both competitive (i.e., the acquirer benefits from the reduction in competition) and technological (i.e., the acquirer takes on the lowest of the two production costs). 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 π_j^M.

Acquirer i's expected profit from proposing to acquire j, at price π_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 π_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:

$$\pi_{i+\{j\}}^{M-\{j\}} - \pi_i^M - \pi_j^M > 0 \tag{3.5}$$

For example, a merger between an efficient firm i and an inefficient firm j is profitable if:

$$\pi^*(n-1, n^*) - \pi^*(n, n^*) - \pi(n, n^*) > 0$$

where the starred variables refer to efficient firms, i.e., those firm that produce at marginal cost c^*, and $\pi^*(.,.)$ and $\pi(.,.)$ are derived from equation (3.2).

We refer to *myopic mergers* as those that occur if and whenever their profitability is positive, i.e., for which inequality (3.6) is necessary and sufficient. Myopic mergers may reflect liquidity constraints on the part of firms (for example, being unable to borrow against future mergers) or can be motivated in terms of explicitly myopic behaviour on the part of the firms involved.

However, as already mentioned, 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. In order to account for these dynamic incentives, we need to extend the pre-production stage to account for multiple merging stages and explicitly consider dynamically consistent (subgame perfect) choices on the part of firms.

Multiple Stages: Merging

Following closely Neary (2007), we assume that the game consists of n stages of pre-production merger activity and a final production stage, entirely analogous to what has been previously described.

As an example, consider the s'th last stage ($s \leq n$) of pre-production activity and suppose the market composition is (n, n^*). Let $R(s, n, n^*)$ be the minimum reward that a high cost firm requires to agree to a merger and $R^*(s, n, n^*)$ be the expected profit of a low cost firm. Neary (2007) shows that a necessary condition for a strategic acquisition of the inefficient firm by the efficient one, requires that, for each s:

$$R^*(s, n-1, n^*) - R^*(s, n, n^*) - R(s, n, n^*) > 0$$

In fact, Proposition 2 and Proposition 5 in Neary (2007) provide the following useful characterization of the occurrence of myopic and strategic mergers, as a function of the cost parameters. Accordingly, a necessary and sufficient condition for *myopic* mergers to occur is:

$$c > \zeta_1 \alpha + (1 - \zeta_1) c^* \qquad \zeta_1 < \zeta_0 = \frac{1}{n^* + 1} \leq 1 \tag{3.6}$$

A necessary and sufficient condition for *strategic* mergers to occur is:

$$c > \zeta_2 \alpha + (1 - \zeta_2) c^* \qquad \zeta_2 < \zeta_0 = \frac{1}{n^* + 1} \leq 1 \tag{3.7}$$

In other words, myopic and strategic mergers are profitable when the difference between c and c^* is greater than some value dependent on the market size α. Simulations in Neary

(2007) suggest that $\zeta_2 < \zeta_1$. That is, that myopic mergers are a subset of strategic mergers: a merger that is not myopically profitable may be strategically profitable.

The inequalities that determine the profitability of mergers in different market configurations are highly non-linear in both the cost parameters (c and c^*) and the market size (α). This makes it at best very difficult to understand the behaviour of merger waves, and their potential triggers, analytically. On the other hand, the agent implementation to which we show next allows us to embed the model in an explicitly dynamic framework.

3.2 Agent Implementation

Timestep Evaluation

For the dynamic simulation of this model, we consider timestep evaluations (i.e., in each timestep, a fixed series of actions take place).

A market is initialised with m firms, each with a fixed marginal cost c or c^*. Since only active firms (i.e., those producing some positive quantity of goods) should be present at initialisation, we choose parameters c, c^* and α to satisfy inequality (3.3), or, equivalently, inequality (3.4).

In addition, at each timestep, there is a random flow of firms that enter or exit the market. New firms are randomly assigned a cost parameter, c or c^*, with equal probability and firms that are no longer able to produce goods exit the market. Also, x random firms are removed, where at each timestep x is drawn with equal probability from $\{0, 1, 2\}$. This ensures a continual turnover of market participants and is a tool employed to prevent *lock-out*, the situation in which firms with production costs greater than a threshold amount are unable to enter the market. This concept is discussed in more detail later on.

Myopic mergers are implemented in the simulation as follows. Within each timestep, the following sequence of events takes place:

1. Each firm i generates a matrix consisting of the payoff achievable in all possible pair-wise mergers with any other firm, j, net of the acquisition cost:

$$\pi_{i+\{j\}}^{M-\{j\}} - \pi_j^M > 0 \quad \forall j$$

2. Each firm i compares the above quantities to the opportunity cost of merging, (i.e., the payoff from not merging), π_i^M.

3. A firm k is randomly selected to act and it chooses to proceed to a merger if and only if this is strictly payoff increasing. If firm k chooses to merge with firm l, then

they consolidate in a single firm that produces at the lowest of their pre-merger marginal costs.

4. All firms take part in a Cournot competition.

This is repeated indefinitely.

By construction, at most one merger may occur in any given timestep. Therefore, one variable of interest to us is *merger desirability*: the number of firms who would find it profitable to merge in a particular timestep, if they were given the opportunity to do so. Within our model, a *wave* of merger desirability occurs if and only if there is a sequence of two or more timesteps for which merger desirability is strictly positive.

We explicitly assume that in case of indifference a firm does not proceed to merge. This may promote fewer mergers taking place, but makes the occurrence of merger waves more apparent. From the agent's perspective, it also results in less chance of inadvertently benefitting competitors via the free-riding effect previously identified.

Myopic decision-making refers to the situation in which agents evaluate the profitability of a merger based purely on the immediate payoff that the merger would provide in the next timestep. In terms of Neary's specification of the model, this implementation corresponds to the following scenario:

Myopic Mergers

(c, c^*) such that inequalities (3.5) and (3.6) are satisfied:

$$\zeta_1\alpha + (1-\zeta_1)c^* < c \leq \zeta_0\alpha + (1-\zeta_0)c^* \qquad \zeta_1 < \zeta_0 = \frac{1}{n^*+1} \leq 1$$

We have already established that some mergers that may not be myopically profitable, may nevertheless be appealing to firms who are able to account for the entire stream of future payoffs they may generate. However, since mergers are endogenous in our model, the profitability of any single merger would depend on the profitability of any other feasible merger. This makes it impossible to implement fully strategic mergers in our simulations.

However, we can move one step in this direction by looking at a slightly extended version of our model, where firms evaluate the payoff that a particular merger decision might afford them in both the next competition stage, and the competition after that. In order to do this, some discounted estimate of future behaviour must be made. For the purpose of this simulation, we consider the case in which agents look at most one timestep ahead. In that discounted future, the agent evaluates the most profitable myopic decision that a randomly selected agent would perform and then compares the payoff their merger decision would give them at that future time. We refer to this specification as *pseudo*-strategic and we note that, in terms of the Neary model, this implementation carries an analogy with the following scenario:

Pseudo-Strategic Mergers

(c, c^*) such that inequalities (3.5) and (3.7) are satisfied:

$$\zeta_2\alpha + (1-\zeta_2)c^* < c \leq \zeta_0\alpha + (1-\zeta_0)c^* \qquad \zeta_2 < \zeta_0 = \frac{1}{n^*+1} \leq 1$$

in the case where $\zeta_2 < \zeta_1$.

In order to understand what may trigger the occurrence of merger waves, we shall also consider the effect of changes in the *exogenous* parameters that determine the profitability of mergers. Namely, we shall consider the following cases:

Demand Shocks

Shifts in the market size, α, during simulation.

We recall that, in our model, the incentive to merge depends on the the size of the market. Ceteris paribus, an increase in α unequivocally raises output and profit via equation (3.1). However, from inequality (3.5), the profitability of a merger depends on the expected post merger profit, net of the acquisition price, and all these quantities are affected by shifts in α. Also, a rewriting of inequality (3.6) in terms of α shows that in order for mergers to occur, α cannot exceed an upper bound, which depends positively on the difference between the marginal costs of inefficient and efficient firms. As a result, the net effect is unclear. In fact, numerical analysis suggest that the effect of α on profitability is non-monotonic and highly non-linear.

Supply Shocks

Changes in the marginal cost of the inefficient firms, c.

It is clear that in our model heterogeneity in firms' costs is a necessary condition for mergers to occur. It is also clear that, ceteris paribus, efficient firms produce more, earn more - the more so, the higher is their cost advantage (from equation (3.1)) - and demand a higher acquisition price. Furthermore, they also benefit relatively more from the decreased competition brought about by a merger. Again, the implied net effect on merger waves is unclear. Inequalities (3.4), (3.6) and (3.7) suggest that the relevant bounds for the market size, α, that trigger merger activity depend on the difference between the marginal costs of production of the inefficient and the efficient firms.

We now provide a discussion with results from simulations of a particular model instance. Due to random number generation in the simulation, the outcome of each simulation is highly path dependent. However, multiple simulation runs enable clear trends to be identified.

Simulation Results

We now provide simulation results of behaviour in a simple market in which all agents behave either myopically or *pseudo*-strategically. We consider the following market:

$$\alpha = 25 \quad c = 6 \quad c^* = 3$$

and suppose that at $t = 0$, $n = n^* = 2$. Every timestep, two firms with random costs assigned from $\{c, c^*\}$ enter the market. In addition to firms that are removed from the market as a consequence of being unable to produce, a maximum of two randomly chosen firms may also be removed. Numerical analysis of inequality (3.5) suggests that for these values of the parameters, most mergers that are profitable involve an efficient acquirer and an inefficient acquiree.

Unless otherwise stated, these values will remain constant throughout all simulations.

First, consider simulated market behaviour with myopic decision-making agents. Figure 3.1 shows the number of active firms in a market over time, along with 'merger desirability': the number of firms that would merge if given the opportunity. As can be seen, there are two distinct types of period of behaviour in merger desirability: periods in which a large number of agents wish to merge, and periods in which none do. Sharp spikes in this value indicate the temporary attractiveness of a new member. Of more interest to us, is the appearance of sustained peaks. The regime-switching behaviour of aggregate merger desirability is a consequence of the α limits and the fact that it is more likely for a market to be stable when agent costs are closely clustered.

We also consider simulated market behaviour with pseudo-strategic decision-making agents using discount factor $\delta = 0.5$. We find that there is no significant difference in the aggregate behaviour of myopic and pseudo-strategic decision-making agents. Therefore, for the subsequent simulations we consider agents that behave myopically.

It is interesting to consider the extent to which these waves differ from those generated by a random walk. Figure 3.2 compares the occurrence of waves in the model in Figure 3.1 with waves generated at random using a Bernoulli process where the probability of merger desirability being positive is $\lambda = 0.25$[2]. We will refer to the sequence of randomly waves generated as the *null model*. As can be seen, there are clear differences between the models. Waves generated by the model are less frequent and more sustained than those generated randomly. These differences are found to be statistically significant.

[2]This value for λ was chosen as it resulted in the output most similar to the model.

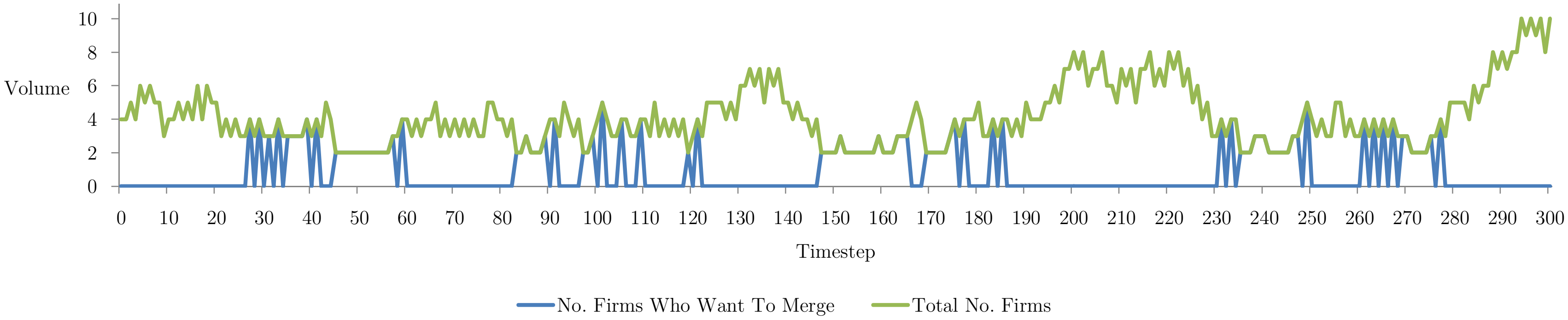


FIGURE 3.1: Waves of merger desirability with myopic decision-making agents. Parameters are: $\alpha = 25$, $c = 6$, $c^* = 3$, and at $t = 0$ $n = n^* = 2$.

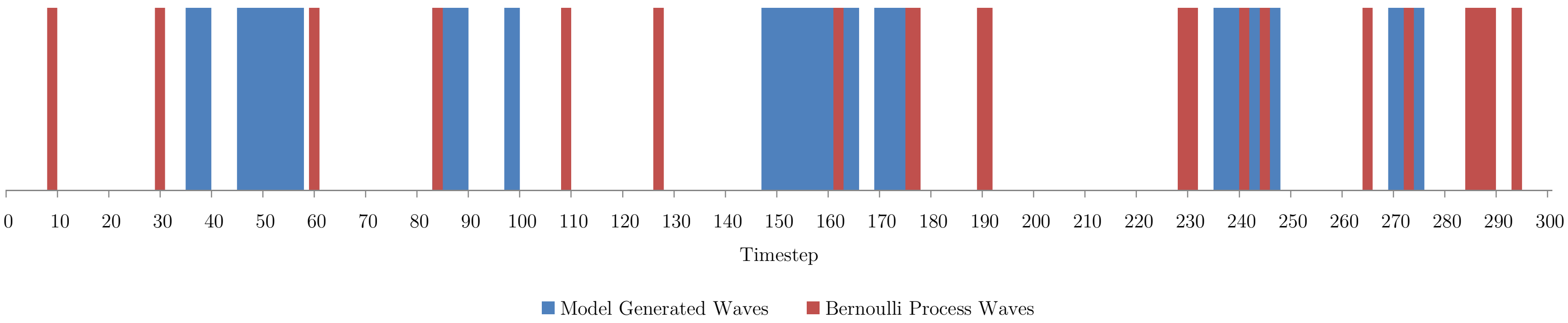


FIGURE 3.2: A comparison of merger desirability waves generated by the model in Figure 3.1 and a random walk (a Bernoulli process with = 0.25).

Therefore, we can conclude that waves generated by the model are significantly different from those generated randomly.

Demand Shocks

We now consider the effect of exogenously generated shifts in the market size α on the emergence 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 3.3 shows the number of active firms and merger desirability, along with α from a representative simulation run. As can be seen, rather than the constant α as used in previous simulations, α is exogenously made to oscillate about $\alpha = 25$. All other market conditions remain the same.

As can be seen, periods of high merger desirability occur for particular α values. Figure 3.4 shows this more clearly by aggregating data from 100 long-duration (5000 timestep) runs of the model. Here, each dot records the number of firms that want to merge at a point during the sinusoidal wave phase of α from a particular simulation. As can be seen for the parameters chosen here, there is a strong relationship between merger desirability and market size α. For low values of α, mergers are generally undesirable.

Supply Shocks

We now consider the effect of an exogenously generated supply shock caused by shifting the value of c during simulation to c', where $c \geq c' \geq c^*$. This may correspond to a decrease in production costs for certain firms, or to a technological innovation.

Figure 3.5 shows the effect of shifting $c = 6$ to $c' = 4$ at 300 timesteps. The cost disruption results in a merger wave within the following 100 timesteps.

As can be seen, there is a gradual increase in the total number of firms after a cost shift, which is then followed by a wave in merger desirability. This does not happen every time a cost shock is applied, but is a trait of the model when this shock generates a merger wave.

To understand why this occurs, consider Figure 3.6, which shows the proportion of low-cost firms in the market over time along with periods of merger desirability. As can be seen, the market favours low cost firms and so they tend to dominate the market quickly after initialisation. Once the number of low-cost firms reaches a threshold value, high-cost firms are forced to exit the market and cannot enter (i.e., lock-out). Equation 3.3 shows that as c decreases, the minimum market size to keep all firms producing also decreases. Additionally, as n^* increases, this value also increases.

Given constant $\alpha = \alpha_0$, this threshold value is given by:

$$n^{*\prime} = \frac{(n^* + 1)(c - c^*)}{(c' - c^*)} \tag{3.8}$$

where c' is the new cost of production for high-cost firms and $n^{*\prime}$ is the number of low-cost firms in the market. If $n^{*\prime}$ becomes larger than this value, it pushes up the minimum market size required to keep all firms producing to above the set market size α.

The random removal of market firms means that occasionally, the number of low-cost firms enables one or more high-cost firms to enter. This may then prompt mergers until the market domination of low-cost firms resumes.

After 300 timesteps, an industry shock is exogenously appplied to the market. The effect this has on the proportion of low-cost firms is stark and goes someway to explaining both the drop in firm number and ensuing merger wave (around 350 timesteps). Lowering the cost of high-cost firms raises the number of low-cost firms needed in the market to create lock-out, given a constant α. Therefore, high-cost firms are once again able to enter the market, along with low-cost firms. The total number of firms increases.

Once the new threshold number of low-cost firms is reached, a series of mergers and a drop in the number of high-cost firms reduces the firm number. As the size of the shock increases, the proportion of high-cost firms the market may support before lock-out also increases. Therefore, it takes longer for lock-out to occur.

Figure 3.7 shows the relationship between the magnitude of the disruption to costs and the properties of the resulting wave. The magnitude of the cost shift for high cost firms is given by: $\frac{c'-c^*}{c-c^*}$. Therefore, this value is 0 when $c' = c$, 0.5 when $c' = 0.5 * (c - c^*)$, and 1 when $c' = c^*$.

Figure 3.7a shows the effect that the magnitude of the cost shift has on the proportion of runs that generate merger waves, and Figure 3.7b shows the average magnitude of merger waves generated. The magnitude of a merger wave is the proportion of firms that want to merge within the 100 timesteps following the initial shock. Since this value is normalised dependent on the total number of firms in the market during a simulation, the maximum value this can take is 100. Both graphs also show the average probability and magnitude of waves in the case when no shocks are applied to the market, and under the null model[3]. In the null model, we will refer to the average magnitude of a wave as the average proportion of timesteps mergers are desirable for (approximately 25).

[3]Recall, the null model is a Bernoulli process with $\lambda = 0.25$.

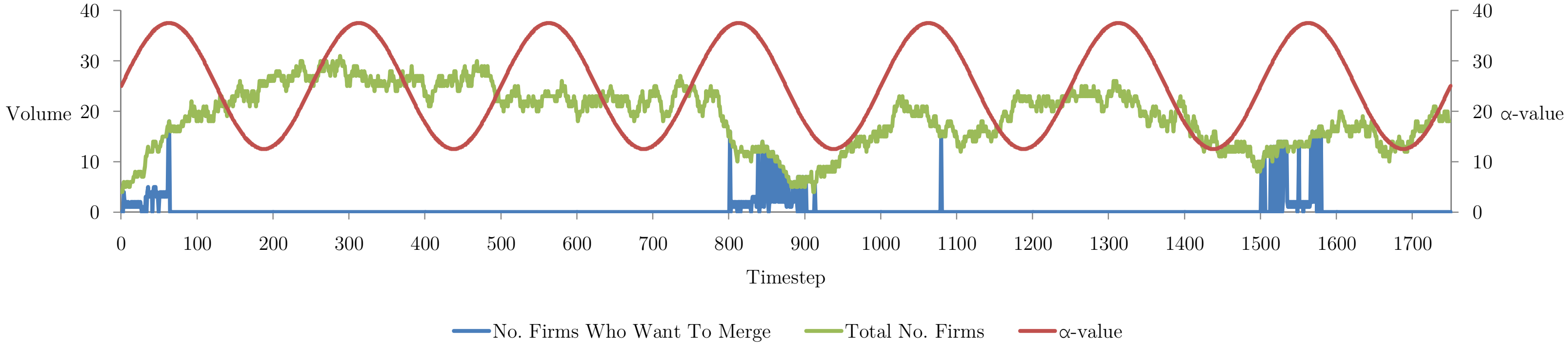


FIGURE 3.3: Waves of merger desirability with exogenously determined sinusoidal α and myopic decision-making agents. Parameters are: α follows a sine wave about 25 with period $= 250$ timesteps and amplitude $= \frac{25}{2}$, $c = 6$, $c^* = 3$, and at $t = 0$ $n = n^* = 2$.

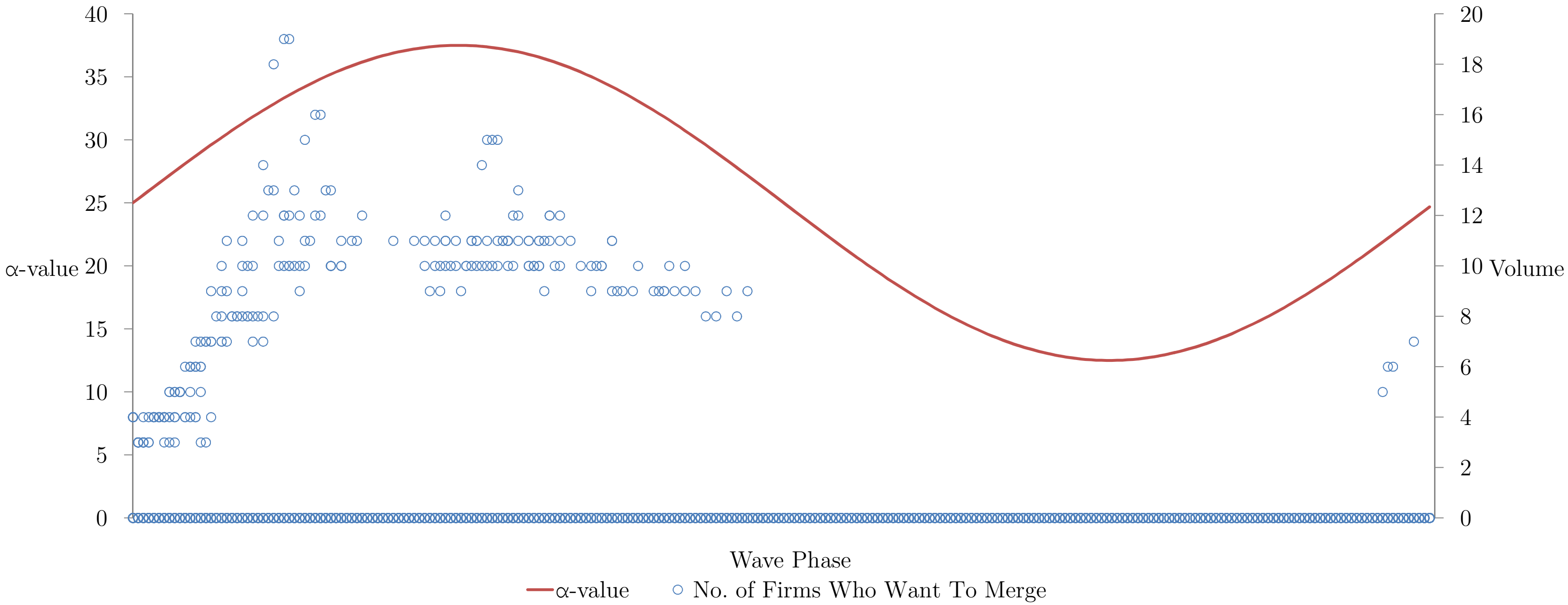


FIGURE 3.4: The degree of merger desirability as a function of the phase of the exogenously determined sinusoidal α. Parameters are: α follows a sine wave about 25 with period = 250 timesteps and amplitude = $\frac{25}{2}$, $c = 6$, $c^* = 3$, and at $t = 0$ $n = n^* = 2$. Data is drawn from 100 runs of a 5000-timestep simulation.

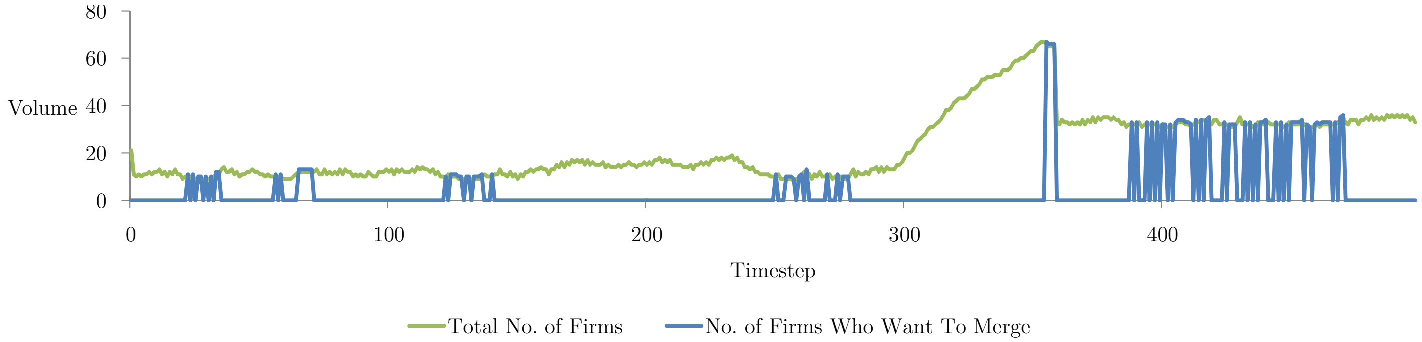


FIGURE 3.5: Waves of merger desirability caused by exogenously generated shock to production costs: $c' = c - 2$. The initial parameters are: $\alpha = \alpha_0$, $c = 6$, $c^* = 3$, and at $t = 0$ $n = n^* = 10$.

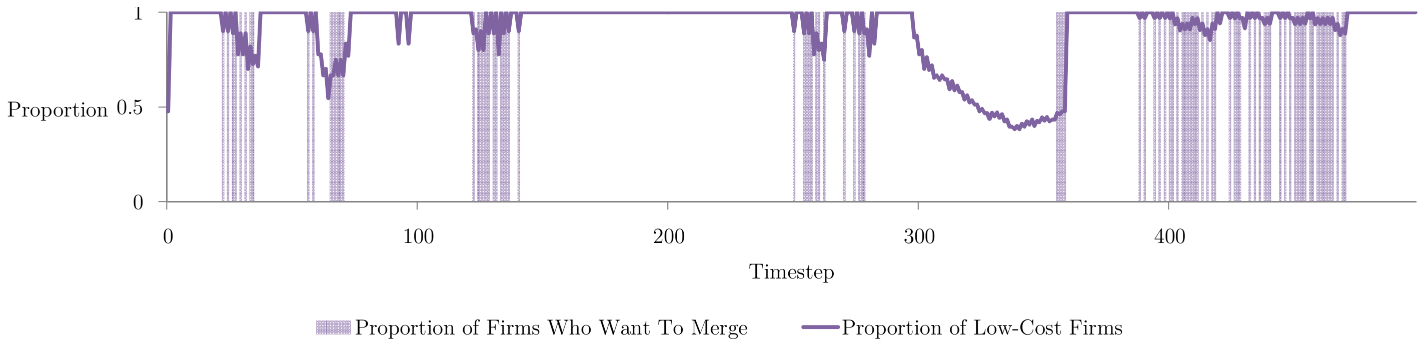
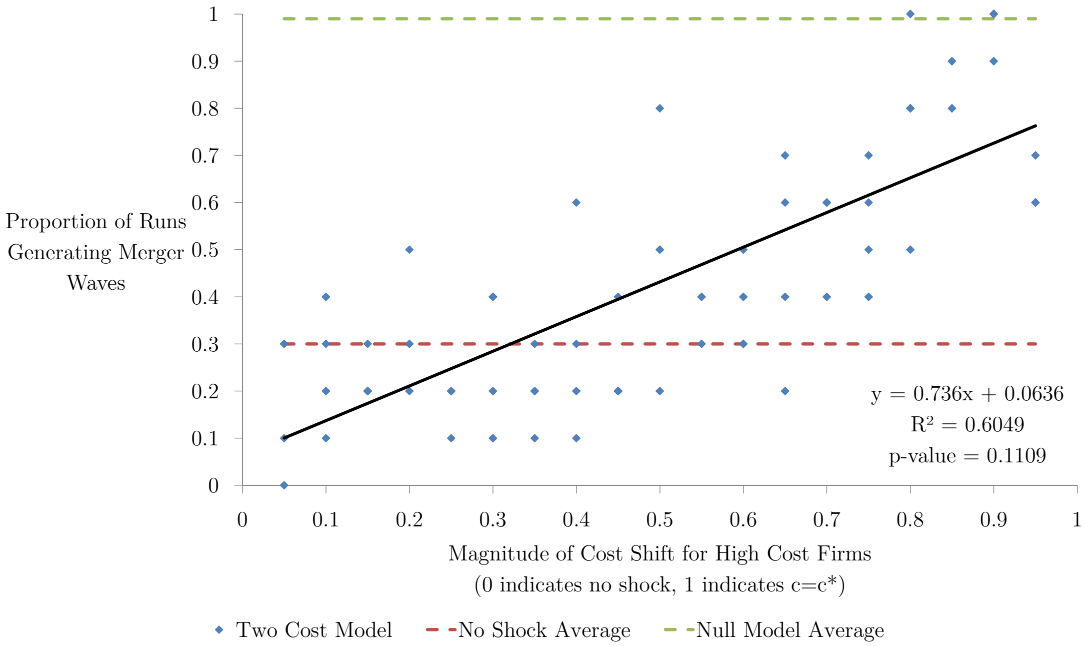
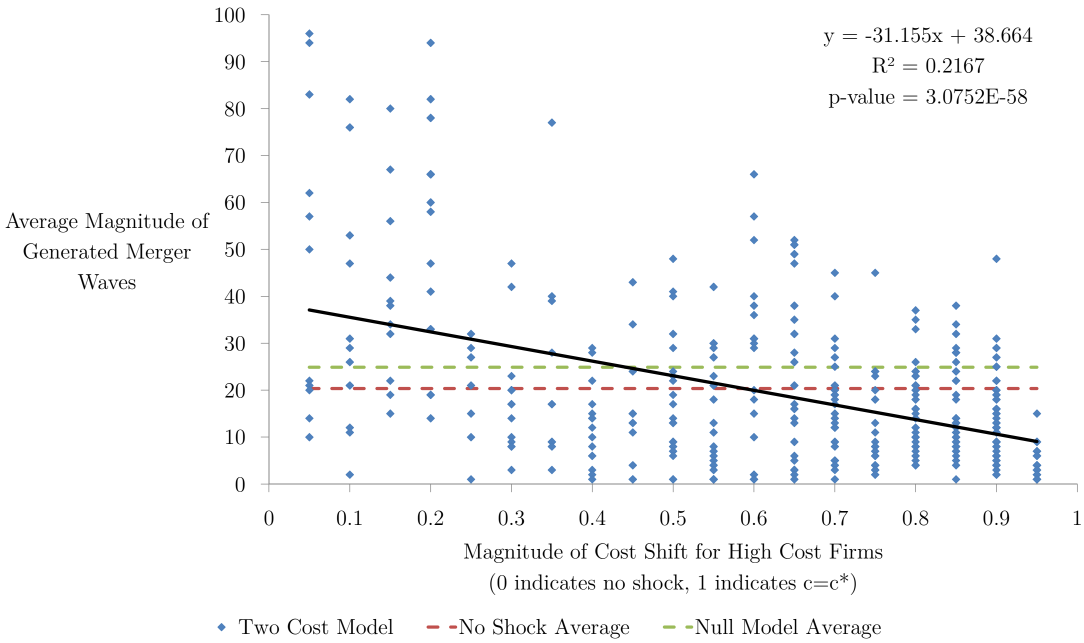


FIGURE 3.6: The proprtion of low-cost firms in the market and the proportion of firms who want to merge (periods of merger desirability) caused by exogenously generated shock to production costs at 300 timesteps: $c' = c - 2$. The initial parameters are: $\alpha = \alpha_0$, $c = 6$, $c^* = 3$, and at $t = 0$ $n = n^* = 10$.



(A)



(B)

FIGURE 3.7: Scatter plots showing the trend in (a) the probability and (b) the extent of merger desirability in the 100 time steps following exogneously generated shocks to production cost. Parameters are: $\alpha = \alpha_0$, c varies relative to c^*, $c^* = 3$, and at $t = 0$ $n = n^* = 2$.

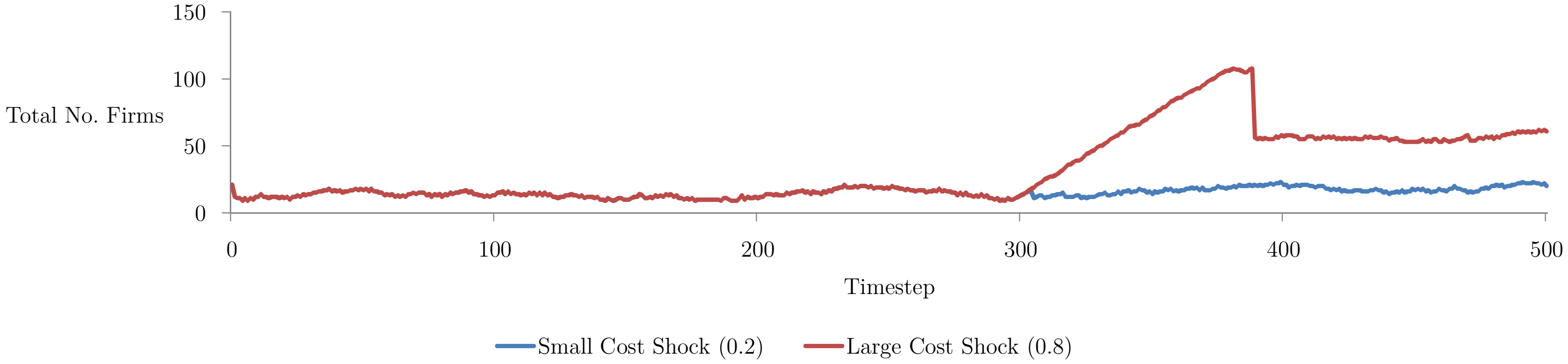


Figure 3.8: Total number of firms in a market over time when subjected to a small (0.2) and large (0.8) cost shock at 300 timesteps. Parameters are: $\alpha = \alpha_0$, c varies relative to c^*, $c^* = 3$, and at $t = 0$ $n = n^* = 10$

Unsurprisingly, the probability of a wave occuring within a 100 timesteps in the null model is 1, significantly different from those generated in the model. However, its average magnitude (24.883), is similar to the no shock average. As can be seen, though an overall trend is visible in each graph, there is also a great deal of variance.

As the size of the shock increases, the magnitude of the resulting merger waves decreases, but the probability of a wave occuring increases[4]. In other words, large shocks are more likely to generate merger waves, but these waves are smaller relative to those generated by small shocks. From Figure 3.7 we can see that these are not independent variables, and that the relationship between them is non-linear. Therefore, if there is a linear relationship between the size of the shock and the proportions of runs generating a wave (see Figure 3.7a), we would expect a non-linear relationship in Figure 3.7b. The low p-value for Figure 3.7b shows that there is clearly a statistically significant correlation between the size of the cost shock and the magnitude of the generated wave. However, the low R^2 suggests that this relationship is non-linear.

Reducing c reduces the value of α required for technological mergers (i.e., those proposed by high-cost firms). Though it also increases the value of α required for competitive mergers (i.e., those proposed by low-cost firms), the overall range of α values that enable profitable mergers increases. This increases the probability of a merger taking place in a given simulation. Therefore, as the size of the shock increases, the probability of a merger wave occuring increases.

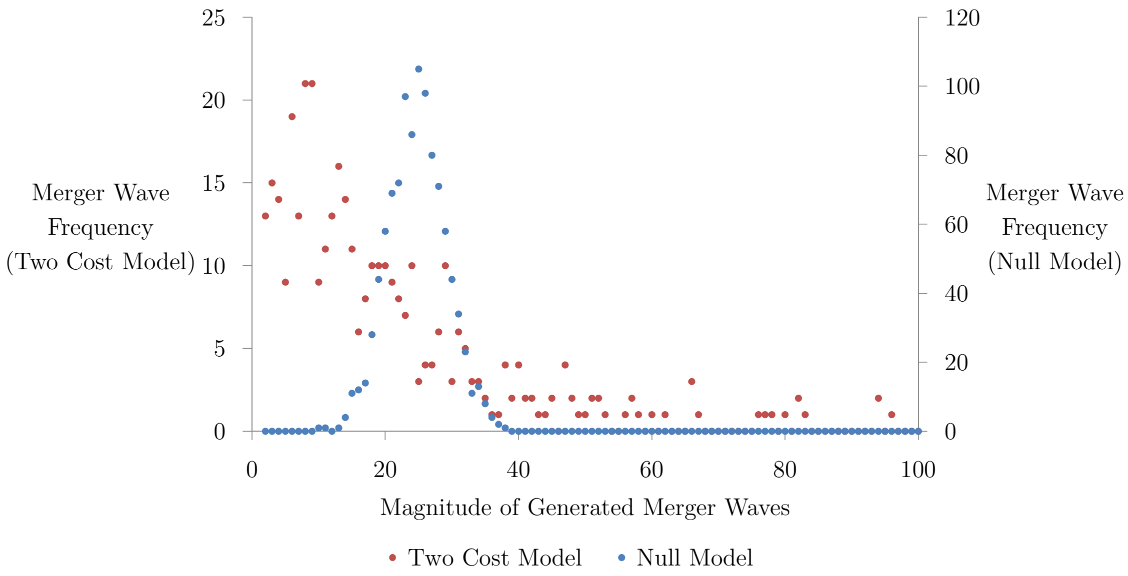
The magnitude of a wave is a measure of how long the wave remains in the market for the first 100 timesteps following the shock. As already mentioned, the larger the shock, the greater the proportion of low-cost firms the market will now support. This increases the number of high-cost firms in the market and delays the time at which lock-out occurs. This delay therefore influences the measure of magnitude, decreasing it as the size of the shock increases (see Figure 3.8).

In addition to this, the total number of firms in a market receiving a large cost shock becomes far larger than markets receiving a small shock. Therefore, after the initial merger wave and high-cost firm lock-out, there is a much larger number of low-cost firms operating in the market. This makes it less likely that the random removal of existing firms will enable high-cost market entrants to enter the market and incite further mergers. This contributes to the reason why as the size of the shock increases, the magnitude of the wave decreases.

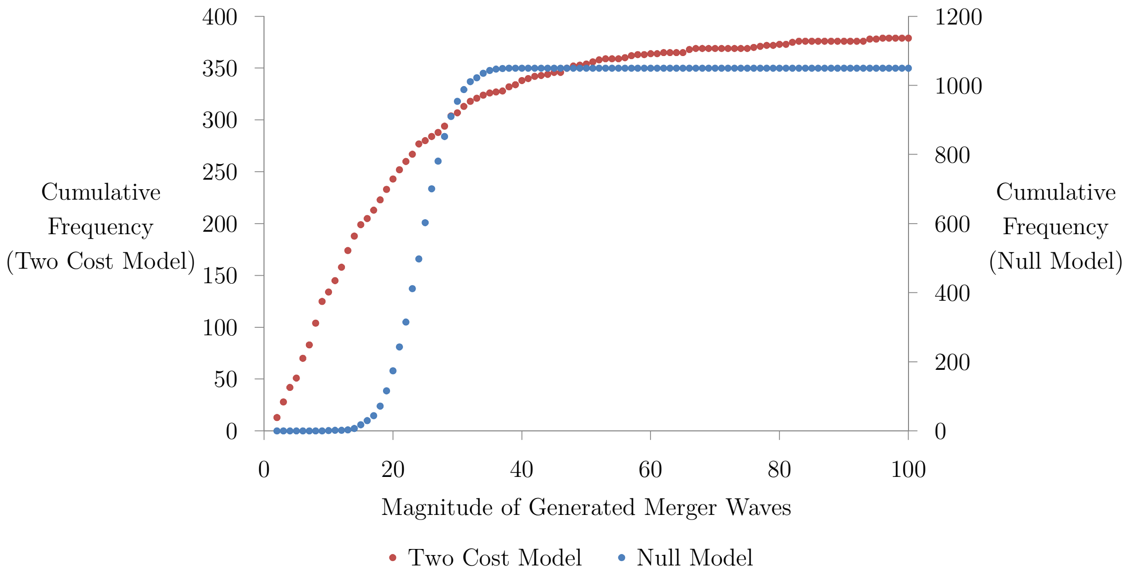
Figure 3.9 shows the relationship between the average probability and extent of merger desirability following a cost shock. It suggests that the larger the magnitude of a wave,

[4] However, the high p-value indicates that there is a high chance of observing this effect even if the variables are uncorrelated.

the less likely it is to occur. This relationship is found to follow an exponential distribution (see Figure 3.10). It also highlights again the significant difference between the null model and the two-cost model.



(A) Distribution



(B) Cumulative Distribution

FIGURE 3.9: The relationship between the probability and extent of merger desirability in the 100 time steps following exogneously generated shocks to production cost. Parameters are: $\alpha = \alpha_0$, c varies relative to c^*, $c^* = 3$, and at $t = 0$ $n = n^* = 2$.

There is also a clear distinction between waves endogenously generated by the model (i.e., when the magnitude of the cost shift is 0, $c' = c$) and those generated by a supply shock.

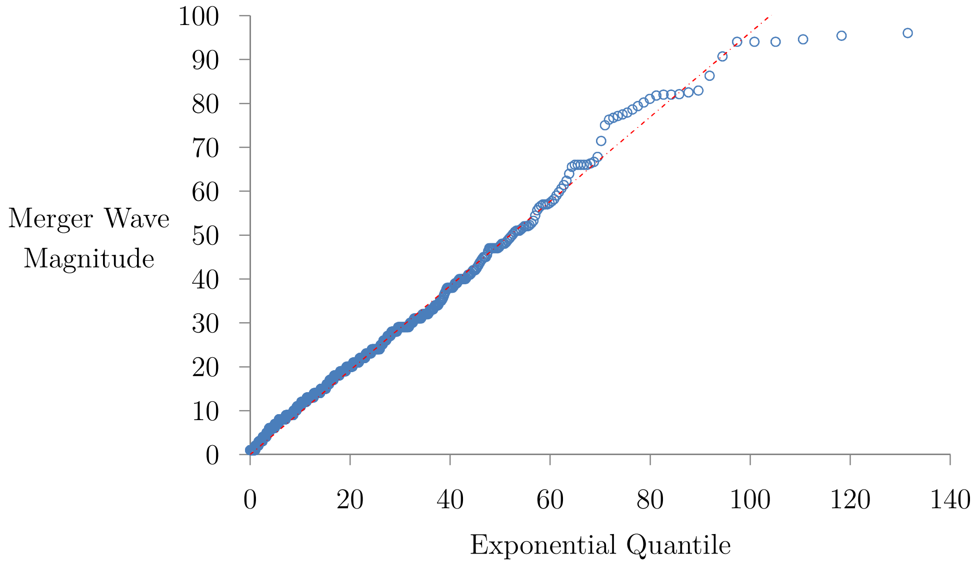


FIGURE 3.10: QQ plot showing the relationship between the merger wave magnitude in the two cost model and an exponential distribution.

Summary

This chapter has developed a dynamic, agent-based model of endogenous merging based on Neary (2007). Through simulation, we have examined how intermittent sustained periods of merger desirability can occur. We have also considered the effect that using myopic and pseudo-strategic firms has on the behaviour of this model.

It was found that:

- The model exhibits a two-phase regime-switching behaviour that generates periods of opportunity in which mergers become desirable to a large number of agents, separated by periods during which mergers are not profitable (i.e., merger waves). This behaviour is consistent with empirical analysis of merger wave data (Gartner and Halbheer, 2009). Merger activity is driven by the relationship between distributions in production cost and market demand.

- Merger waves can occur endogenously in the model, consistent with the theory that random fluctuations in market dynamics create periods in which merging becomes desirable. These endogenously generated merger waves were found to be significantly different from those generated in the null model (see Figure 3.2); they were found to be less frequency and more sustained. This supports the view that there are waves in merger activity (Gartner and Halbheer, 2009).

- Merger waves can be generated by shocks consistent with the behavioural theories of merger wave causes (see Figures 3.3 and 3.4). Our results also suggest that during depression periods high cost firms are forced out of production, preventing any merger activity.

- Merger waves can be generated by shocks consistent with the neoclassical theories of merger wave causes (see Figures 3.5 and 3.6). Our results suggest that the larger the shock applied to a market, the larger the probability of causing a merger wave, but the smaller the magnitude of that wave (see Figure 3.7). We also find that the larger the magnitude of the wave, the less likely it is to occur (see Figure 3.10). Again, these wave characteristics were found to be significantly different from those generated by the null model (see Figure 3.9).

- No difference was found in behaviour between myopic and pseudo-strategic decision-making firms.

Overall, our results support the view that there are waves in merger activity, which are significantly different from those generated by a null model. The two cost model has also demonstrated its ability to generate waves consistent with neoclassical and behavioural theories of merger wave causes.

In the next chapter, we will extend this model using Qiu and Zhou (2005) to examine the effect of increased firm heterogeneity.

Chapter 4

Multi-Cost Firms

In the previous chapter, a simple agent-based model of endogenous merging was introduced. The model demonstrated how aggregate, dynamic merger behaviour could be used to generate merger waves. However, it is important to consider the effect that certain design choices have on model outcomes; which results are generated by design choices and which are intrinsic characteristics of the game? Therefore, in this chapter we extend the model to investigate the effect of increased heterogeneity in firms.

In Qiu and Zhou (2005), firms engage in a two-stage game as in Neary (2007): in the first stage, they decide whether or not they want to merge, and in the second they compete. However, firms are no longer assigned either a high or low cost. Instead, costs are drawn from a given range.

4.1 A Dynamic Model

Let us now outline the changes to the previous model.

Production Stage: Cournot competition

A market is initialised with M firms ($i \in 1, 2, 3 \cdots m$). Each firm i is assigned a fixed marginal cost c_i. This cost is publicly known. The firms are indexed so that $c_1 \leq c_2 \leq \cdots \leq c_m$.

Firms produce quantities as before (see equation (3.1)).

To ensure all operating firms are producing non-negative quantites at initialisation (equation (3.2) in the previous model), the market size, α, must follow:

$$\alpha > \alpha_0 \equiv (m+1)c_m - \sum_{i=1}^{m} c_i \tag{4.1}$$

First Phase: Evaluating Merger Profitability

The decision to merge is motivated just as before. Therefore, if firm i merges with firm j, the newly formed firm adopts the lowest production cost of the two. That is, c_i becomes $\min(c_i, c_j)$ where firm i is the proposing firm.

4.2 Agent Implementation

Just as before, the model is a repeated, two-stage game.

4.2.1 Timestep Evaluation

At initialisation, there are m firms. Dependent on the simulation, market entrants may be modelled by the introduction of new agents, and agents unable to produce any good are removed from the market. As in the previous model, agents are randomly removed in order to prevent permanent 'lock-out'. Lock-out is the situation in which firms assigned a cost above a particular threshold will never be able to enter the market. Since the market favours low-cost firms, the random removal of agents encourages a constant turnover of firms.

Since only active firms (i.e., those producing some positive quantity of goods) should be present at initialisation, α should satisfy:

$$\alpha > \alpha_0 \tag{4.2}$$

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

$$\alpha \leq \frac{(m+1)}{(m-1)^2 - 2}((m^2-1)c_j - 2mc_i) - \sum_{k=1}^{m} c_k \equiv \alpha_{i,j}^M \tag{4.3}$$

If $\alpha_{i,j}^M \geq \alpha_t \geq \alpha_0$ for some i, j such that $i \neq j$, there is at least one profitable merger in the system.

- When $\alpha > \alpha_{i,j}^M \ \forall i \neq j$, the market size is too great 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 α_{max} and α_{min} as the maximum and minimum values of α for which mergers are profitable.

$$\alpha_{\text{max}} = \max(\alpha_{i,j}^{M}) \qquad \forall i, j \;\; i \neq j \tag{4.4}$$

Simulation Results

Just as in the previous model, the distribution of production costs in the market determines whether or not it is a profitable time to merge, given the market size, α. However, given the added complexity of multiple production costs, it is useful to begin by considering the effect of introducing a single entrant into a stable market.

A market is stable when no agents wish to merge (i.e., when $\alpha_{i,j}^{M} < \alpha \; \forall i \neq j$). Therefore, the effect of a new firm i on the market depends on c_i and the existing configuration of the market. If the distribution of costs is sufficiently changed by a market entrant, one or more mergers may become newly profitable. Similarly, if the current market size, α, is affected, the extent of merger desirability is also affected.

The market may, therefore, be in one of three states based on α (see Figure 4.1):

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.

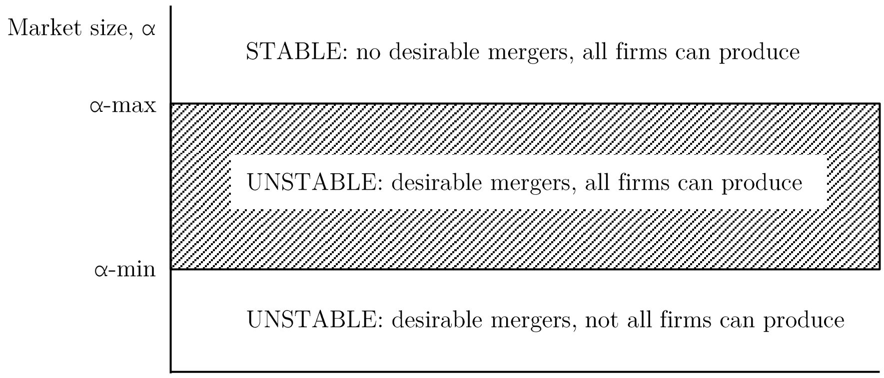


FIGURE 4.1: Abstract borders of market size values that incentivise merging and production.

Consider a market of firms with the same production costs. The benefit of merging would be the reduced market competition. Therefore, it is interesting to ask if there is a size of market for which a same-cost market would be unstable? There is. However, this occurs when the number of agents is very small in the market (≈ 2). This is because, for any two agents to merge, the payoff from merging must be greater than the payoff from not merging:

$$\begin{aligned} \pi_i^M &< \pi_i^{M-1} \\ (\frac{\alpha + \sum_{i=1}^{m} c_i}{m+1} - c_i)^2 &< (\frac{\alpha + \sum_{i=1}^{m-1} c_i}{m} - c_i)^2 - (\frac{\alpha + \sum_{i=1}^{m} c_i}{m+1} - c_i) \end{aligned} \tag{4.5}$$

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

$$(\frac{\alpha + cm}{m+1} - c)^2 < (\frac{\alpha + c(m-1)}{m} - c)^2 - (\frac{\alpha + cm}{m+1} - c) \tag{4.6}$$

Figure 4.2 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.

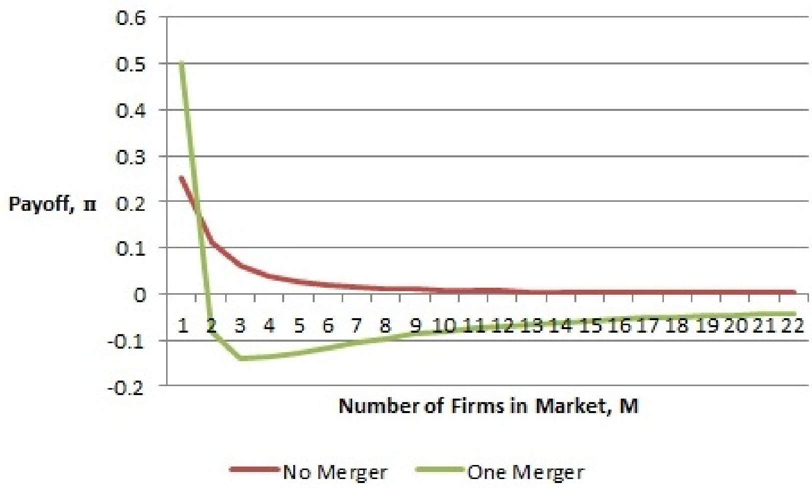
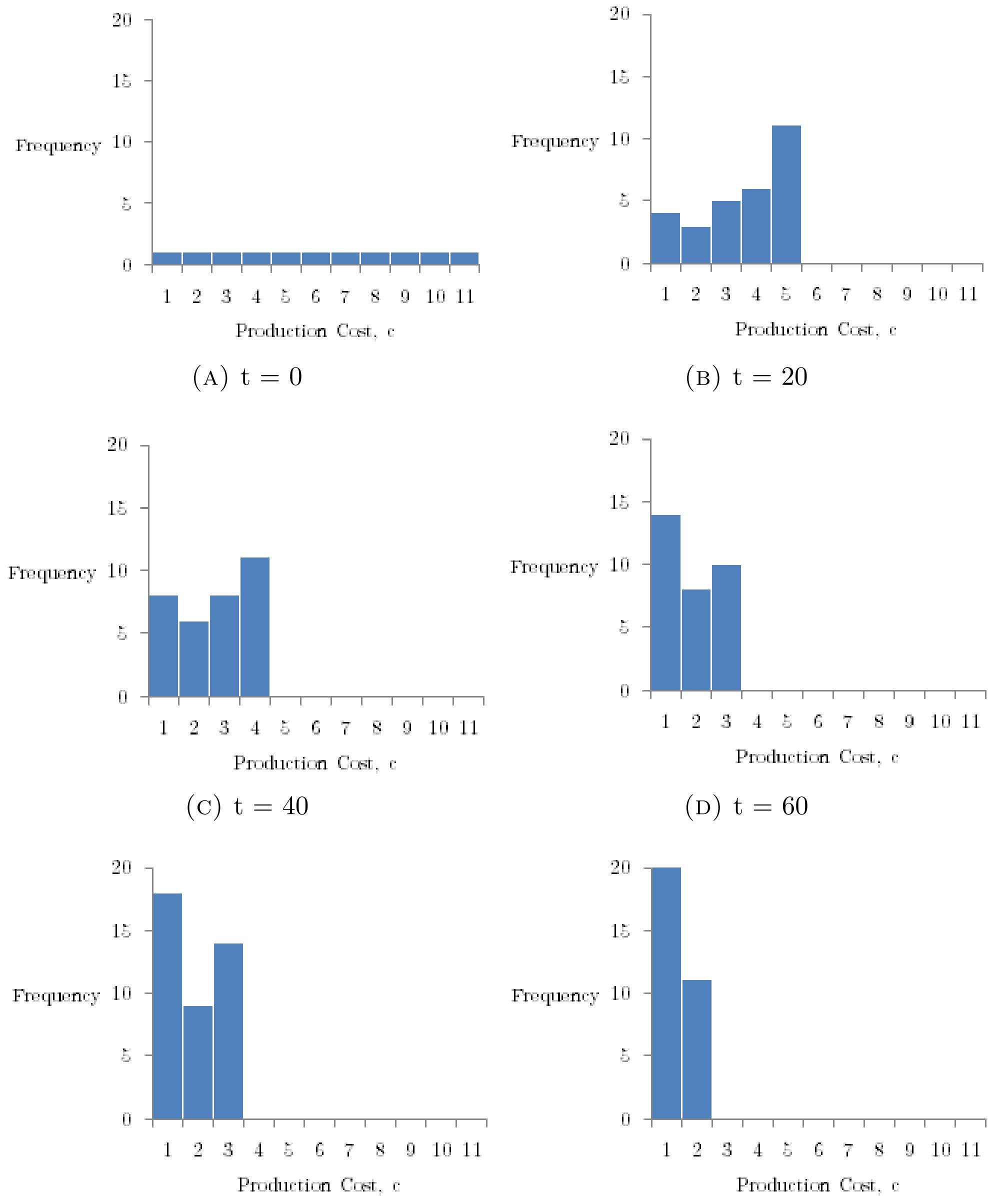


FIGURE 4.2: Payoff from Merging vs. Not Merging for $c_i = 10$ and Varying M

Consider behaviour at firm level.

Trivially, firms with a lower production cost are favoured by the market. Figure 4.3 shows the distribution of costs within a market at four points in a multiple production cost market simulation. The initial 11 firms have uniformly distributed costs. As mergers take place, new firms enter the market, and some firms are forced to exit, the distribution of costs narrows to focus on firms with the lower production cost.



(A) t = 0

(B) t = 20

(C) t = 40

(D) t = 60

(E) t = 80

(F) t = 100

FIGURE 4.3: Distribution of firms' costs of production during a simulation. Parameters are: $\alpha = \alpha_0 + 1$, $n = 11$, $c_i = \{1, 2, \cdots, n\}$.

Once this happens, firms with high production costs are essentially locked-out of the market, since they are no longer able to produce any goods given their costs. The random removal of agents encourages a more dynamic turnover of firms. However, the extent to which this enables higher cost firms to enter the market becomes less as the distribution of production costs for the remaining firms clusters around smaller numbers.

It is interesting to consider whether all higher production cost entrants to the market will be unable to produce any good. Suppose we introduce a firm which would have a higher production cost, c_m, to all existing firms in the market. For it to be able to produce:

$$\begin{aligned} q_i^M &> 0 \\ \frac{\alpha + \sum_{i=1}^{m-1} c_i}{m+1} - c_i &> 0 \\ \Rightarrow c_m &< \frac{\alpha + (c_1 + c_2 + \ldots + c_{m-1})}{m} \end{aligned} \tag{4.7}$$

That is, the production cost of the new firm must be within some bound defined by the existing market for it to be able to compete. This is to be expected of real-world markets and provides us with an upper bound on the production cost of a viable entrant.

It is interesting to consider the effect that merging has on the likelihood of firm survival. Firms with a lower production cost are more likely to be able to find mergers with high cost firms profitable. However, the free-riding effect of mergers means that, given two low cost firms, if one engages in a merger to reduce competition, the other will receive exactly the same benefit from that reduction in competition. Intuitively, a higher cost firm merging with a lower cost firm will perform better given the new cost than a higher cost firm who does not merge.

Figure 4.4 shows the proportion of firms that engaged in a positive number of mergers over a simulation broken down by firms that were in production at the end of a simulation and those that were not. As can be seen, a larger proportion of the surviving firms had engaged in mergers than in the extinct firms. This relationship becomes even more stark when the random removal of firms is removed from the simulation.

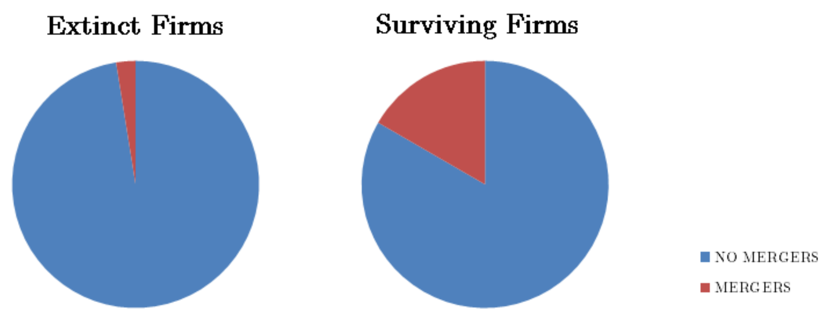


FIGURE 4.4: Proportion of extinct and surviving firms that have engaged in a positive number of mergers during a 1000-timestep simulation. Parameters are: $\alpha = \alpha_0$, $m = 11$, $c_i = \{1, 2, \cdots, m\}$.

Consider behaviour at market level.

Just as in the previous model, we now consider the dynamic aggregate effect of mergers on the whole market.

First, consider simulated market behaviour with myopic decision-making agents. Figure 4.5 shows the number of active firms in a market over time, along with merger desirability for both myopic and pseudo-strategic decision-making agents (as defined in the previous chapter). These results are from a seeded simulation to reduce error. Just as before, the model generates merger waves. Interestingly, unlike in the previous two-cost model, there is a clear difference in the aggregate behaviour of the firms. This magnitude of this difference is affected by the discount factor δ, which determines the weight placed on estimated future behaviour.

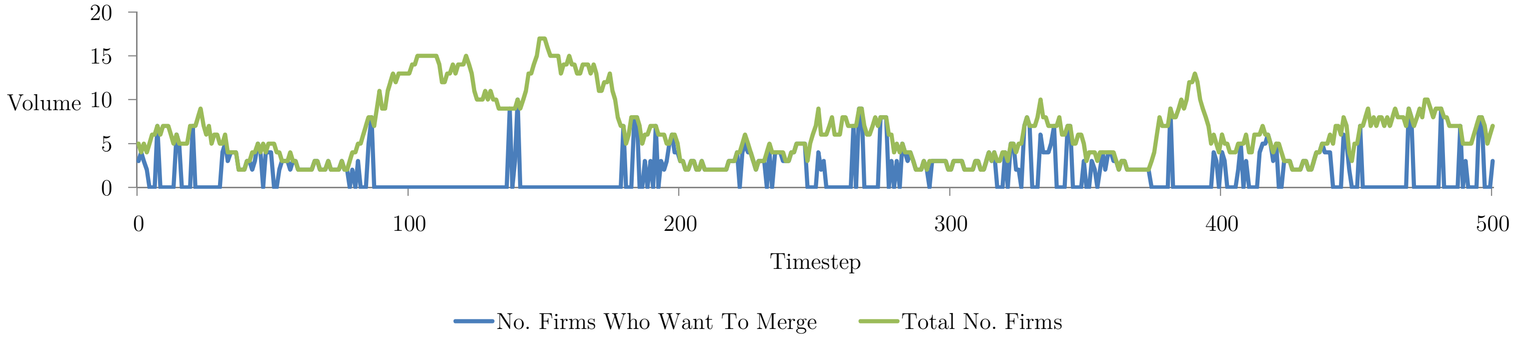
As can be seen, waves generated by pseudo-strategic decision-making agents appear more sustained than those by myopic. In the simulation example given, this is particularly pronounced, but nevertheless is a trait of the model. As δ increases, agents place more importance in the estimation of the future market. Therefore, the difference between myopically and pseudo-strategically behaving agents increases when δ increases.

It is interesting to consider why there is this difference between myopic and pseudo-strategic decision-making agents, coupled with why this was not the case in the two cost model.

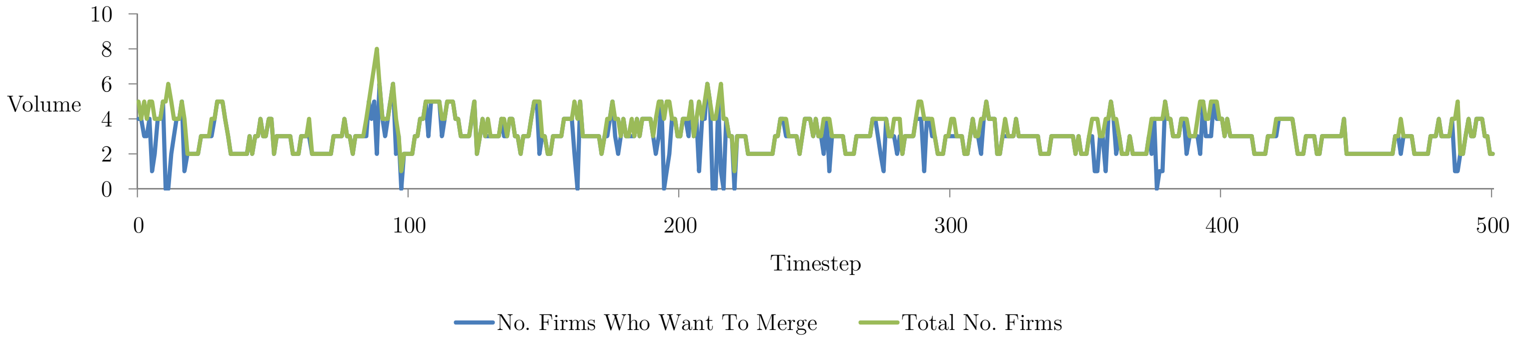
Each timestep, two new firms attempt to enter the market and at most two are randomly removed. This turnover of agents was implemented in order to prevent permanent lock-out of higher cost agents. In the two-cost model, the turnover is unlikely to significantly affect the cost distribution of a market in the next timestep. Therefore, pseudo-strategic agents (i.e., those that estimate the value of a merger in a future timestep) behave in a similar way to myopic agents.

However, in the multi-cost model, estimation of the future becomes much more difficult since costs are drawn from a range of values and it is much less likely that lock-out occurs. This leads to a situation in which the distribution of costs in a future timestep is much less predictable. Therefore, there is a starker difference between myopic and pseudo-strategic agents.

Waves in merger desirability occur endogenously in the model. However, just as before, waves may be generated by exogenously controlled demand and supply shocks.



(A) Myopic Agents



(B) Strategic Agents

FIGURE 4.5: Waves of merger desirability with seeded myopic and strategic decision-making agents. Parameters are: $\alpha = \alpha_0 + 1$, $m = 5$, $c_i = \{1, 2, \cdots, m\}$and $\delta = 0.5$ for strategic agents.

Demand Shocks

Consider the effect of exogenously generated shifts in the market size α on the emergence 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 4.6 shows the number of active firms and merger desirability, along with α from a representative simulation run. The market size, α, is exogenously made to oscillate about $\alpha = \alpha_0 + 1$. The figure shows seeded runs with both myopic and pseudo-strategic decision-making agents. Again, a clear difference can be seen in behaviour.

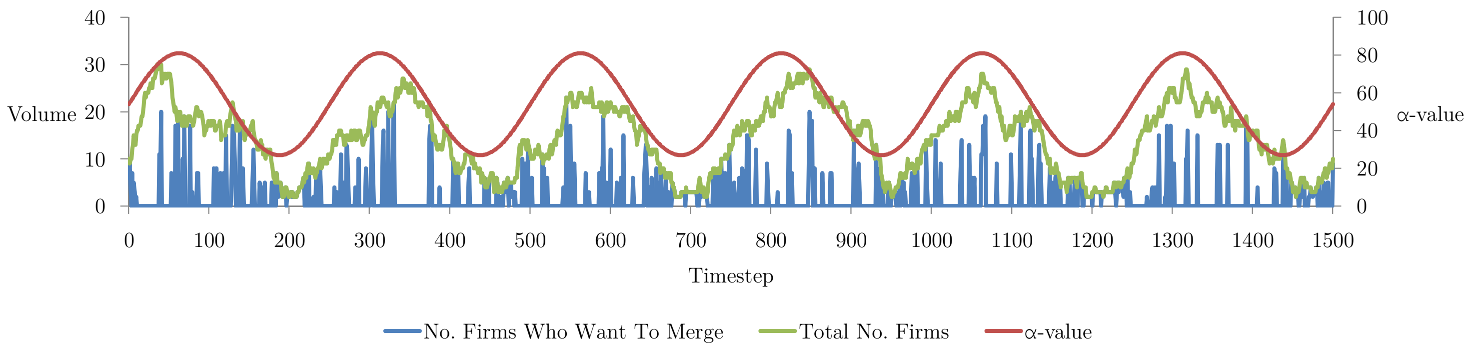
As in the previous model, merger waves can be generated by exogenous changes in market size, though do not necessarily occur during every oscillation of α. Figure 4.7 aggregates merger data from 100 long-duration (5000 timestep) runs of the model. Here, each dot records the *proportion* of firms that want to merge at a point during the sinusoidal wave phase of α from a particular simulation. As can be seen, the relationship between merger desirability and market size α is maintained in the single market model with multiple production costs.

Once again, there is a clear difference in the behaviour of pseudo-strategic and myopic decision-making agents.

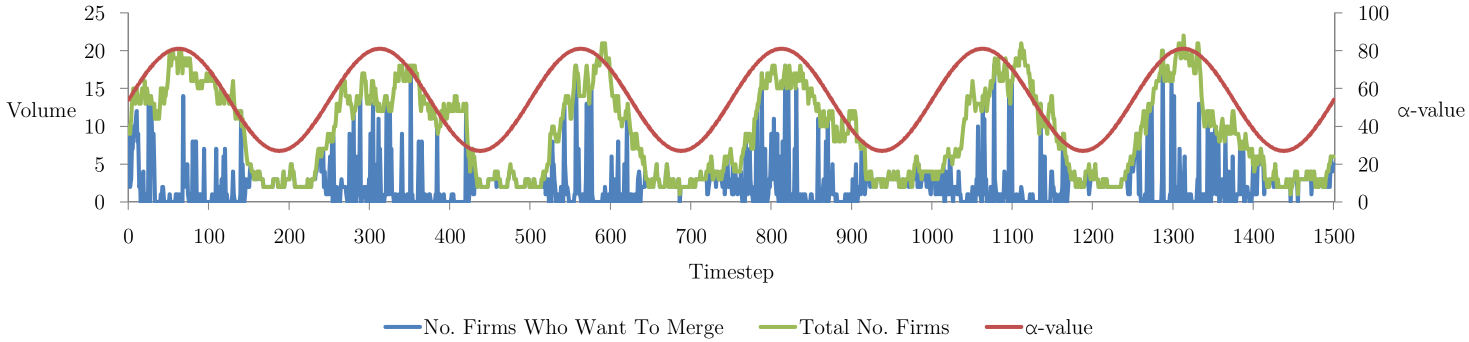
From Figures 4.6 and 4.7, there is a clear difference in the type of merger wave occurring at different points in the cycle for myopic and pseudo-strategic decision-making agents. Figure 4.7 shows that waves in merger desirability involving a high proportion of the agent population occur primarily during depression periods and early recovery (i.e., the troughs in market size) for myopic agents. However, for pseudo-strategic agents, such waves are prominant for a larger proportion of the cycle: from mid-recession to the early peaks of a boom in market size.

Furthermore, Figure 4.6 shows that, during depression periods and early recovery, pseudo-strategic agents exhibit an almost constant merger desirability. This is not the case for waves created by myopic agents, which do not significantly differ in duration during these periods.

Overall, we see that pseudo-strategic decision-making agents are more inclined to merge. Additionally, as δ is increased (i.e., the more emphasis that is placed on the future payoff), this effect increases. This is not surprising, since the benefit of merging in the current timestep is carried forward to the next timestep, whilst the cost of merging is incurred only in the current timestep. Therefore, some mergers that are myopically unprofitable may become strategically possible. For instance, a firm considering a merger to reduce production cost might make enough profit in the future to payoff the initial cost of merging.

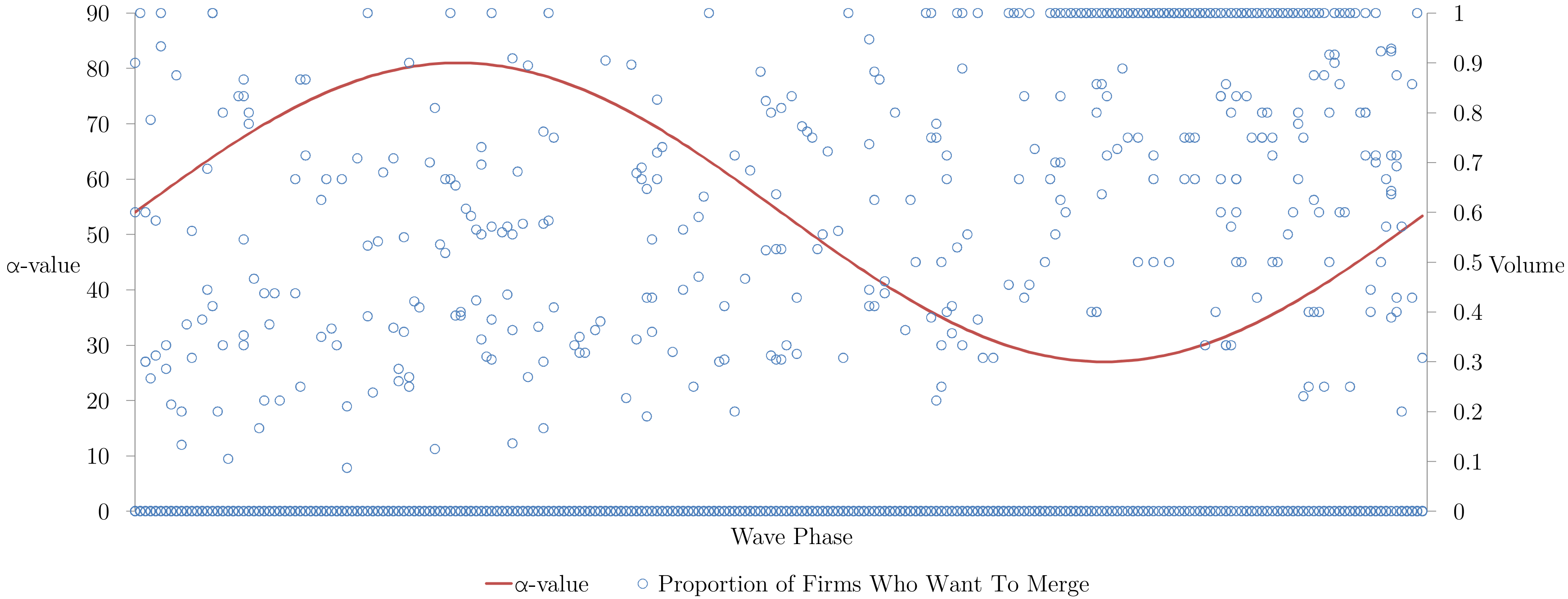


(A) Myopic Agents



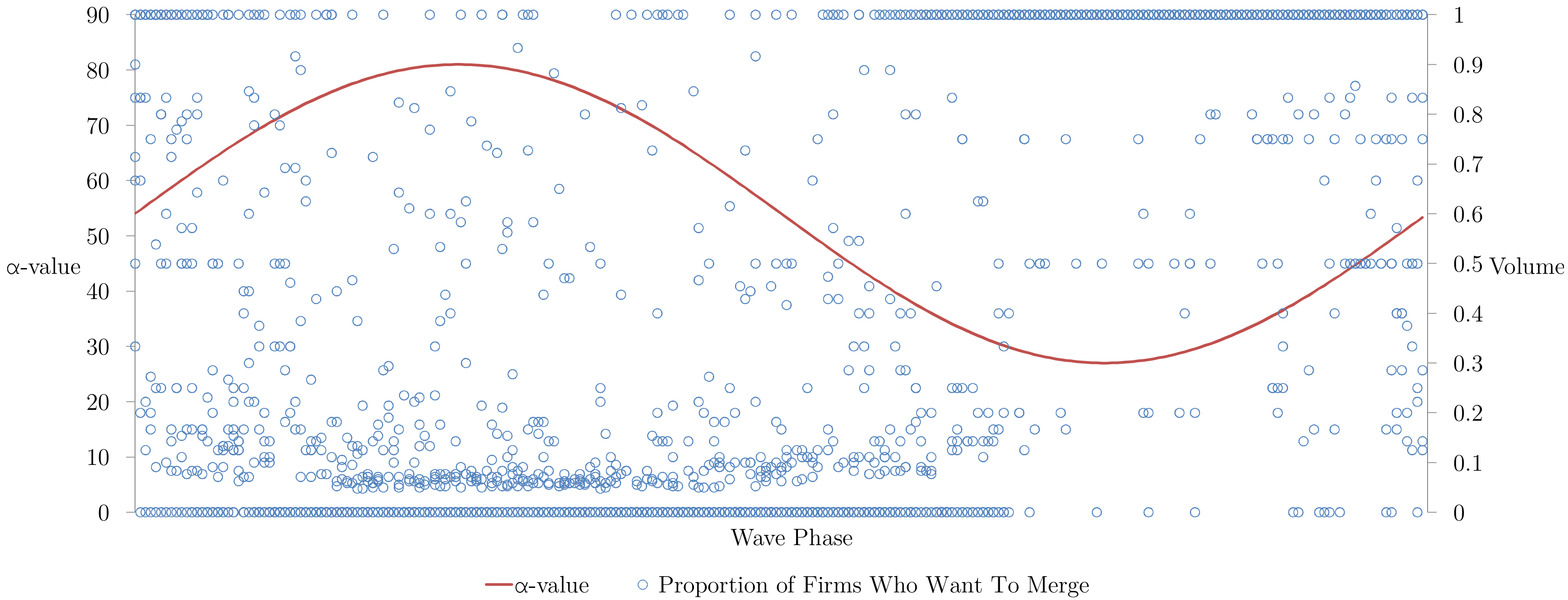
(B) Strategic Agents

FIGURE 4.6: Waves of merger desirability with exogenously determined sinusoidal α and seeded for both myopic and strategec decision-making agents. Parameters are: α follows a sine wave about $\alpha_0 + 1$ with period $= 250$ timesteps and amplitude $= \frac{\alpha_0+1}{2}$, $m = 10$, $c_i = \{1, 2, \cdots, m\}$, and $\delta = 0.5$ for strategic agents.



(A) Myopic Agents

FIGURE 4.7: 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 α. Parameters are: α follows a sine wave about $\alpha_0 + 1$ with period $= 250$ timesteps and amplitude $= \frac{\alpha_0+1}{2}$, $m = 5$, $c_i = \{1, 2, \cdots, m\}$, and $\delta = 0.5$ for strategic agents. Data is drawn from 100 runs of a 5000-timestep simulation.



(b) Strategic Agents

Figure 4.7: 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 α. Parameters are: α follows a sine wave about $\alpha_0 + 1$ with period $=$ 250 timesteps and amplitude $= \frac{\alpha_0+1}{2}$, $m = 5$, $c_i = \{1, 2, \cdots, m\}$, and $\delta = 0.5$ for strategic agents. Data is drawn from 100 runs of a 5000-timestep simulation.

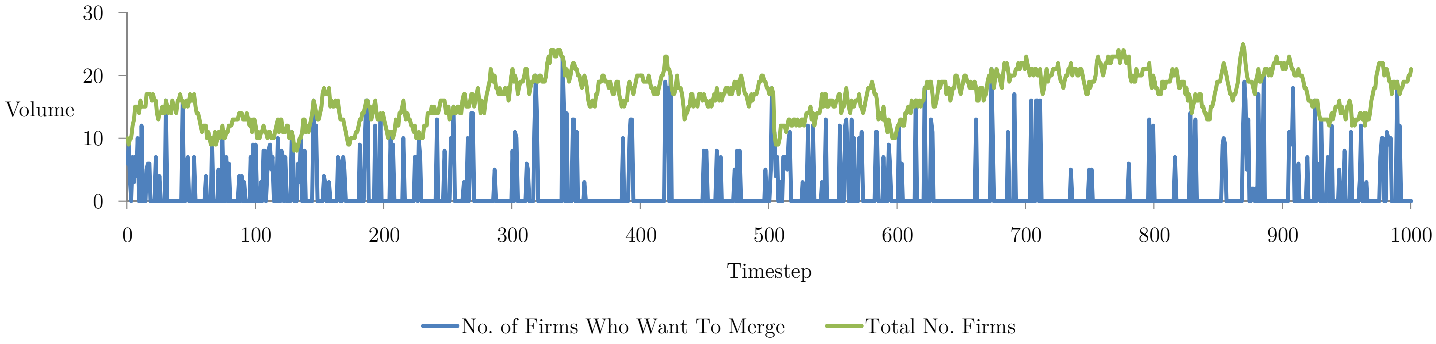
However, it is interesting to note that merger waves with multi-cost agents appear at different points in the market size wave phase than with two-cost agents (see Figures 3.4 and 4.6). During periods of recession, there is a reduction in the number of higher cost agents in the market, since they are less able to produce in the lower demand. Higher-cost agents have more incentive to merge to reduce production costs and are also cheaper targets of mergers to reduce competition. In the two-cost market, once lock-out occurs it removes all high-cost firms from the market. Therefore, during recession and depression periods, no mergers take place because it is unlikely that any high-cost firms are operating in the market.

Whereas, in the multi-cost model, there is a more gradual reduction in merger activity owing to the finer strata of costs. Therefore, during recession periods, competition increases amongst remaining firms. Additionally, during early recession periods there is less merger activity. Again, this is likely to be caused by the slow reduction of the easy to merge with higher-cost firms, whilst demand is still quite high.

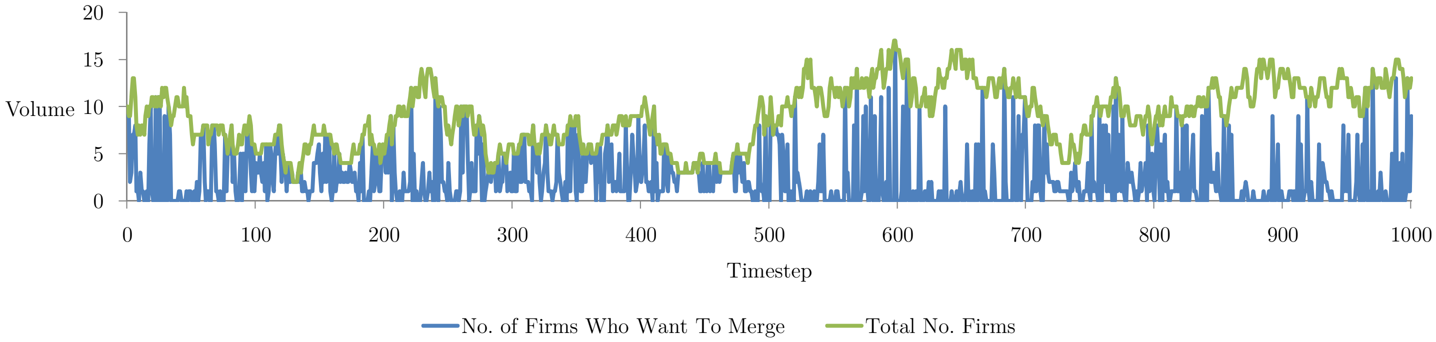
Supply Shocks

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 4.8 shows simulation results from this shift.

Unlike the simple two-cost model, identifying waves caused exclusively by the supply shock is difficult. This is because there is already as significant amount of merger activity in the market already caused by the frequently changing cost distributions of firms. This frequent change is the result of the random removal 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 4.9).

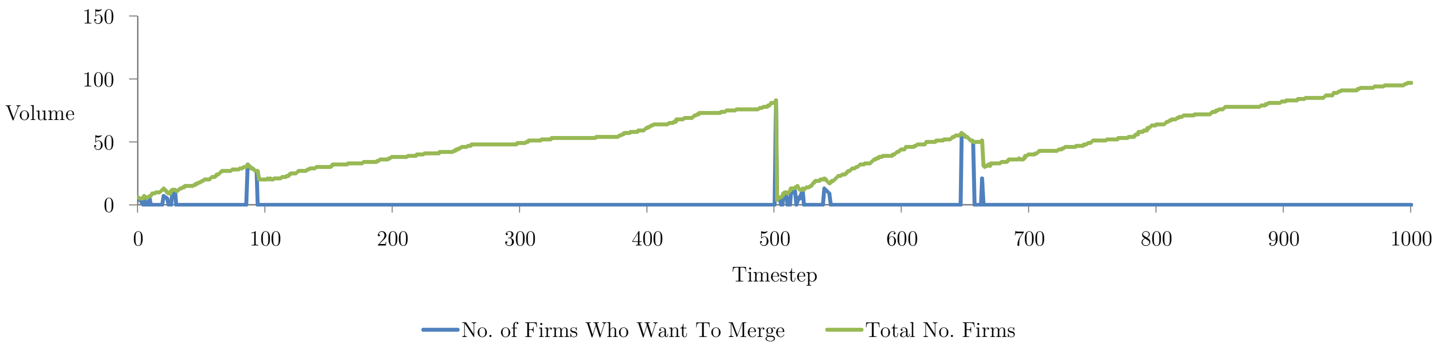


(A) Myopic Agents

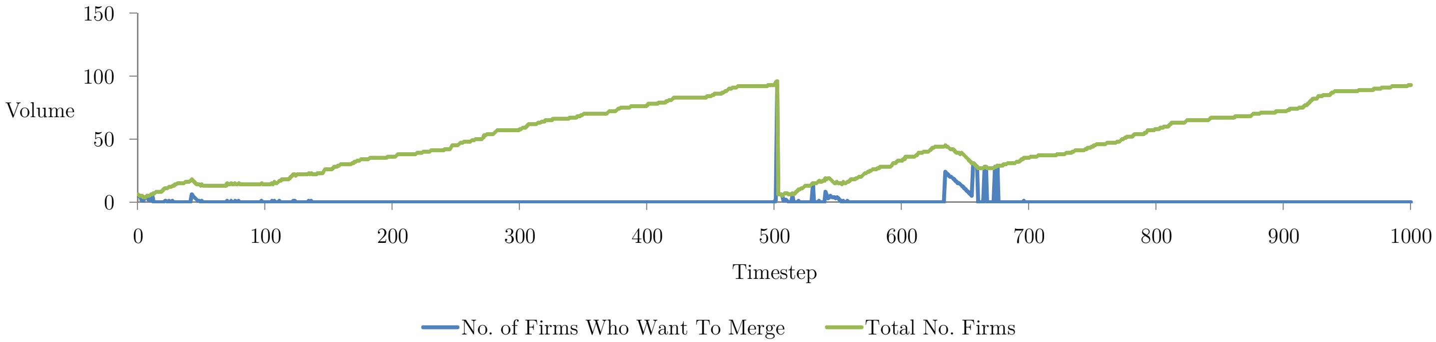


(B) Strategic Agents

FIGURE 4.8: Waves of merger desirability with an exogenously generated cost shift at t = 500, and seeded for both myopic and strategec decision-making agents. Parameters are: $\alpha = \alpha_0 + 1$, $m = 10$, and $\delta = 0.5$ for strategic agents. Initially, c_i is drawn from $\{11, 20\}$. After 500 timesteps, c_i is drawn from $\{1, 10\}$.



(A) Myopic Agents



(B) Strategic Agents

FIGURE 4.9: Waves of merger desirability with an exogenously generated cost shift at t = 500 with no random removal of agents, and seeded for both myopic and strategec decision-making agents. Parameters are: $\alpha = \alpha_0 + 1$, $m = 10$, and $\delta = 0.5$ for strategic agents. Initially, c_i is drawn from $\{11, 20\}$. After 500 timesteps, c_i is drawn from $\{1, 10\}$.

Summary

The chapter has considered an alternative way of modelling endogenous merging in a single market based on Qiu and Zhou (2005). The main difference between this and the previous model is the increased heterogeneity between firms; in the previous market, firms were either of high or low production cost, whereas now their costs are randomly assigned from within a given range. The effect of this change on the behaviour of the model was then investigated.

It was found that:

- Just as in the previous model, the model demonstrates two-phase regime-switching merger activity (i.e., merger waves) consistent with empirical analysis of merger wave data. This wave activity can arise endogenously in the model or be generated by shocks consistent with behavioural (see Figure 4.6a) and neoclassical (see Figure 4.9) theories of merger wave causes. Again, these waves are found to be significantly different from those generated in the null model, supporting the view that there are waves in merger activity.
- However, unlike the previous model, myopic pseudo-strategic decision-making agents behave differently (see Figures 4.5 and 4.7). It is found that pseudo-strategic agents are more inclined to merge and tend to cause more sustained peaks in merger activity.
- It was found that firms who engage in at least one merger make up a larger proportion of surviving firms (i.e., those still in production at the end of a given simulation) than extinct firms (i.e., those who exit the market before the end of a given simulation) (see Figure 4.4). This suggests that merging increases the likelihood of surviving in a competitive market.

Overall, the behaviour of firms in the multi-cost model supports our previous findings surrounding merger wave generation. Having developed an understanding of the single market model, the next two chapters develop a model of multiple markets connected through supply chains. This is done to enable us to examine the effect of dependencies on merger behaviour.

Part II

A Multi-Market Model

Markets do not exist in isolation but are connected through a series of complex dependencies, such as geographical proximity, cultural similarities, political treaties, etc. The most obvious of these are supply chains and trade agreements. These dependencies alter the dynamic of firms operating in different markets. For example, if there is an increase in demand for a particular type of car, the manufacturer is likely to respond by stepping up production. This, in turn, will affect the firms and markets that supply the manufacturer with the goods to produce this car. Such changes to demand are among the causes of merger waves (Harford, 2005) and, as highlighted in Ahern and Harford (2013), dependencies between markets play an important role in the spread of merger waves. Therefore, it is important to consider the effect of inter-market connections on merger behaviour in our model.

Part II develops the single market model into a more complex multi-market agent world. The markets are connected through exogenously defined supply chains made up of endogenously created agent-level purchase agreements, which dynamically change across a simulation. Firms in a supplier market produce goods which are bought by firms in distributor markets. An example of this can be seen in Figure 4.10, which shows an imaginary supply chain for edible plants such as vegetables and herbs. The plants are initially cultivated by firms competing in the top *Plant Nurseries* market. They are then sold to firms in the *Wholesalers* market who tailor the produce for *Retailers* and *Restaurants*. The firms in both of these markets again tailor the produce for *Consumers*. Here, consumers are represented as competing firms, however arguably they could be excluded from this diagram completely. As was highlighted in Chapter 2, the markets themselves may be defined by any number of things: from the type of good they produce to their geographical location.

In the next chapter, a series of simulated agent worlds are investigated in which a number of markets are connected in different network configurations, such as trees and lattices. The effect of each structure on merger behaviour is studied.

Then, the nature of the dependency is altered by introducing individual agent expectations on future demand based on the past: supplier firms update their production based on how much they expect to sell. The effect of this change on the multi-market world is then investigated.

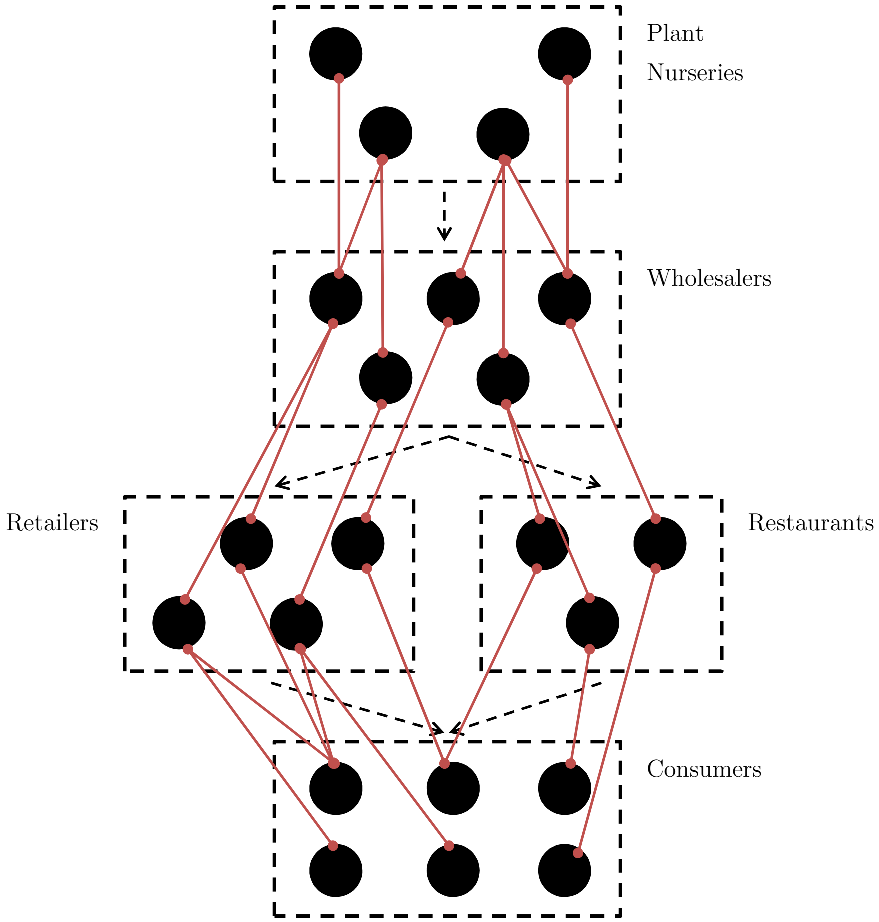


FIGURE 4.10: An imaginary supply chain for edible plants. Key: black circles represent firms, dashed boxes outline markets, dashed arrows show the fixed suppy chain, and red lines show temporary supplier relationships between firms.

Chapter 5

A Supply Chain Model

In this chapter, we consider structures of multiple markets connected by supply-chains in linear, tree, inverted-tree, lattice, loop and star network formations. By considering such a variety of multi-market structures, we are able to better understand the effect of extending the single-market model into multi-market worlds.

Figure 5.1 shows the multi-market structures that will be considered in this chapter. Each box represents a market of competing firms as in the single-market model. The arrows indicate the flow of goods from supplier 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 5.1b), 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.

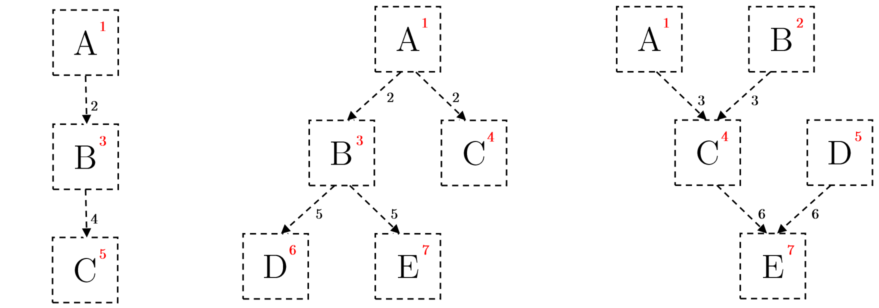
5.1 Simulation Process

To further illuminate this process, consider a simple multi-market world with two markets: a supplier market S and a distributor market D. Each timestep, agents in the distributor market must endogenously find suppliers in order to produce their goods.

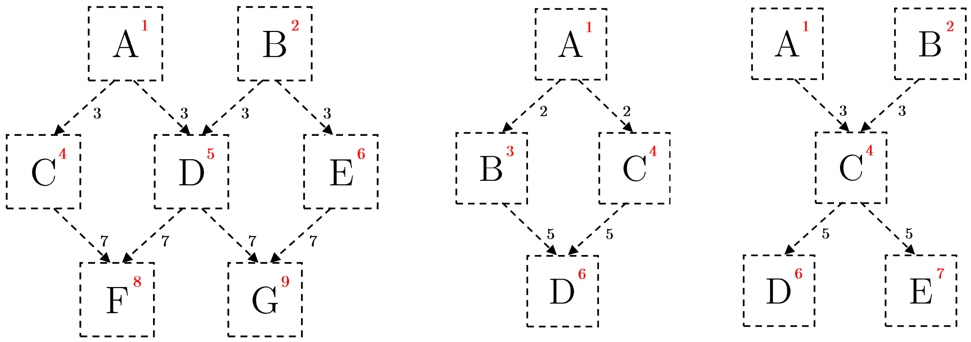
First, both markets are initialised as in the single market model.

```
INITIALISE market(S):= new market
INITIALISE market(D):= new market
```

For each timestep in the remainder of the simulation: firms in market S merge and produce goods as in the single market model; then firms in market D merge and source



(A) Chain (B) Tree (C) Inverted Tree



(D) Lattice (E) Loop (F) Star

FIGURE 5.1: 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.

supplies from firms in market S (see abstract methods below for details); then firms in market D produce goods as in the single market model.

```
FOR time:=0 TO simulation length {
  MERGE(S)
  PRODUCE(S)
  MERGE(D)
  SUPPLY(S, D)
  PRODUCE(D)
}
```

As in the previous model, two entrants with randomly assigned costs enter the 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.

```
MERGE(market) {
  ADD 2 firms to market
  REMOVE up to 2 firms
  IF at least 1 firm wants to merge {
    firm i := random firm who wants to merge
    i merges with most profitable target firm
  }
}
```

When firms in a market produce goods, each firm calculates the amount they would ideally produce (their Cournot quantity). If they have enough supplies, they produce that amount. Otherwise, they produce as much as they can. Note: we assume that one unit of supply good is required to produce one good. Additionally, markets who have no supplier markets are assumed to have access to infinite supplies. If a firm produces no goods, it exits the market.

```
PRODUCE(market) {
        FOR firm f IN market {
          quantity q := f's desired Cournot quantity
          quantity s := f's current supplies stock
          IF s >= q {
            f produces q goods
          } ELSE {
            f produces s goods
          }
          IF q == 0 OR s == 0 {
            f exits the market
          }
        }
}
```

Top level supplier markets (i.e., those without an explicitly defined supplier market) may obtain as many supply goods as they need. However, other markets must use the goods that have been produced in that timestep by their suppliers. Note: this is why there is an explicit ordering on the evaluation of each market in Figure 5.1.

Firms in distributor markets are responsible for obtaining supplies from firms in supplier markets. Although there is no explicit additional cost of visiting a supplier, firms source their goods from as few suppliers as possible. Agents in the supplier market have no preference on who buys their goods, and agents in the distributor market are indifferent between suppliers offering more or an equal number of goods than required. Once a distributor firm has obtained all the goods it either wants or can obtain, it is the next firm's turn to obtain supplies. There is no memory of these purchase agreements between firms beyond the current timestep. Additionally, distributor firms that are unable to locate any supplies and supplier firms that are unable to sell any goods exit the market.

```
SUPPLY(supplier, distributor) {
  randomly order firms in distributor
        FOR firm f IN distributor {
          quantity q := f's desired Cournot quantity
          f locates maximum supplies from fewest suppliers
        }
        FOR firm f IN supplier {
          quantity s := f's sold supplies
          IF s == 0 {
            f exits the market
          }
        }
}
```

In this model, myopic rather than pseudo-strategic agents are used. This minimises merger behaviour, as found in the Part I, and thus enables behavioural trends to be more easily identified. Additionally, the market size α is not adjusted to reflect changes to connected markets[1]. This limits the spread of waves caused by changes in demand and allows us to focus on the auxiliary effects of connecting markets.

Of additional consideration is the extent to which markets at the same level are producing *complementary* or *substitutable* goods. For example, in Figure 5.1c 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.

As in the previous chapters, a ***stable*** market is one in which no mergers are desirable; when $\alpha > \alpha_{\max}$ (see Figure 5.2).

[1] In the next chapter, we introduce agent expectations to create a closed multi-market world in which firms adjust their production based on expected future demand.

5.2 Simulation Behaviour

In order to understand the behaviour of firms in this dynamic, networked multi-market model, we now consider trends in simulation output for each of the structures outlined in Figure 5.1, identifying how they differ from both each other and — where relevant — the single-market model.

5.2.1 The Relationship Between Waves and Links

Ahern and Harford (2013) finds that merger waves can spread along supply chains, originating in one market propagating throughout a network. Therefore, first we consider whether the introduction of a simple supply-chain mechanism to the model enables waves to be incited in markets that would remain stable (i.e., not exhibit merger waves) as a disconnected single-market. We present the following hypothesis:

Hypothesis: The introduction of dependencies between markets enables activity in one market to incite mergers in an otherwise stable connected market.

As can be seen in Figure 5.2, for a market to be stable, the current value of α must be greater than α_{max}, the maximum value of α for which at least one merger is profitable.

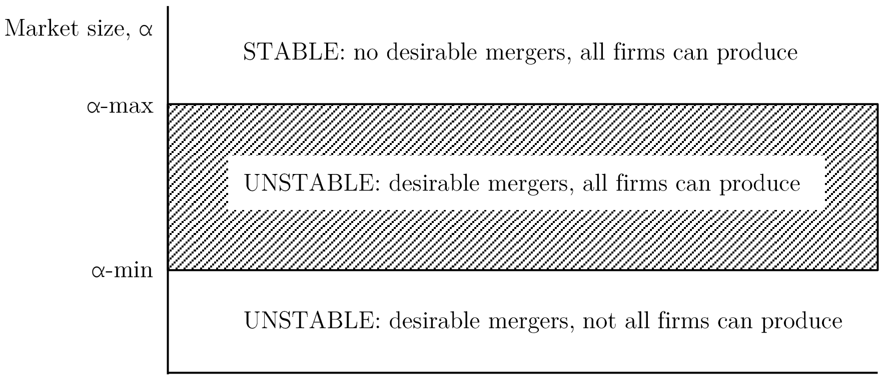


FIGURE 5.2: Abstract borders of market size values that incentivise merging and production.

Recall:

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

Therefore, $\alpha^M_{i,j}$ 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 α and fixed production cost boundaries) may become destabilised by changes to the total number of firms m. Figure 5.3 shows the relationship between the number of firms in a market (m) and the maximum $\alpha^M_{i,j}$ for a fixed $c_i \neq c_j$. The specific values of the market are not important; the shape of the graph is consistant across all values.

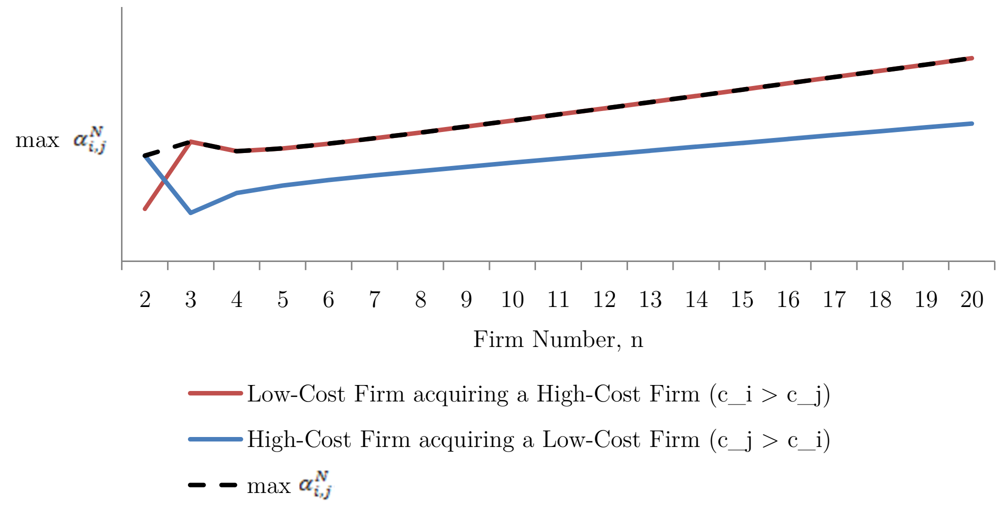


Figure 5.3: Relationship between the number of firms in a market (m) and the maximum $\alpha^M_{i,j}$) for a fixed $c_i \neq c_j$, when $c_i > c_j$ and when $c_j > c_i$.

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

The graph shows that, for $m \geq 4$, 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 α.

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 α-value, it is also possible that a shock that lowers 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^B_i and let the maximum quantity of goods desired by a single agent be $q^B_{\max}$.

5.2.1.1 Chain

Consider the chain multi-market structure in Figure 5.4.

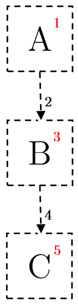


Figure 5.4: Chain

Given that the order in which firms in market C 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:

$$Q_A \leq Q_B - q^B_{\max} \tag{5.1}$$

Note that there is no difference between substitutable or complementary goods.

Market B is wholly reliant on market A for supplies. Any change in the quantity produced by market A, or market A's suppliers (if the chain is extended), 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.

5.2.1.2 Tree

Recall the tree multi-market structure in Figure 5.5.

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

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

$$Q_A \leq Q_B - q^B_{\max} \tag{5.2}$$

In this configuration, we note that there is no difference between substitutable or complementary goods. However, there is a fixed limited supply from A for all dependent markets.

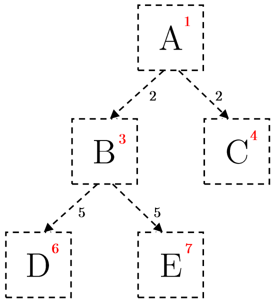


Figure 5.5: Tree

It is clear that market B is not just vulnerable to behaviour in its supplier market A, but A's other distributor markets $\{C \cdots N\}^2$. 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.

5.2.1.3 Inverted Tree

Recall the inverted tree multi-market world in Figure 5.6.

Let us consider the general case with $\{A, B, \cdots N\}$ 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:

[2] Recall: firms in markets who share their supplier markets source supplies simultanously.

$$Q_A \vee Q_B \vee \cdots Q_N \leq Q_C - q^C_{\max} \tag{5.3}$$

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 $q^C_{\max}$ is selected last to locate suppliers, this condition is necessary to ensure disruption in the connected market C.

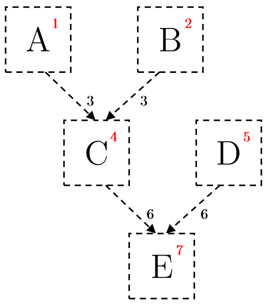


Figure 5.6: Inverted Tree

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

$$Q_A + Q_B + \cdots Q_N \leq Q_C - q^C_{\max} \tag{5.4}$$

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 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[3]. 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.

However, for supplier markets, there is a trade-off to be considered. When goods are complementary, just as before 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

[3]Recall that if a supplier is unable to sell any produce it is forced to exit the market.

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.

5.2.1.4 Lattice, Loop and Star

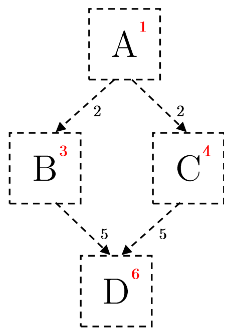


FIGURE 5.7: Loop

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 5.7. 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):

$$Q_A \leq Q_B - q_{\max}^B \tag{5.5}$$

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

$$Q_B \vee Q_C \vee \cdots Q_N \leq Q_D - q_{\max}^D \tag{5.6}$$

And, in the case of substitutable goods:

$$Q_B + Q_C + \cdots Q_N \leq Q_D - q_{\max}^D \tag{5.7}$$

Consider the star structure in Figure 5.8. 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:

$$Q_A \vee Q_B \vee \cdots Q_N \leq Q_C - q_{\max}^C \tag{5.8}$$

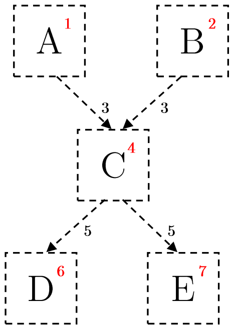


FIGURE 5.8: Star

In the case of substitutable goods:

$$Q_A + Q_B + \cdots Q_N \leq Q_C - q_{\max}^C \tag{5.9}$$

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

$$Q_C \leq Q_D - q_{\max}^D \tag{5.10}$$

Now consider the lattice structure in Figure 5.9. 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).

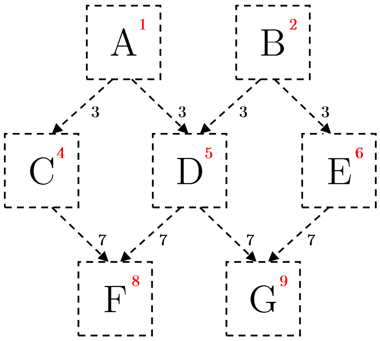


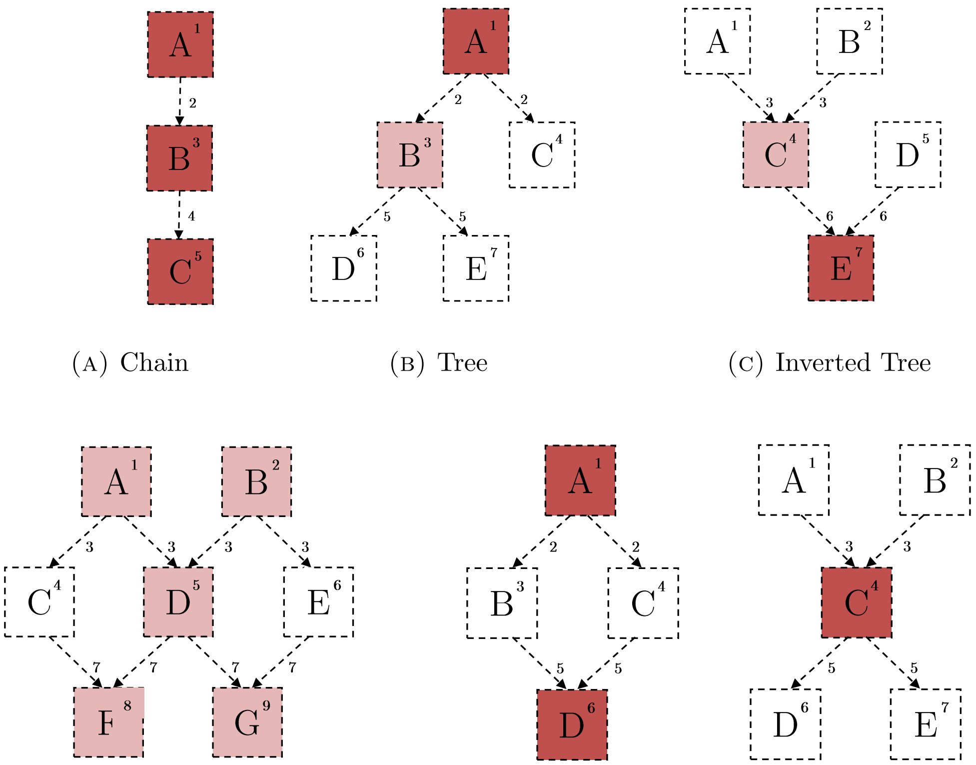
FIGURE 5.9: Lattice

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.

5.2.1.5 Network Vulnerability

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 5.10 and 5.11 show the extent to which the removal of a market affect other markets within a network when considering substitutable and complementary goods.

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.



(A) Chain (B) Tree (C) Inverted Tree

(D) Lattice (E) Loop (F) Star

FIGURE 5.10: 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.

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.

5.2.2 The Relationship Between Waves and Variance in Production Cost

Since it is the difference in production cost between firms that is the main driving force behind merging in this model, it is important to identify the relationship between merger waves and cost. It is also interesting to consider whether the introduction of market dependencies affects this relationship.

By design, the distribution of costs at any given timestep during a simulation is non-trivial. Therefore, in an attempt to capture some elements of the distribution, we will consider the variance and range of production costs.

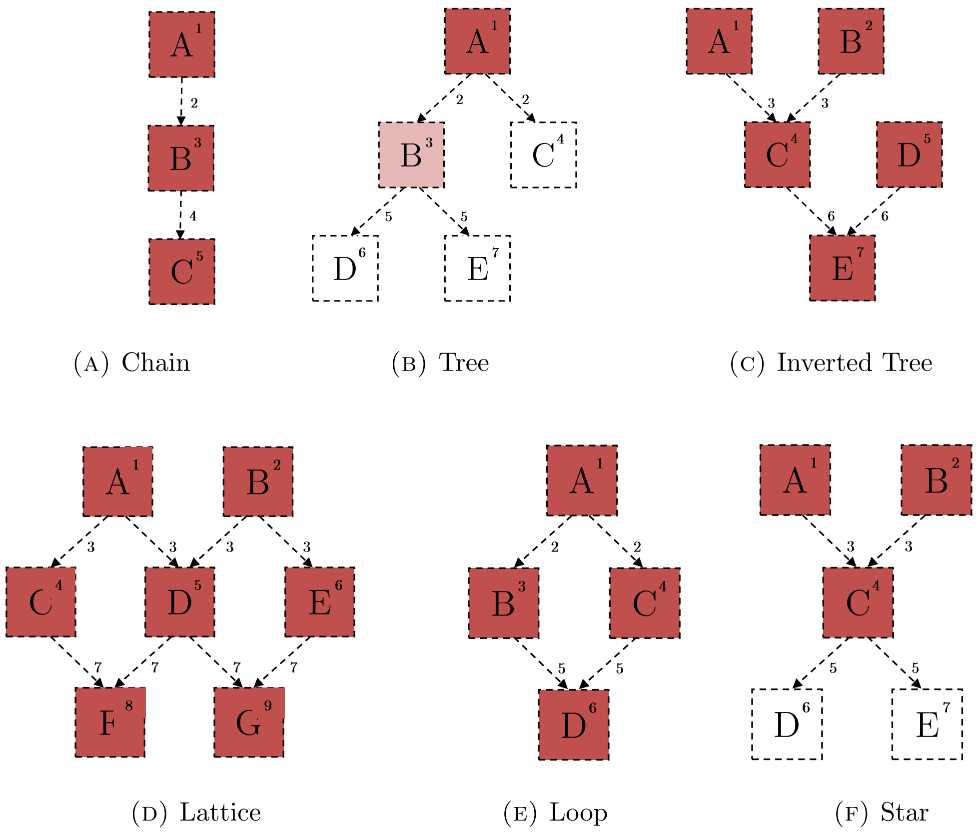


FIGURE 5.11: The importance of each market in the structure to other markets when firms produce complementary goods. The removal of a single red market will cause all markets to cease production; the removal of a pink market will cause at least one other market to cease production; the removal of a white market will not necessarily cause any other market to cease production.

Hypothesis 1: The greater the variance in production cost, the greater the likelihood of a merger wave.

Variance is a loose measure of spread in the distribution of costs. Therefore, when there is a large variance in production costs, we might assume that there would be a larger spread in the cost distribution. By extension, this might increase the likelihood of merger behaviour. However, we find this is not the case.

Figure 5.12 shows the distribution of variance, range, minimum and maximum values in production cost across a long running simulation in the single market model. Each graph distinguishes between distributions when mergers do and do not take place in the simulation.

As can be seen, there is no clear difference between merging and non-merging timesteps. This is not necessarily surprising, since the metrics used are only a loose measure of cost distribution in the market. As already identified in previous chapters, it is both the production costs of firms and the number of firms at these costs (i.e., the overall cost distribution) with respect to α that determines whether or not mergers are incentivised.

This is also found to be true of markets in each of the multi-market structures in Figure 5.1.

Hypothesis 2: Merger waves reduce the variance in production cost in a market.

Since mergers are made to reduce a firm's production cost or remove competition, and since the greater a firm's production cost the cheaper it is to acquire, we would assume that following a merger wave a market would experience a decrease in production cost variance. This is indeed the case.

Figure 5.13 shows the variance in production cost in a market both before and after 9 merger waves during a long duration simulation. As can be seen, following each wave there is a reduction in variance. This is not a surprising result. Despite market entrants, mergers (whether for technological or competitive advantage) tend to remove higher production costs from the market[4]. This is statistically supported (one-tailed sign test; dof = 9, $p < 0.001953$).

Again, this is also found to be true of markets in each of the multi-market structures in Figure 5.1.

5.2.3 The Relationship Between Survival and Production Cost

In real-world markets, there is a strong pressure on firms to innovate, improve efficiencies and reduce production costs in order to remain competitive. Successful, long-running firms, such as IBM, attribute a lot of their success to being able to adapt to changing times in this way. We now consider whether production efficiencies are also indicators of survival for firms in our model.

In the supply-chain model with multiple markets, the survival of a firm no longer depends solely on its production cost relative to other firms. The need for firms to locate suppliers and sell their produce makes it interesting to consider the relationship between the survival of a firm and its production cost.

Hypothesis 1: Firms with a lower production cost 'live' longer.

As discussed in the previous chapter, the turnover of firms in a market, encouraged by their random removal and entrance, ensures that lock-out[5] does not occur. Therefore, since the production costs assigned to firms are drawn from a fixed range, the mean and variance in production cost remain more or less constant across a simulation.

[4] Merger targets are shown in more detail in Figure 5.17.

[5] Recall: lock-out is the process under which firms assigned certain production costs are unable to enter the market due to the current cost distribution within a market.

However, consider the lifetime of a firm (i.e., how many timesteps it is actively in production for) in relation to its production cost. Figure 5.14 shows a heat map of the lifetime and production costs of firms within a single market model across a 1000 timestep simulation.

As can be seen, the relationship is non-trivial. Higher-cost firms tend to have the lowest levels of survival. However, the market does not necessarily favour just the lowest cost firms, but the middle-to-lower cost firms as well. Therefore, we will simplify the graph by considering the (normalised) median lifetime for agents with a given production cost. This is shown in Figure 5.15.

Overall, all markets exhibit the same approximate relationship between median survival and production cost: lower- to middle-cost agents live longer than higher-cost agents. However, the position of markets within an agent world has a significant effect on the lifetime of firms within it. As a consequence of this, in markets where there is a high turnover of agents, there is less of a significant change in the (normalised) median lifetime across production costs.

For markets in the chain world (Figure 5.15b), the lifetime of firms within each market is approximately equal for a given production cost.

However, in the tree world (Figure 5.15c), firms in the sole supplier market A have longer lifetimes then firms in markets B and C, which tend to have longer lifetimes than firms in markets D and E. The reverse is true of the inverted tree world (Figure 5.15d). This is not surprising since survival depends on not only the ability to produce, but the ability to sell goods. Therefore, markets who act as sole suppliers or distributors are less likely to be forced to exit the market because they cannot source or sell their goods.

In the lattice world (Figure 5.15e), firms in market D have a clear advantage when it comes to obtaining supplies than firms in markets C and E, since they have two markets from which to obtain supplies. Therefore, the average lifetime of firms are lower in C and E than D. Meanwhile, markets A and B have firms with the highest survival costs, since supply is 'infinite' and there are three demand markets. Interestingly, since markets F and G are reliant on the produce from C, D and E, any limitations in those markets limit the number of firms that can be supported. Therefore, lifetimes are also reduced in F and G.

Interestingly, despite being able to produce the most, the lowest cost firms often have a slightly lower lifetime than middle- to lower-cost firms (although substantially more than high-cost firms). However, this is not surprising, since a firm's lifetime ends when it either exits the market or becomes the target of a merger. Though lower-cost firms are less likely to be forced to exit a market, their production costs make them desirable merger targets.

Hypothesis 2: The way in which supplies are sourced by downstream firms affects the relationship between agent production costs and lifetime duration.

Firms are chosen at random to obtain as many supplies as they can until they either cannot obtain any more, or have enough. Since there are on average more middle- to lower-cost firms active in a market at any given time[6], such a firm is more likely to be chosen at random and so obtain all the goods it needs to survive. This may explain the non-linear relationship between agent lifetime and production cost. However, the significance of the supply sourcing mechanism used by downstream firms in this relationship must be considered.

Suppose instead that a bias was imposed so that lower-cost firms were allowed to obtain their goods first. This is shown in the graph of agent median lifetimes and costs for the chain market in Figure 5.16a. Similarly, Figure 5.16b shows the case when higher-cost firms are allowed to obtain their goods first.

As can be seen, regardless of the additional bias, the relationship between lifetime and production cost remains the same.

Hypothesis 3: A firm's production cost affects the reason why it is no longer in operation.

It is interesting to consider the relationship between a firm's cost and the reason it goes out of production[7].

Figure 5.17 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 high- and 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).

Figure 5.18 considers how this relationship might change following an industry shock to a market. As can be seen, there is no signficant difference in the exit behaviour of firms in the market.

5.2.4 The Relationship Between Waves and Profitability

Consider now the relationship between merger waves and the profitability of a market (i.e., the average profit received by all active agents in a market). Unlike in the single

[6]As already discussed, lower cost firms are favoured by the market design, since they can produce more. Higher cost firms find it more difficult to enter a market and are more likely to be forced to exit through competition.

[7]Recall: a firm may exit the market as a merger target, because it is no longer able to produce, or because it is randomly removed.

market model, we cannot assume that all goods produced by a market will be sold. Therefore, we must redefine profitability for the multi-market case:

$$\pi_i^M = (P \cdot s_i^M) - (c_i \cdot q_i^M) \tag{5.11}$$

where π_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.

Trivially, since agents are fully rational, mergers are only undertaken when profitable for the firm in the immediate short-term. For the individual, the long term payoff is greater for acquiring high-cost firms the lower the low-cost target's production cost.

Hypothesis: The average profitability of firms in a market increases as a result of merger waves.

Mergers reduce the number of firms operating in a market. For all remaining firms in the market followng a merger, the reduction in the number of competitors is beneficial: the free-riding effect. Dependent on the nature of the merger, there might be an additional technological benefit (i.e., reduction in production cost) for the acquiring firm.

Figure 5.19 shows the relationship between the average market profitability and firm number in the single market model. As is shown, profitability in a market increases when firm number decreases.

However, a number of processes control the number of entrants and exits in a market in each simulation timestep:

- Even during a merger wave, at most one merger may take place (-1);
- A random number between 0 and 2 firms may be forced to leave the market (0, -1, -2);
- Two new firms will attempt to enter the market, their success dependent on their assigned production costs and the current cost configuration of the market (0, +1, +2);
- Market play, such as lock-out or an inability to locate a buyer/supplier, may cause some firms to go out of production (-x).

Therefore, though the effect of a merger on a closed market is straightfoward, these additional considerations make the relationship between merger waves and profitability non-trivial.

Figure 5.20a shows the distribution of change in average profitability from a 5000 timestep simulation. The blue shows the overall distribution for the market and the red considers only changes in average market profitability post-merger. Figure 5.20b shows the cumulative distribution for both datasets. As is clearly shown, there is very little difference in the behaviour of both datasets. That is, post-merger changes in average market profitability closely reflect the overall market. This is not surprising since market profitability, when production cost boundaries are fixed, is largely determined by firm number, which is much more heavily influenced by those factors listed above than mergers.

Average profitability in a market is normally distributed. However, when considering the timestep change in average profitability, we can see a tri-modal distribution (see Figure 5.20a). This is prominent across all simulations of both single and multi-market worlds.

The distribution shows that in the majority of cases, there is very little change in profitability between timesteps; the central mode. In a simulation with fixed cost boundaries, market firm number's settle around a particular size. The smaller this number, the larger the width of this tri-model distribution.

Sometimes, there may be a larger increase caused by a large decrease in competition (i.e., firm number); the high mode. This is caused by a significant reduction in firm number. For example, higher cost firms may become locked out and low cost firms might be randomly removed.

Shifts in the other direction are caused by a significant increase in firm number; the low mode. For example, there are a maximum number of entrants to a market and a minimum number of exits.

What determines a significant increase or decrease in firm number is defined by the market. However, for the simulation given, the change to firm number between timesteps was within $\{-2, -1, 0, 1, 2\}$ (i.e., there was at most an overall decrease of 2 firms in the market, and increase of 2 firms).

Figure 5.21 shows the change in profitability following a given change in firm number. As can be seen, larger changes in firm number tend to result in larger changes in profitability, whilst increases in firm number cause a decrease in profitability.

As we know from previous investigation, connected markets are affected upstream in a similar way as downstream, and changes to firm number can affect other markets. This effect, therefore, exists in the multi-market model as well.

5.3 Summary

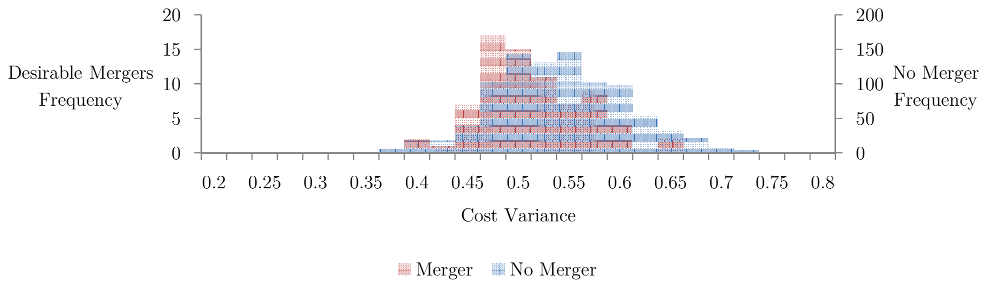
This chapter has extended the single market model presented in Part I into a multi-market agent world through supply chains. We have considered a number of different multi-market structures to examine the effect these connections have on the overall behaviour of the model.

Just as in real-world studies of connected markets (see Ahern and Harford, 2013), it was found that supply-chain links enable merger waves to spread between markets. Whilst the characteristics of wave behaviour were unchanged from the single market model, the introduction of supply chains enabled an additional source of wave-generating shocks to a market. Additionally, the susceptibility of a market to disruptions in other markets depends on the structure of its relationships to other markets, as well as the distribution of firms within it.

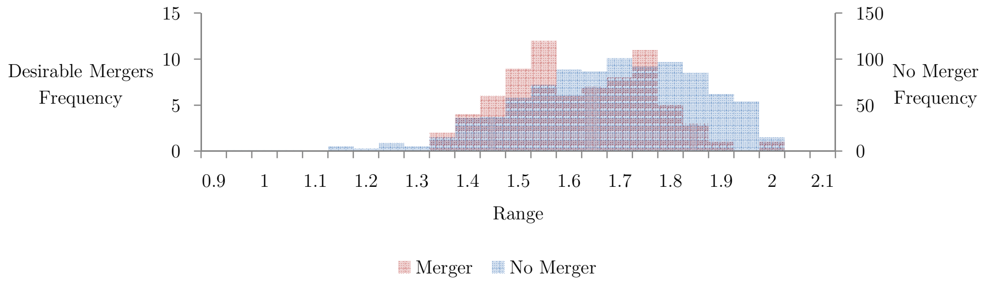
It was also found that:

- Merger waves significantly reduce the variance in production cost in a market (see Figure 5.13). Since some variance in production costs is necessary for mergers to occur, this suggests that without entrants a market is likely to reach an equilibrium in which no further mergers will occur.
- There is a non-trivial relationship between the lifetime of an agent and its production cost (see Figure 5.15); lower- to middle-cost agents live longer than higher-cost agents. This is a consequence of the agent's ability to source and sell goods, and suggests that agents with a higher production cost are at a disadvantage in the supply chain. Additionally, the position of a market within a multi-market world affects the lifetime of firms within that market.
- Merger targets have either high or low production costs (see Figure 5.17). This is a consequence of the motivations for merging; competitive and/or technological. It also suggests why middle-cost firms have some of the highest lifetimes on average.
- There is a non-trivial relationship between merger waves and the profitability of firms within a market (see Figure 5.20) caused by the timestep fluctuations in market participants. This could suggest a reason why a consensus has yet to be reached in the empirical literature about the effect on profitability following a merger (see Table 2.1).

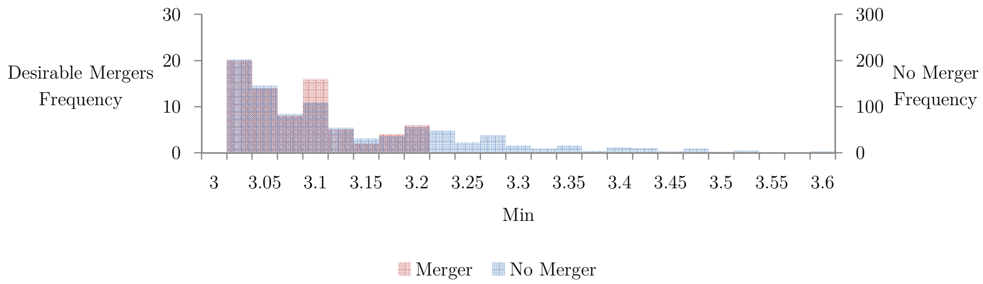
In the next chapter, we will extend this model further to investigate the effect of introducing agents who are able to dynamically adjust their production following changes in supply and demand.



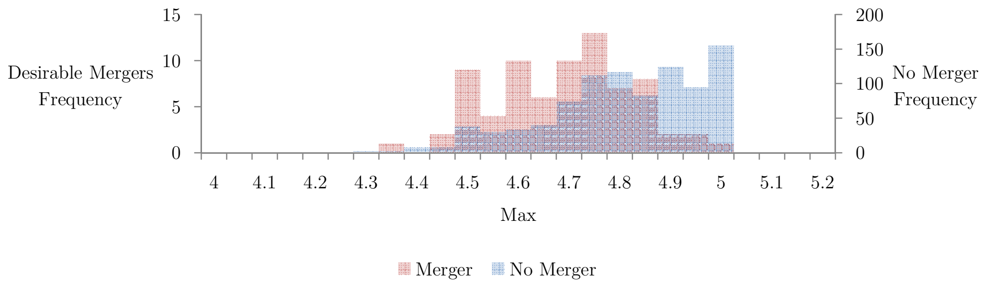
(A) Variance.



(B) Range.



(C) Minimum Cost.



(D) Maximum Cost.

FIGURE 5.12: The distribution in variance, range, minimum and maximum values in production costs when firms merge (red) and do not merge (blue). Data taken from a 1000 timestep simulation.

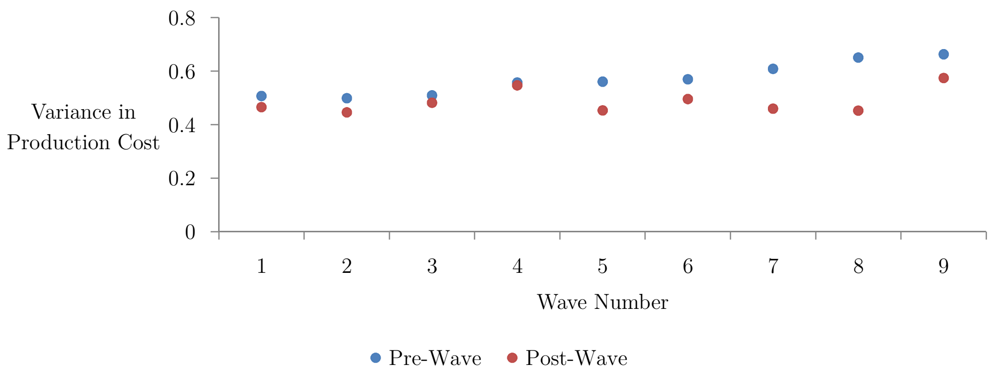


FIGURE 5.13: The pre- and post-merger variance in production cost for 9 waves within a 1000 timestep simulation.

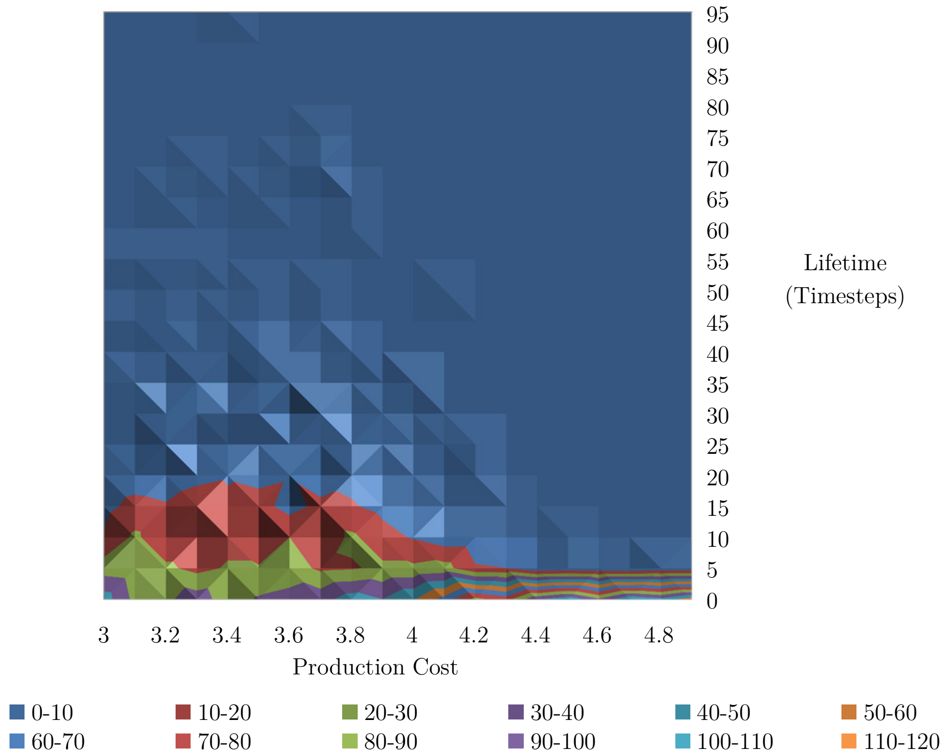
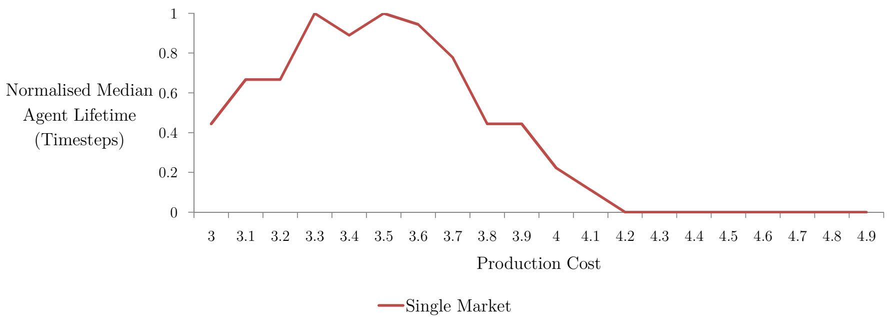
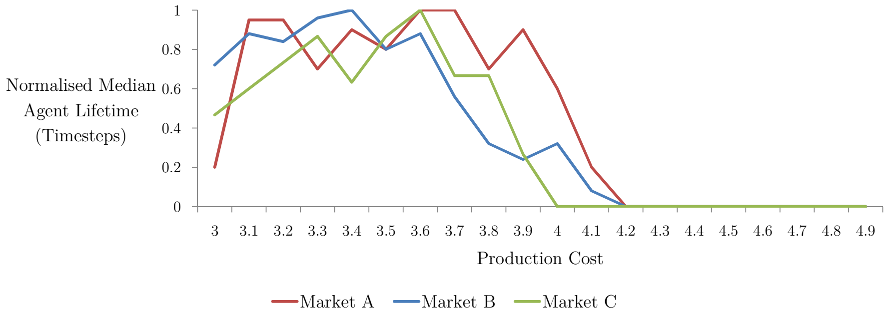


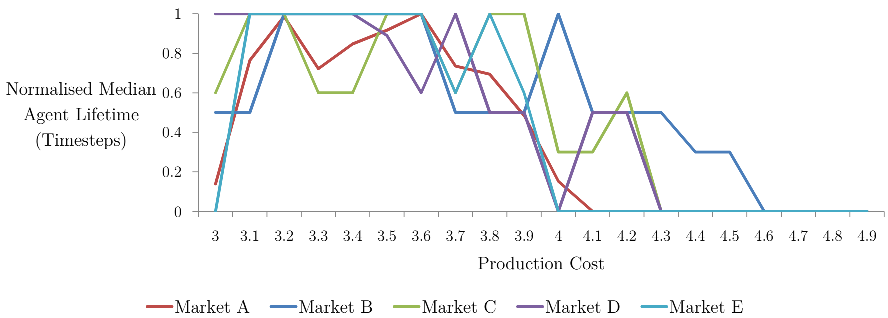
FIGURE 5.14: Heat map showing the relationship between agent production cost and lifetime in the single market model across a 1000 timestep simulation. Costs are drawn from a range between 3 and 5, α is intialised to α_0 and $m = 10$. Colours indicate the number of firms with a given production cost and lifetime.



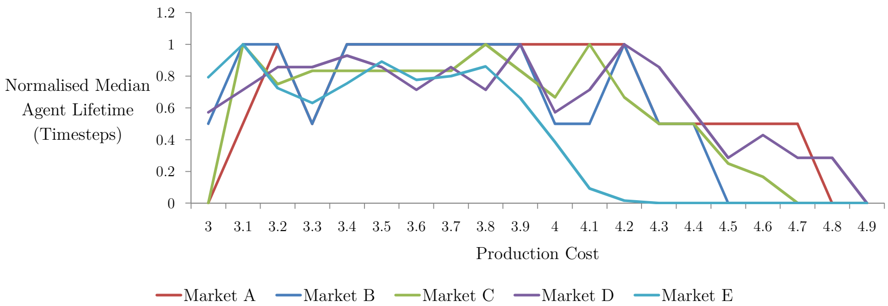
(A) Single Market.



(B) Chain

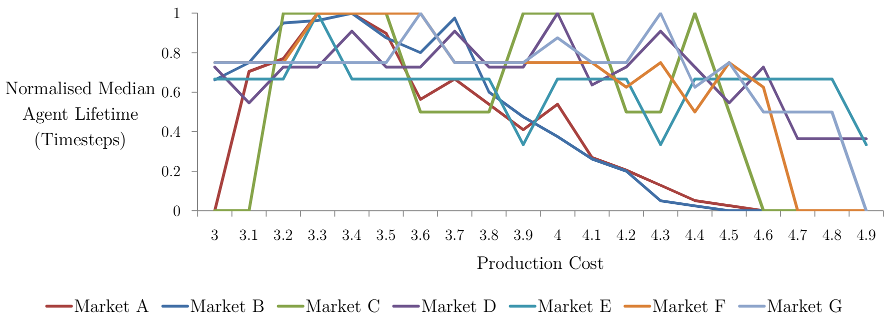


(C) Tree

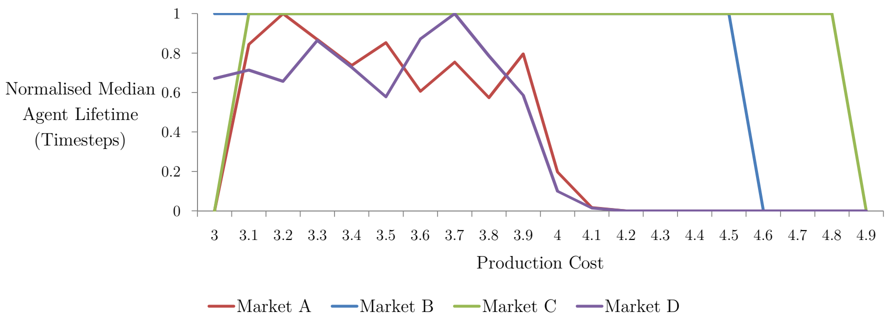


(D) Inverted Tree

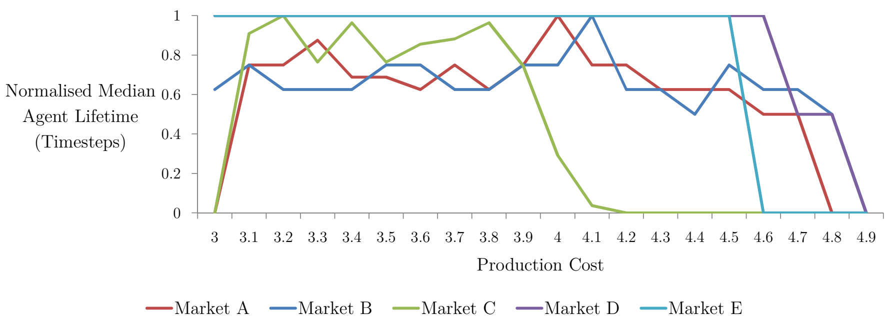
FIGURE 5.15: Median agent lifetime against production cost for markets with different configurations across a 1000 timestep simulation. Costs are drawn from a range between 3 and 5, α is intialised to α_0 and $m = 10$.



(E) Lattice

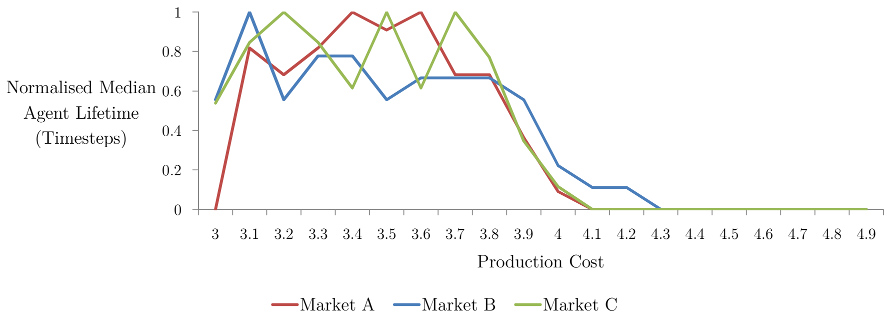


(F) Loop

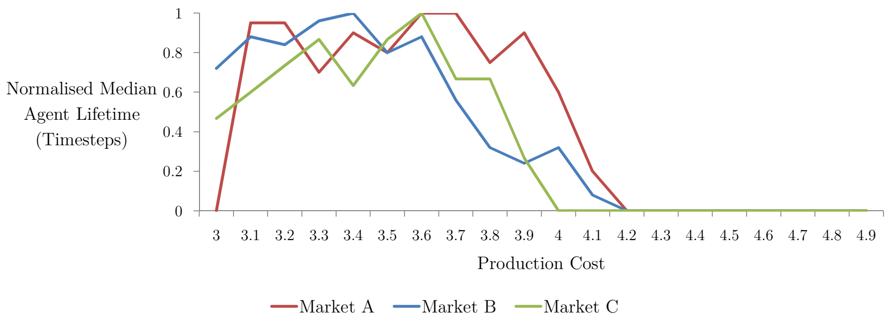


(G) Star

FIGURE 5.15: Median agent lifetime against production cost for markets with different configurations across a 1000 timestep simulation. Costs are drawn from a range between 3 and 5, α is intialised to α_0 and $m = 10$.

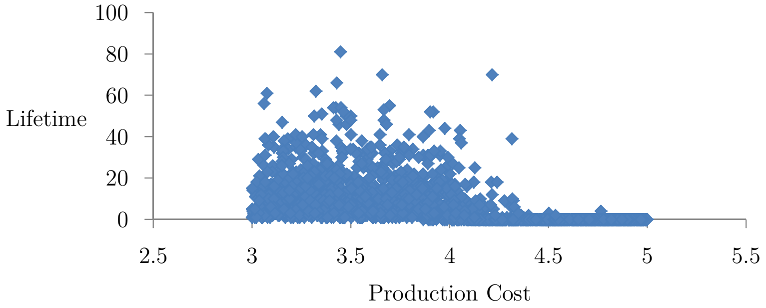


(A) Low-cost firms obtain supplies first.

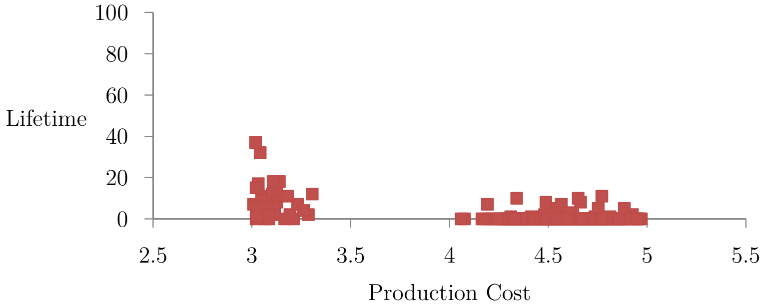


(B) High-cost firms obtain supplies first.

FIGURE 5.16: Median agent lifetime against production cost for markets within a chain configuration across a 1000 timestep simulation when a bias is imposed on which agents obtain supplies first. Costs are drawn from a range between 3 and 5, α is intialised to α_0 and $m = 10$.

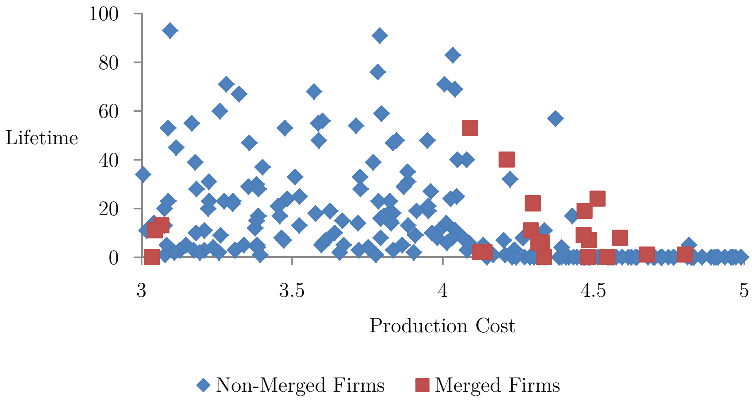


(A) Non-Merged Firms.

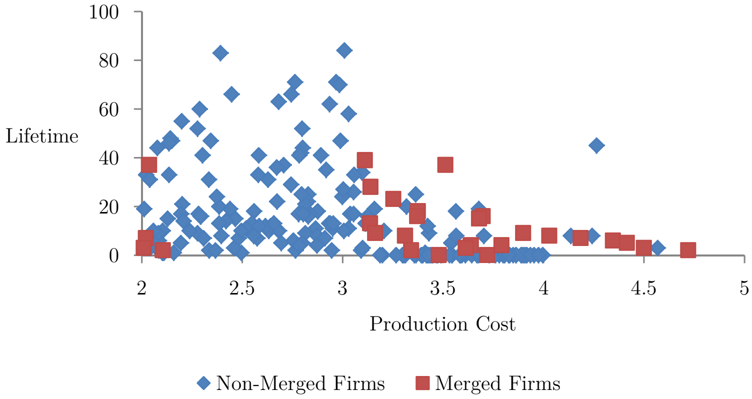


(B) Merged Firms.

FIGURE 5.17: Production cost and agent lifetime categorised by firms who exit the market through mergers and those who are forced to leave through an inability to produce. Costs are drawn from a range between 3 and 5, α is intialised to α_0 and $m = 10$.



(A) Unshocked Market.



(B) Shocked Market.

FIGURE 5.18: Production cost and agent lifetime categorised by firms who exit the market through mergers and those who are forced to leave through an inability to produce in a shocked market and an unshocked market. Costs are drawn from a range between 3 and 5, α is intialised to α_0 and $m = 10$.

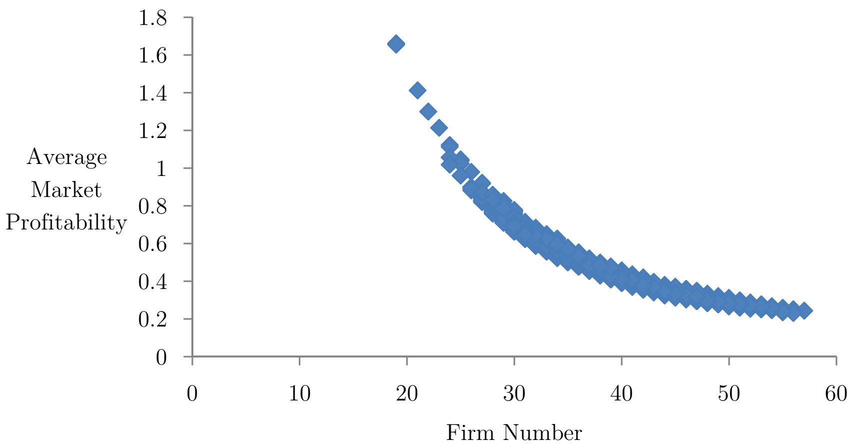
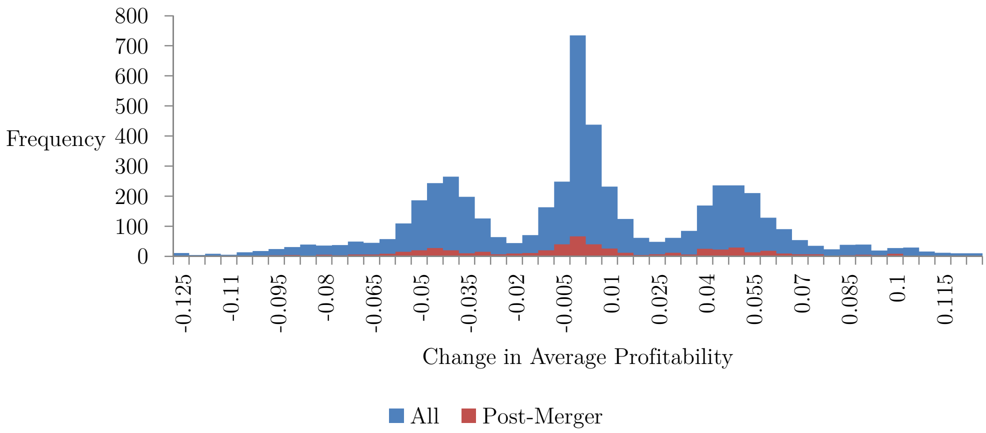
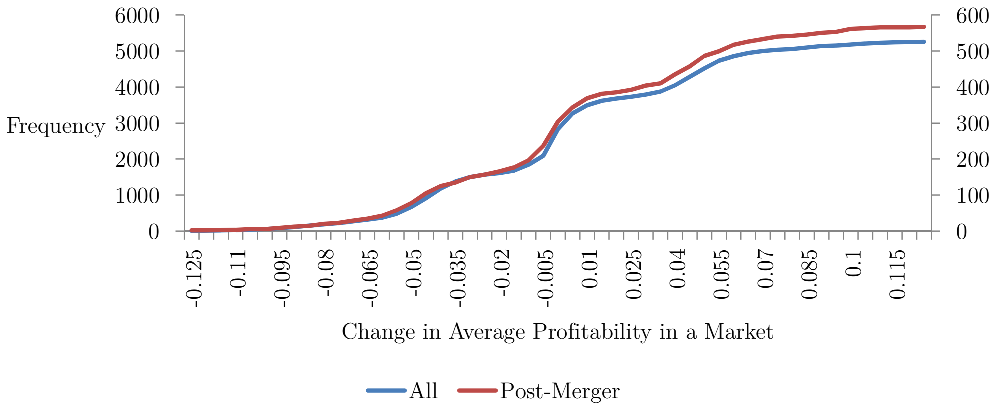


FIGURE 5.19: The relationship between average market profitability and firm number. Data is from five 1000 timestep single-market simulations. Costs are drawn from a range between 3 and 8, α is intialised to α_0 and $m = 10$.



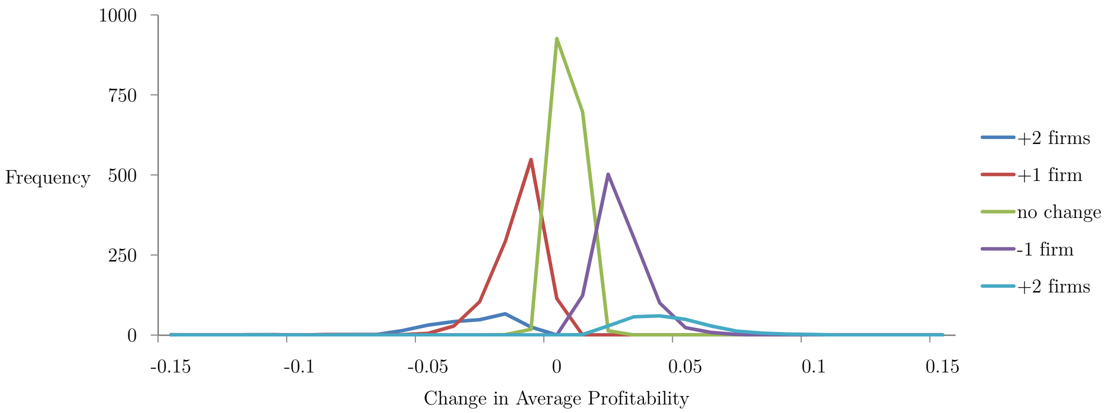
(A) Distribution.



(B) Cumulative Distribution.

FIGURE 5.20: The distribution of change in average market profitability overall and post-merger. Data is from a 5000 timestep single-market simulations. Costs are drawn from a range between 3 and 8, α is intialised to α_0 and $m = 10$.

(A) Raw Data.



(B) Distribution.

FIGURE 5.21: The relationship between change in average market profitability and change in firm number. Data is a 5000 timestep single-market simulations. Costs are drawn from a range between 3 and 8, α is intialised to α_0 and $m = 10$.

Chapter 6

Introducing Agent Expectations

In the previous chapter, it was shown how basic supply chain connections enable merger waves to spread between markets by altering the firm number. We also investigated the effects that these connections had on market behaviour. In this chapter, we finalise the multi-market model by creating a closed system in which firms in supplier markets react to changes in distributor demand by varying their production quantities. For example, if distributor demand increases, firms in a supplier market increase their production to cater for that demand. Similarly, firms that are overproducing will reduce their production. This creates a reactive, closed economic system in which demand drives supply.

6.1 Simulation Process

The previous model is extended by introducing an individual expected α-value $E(\alpha^S_{i,t+1}|\phi)$ for each firm i in supplier market S at time $t+1$, where ϕ is the information an agent uses in making its forecase. This value is its *expected demand.* In cases of overproduction or underproduction, firms adjust their expected demand.

Consider a market S. At time t, S produces a total quantity of $Q_S(t)$ and receives demand for a total quantity of $Q^d_S(t)$.

If $Q_S(t) = Q^d_S(t)$, the demand has been accurately met. Otherwise, one or more firms will adjust their expected demand so that, if there were no changes to the market's firm composition in the next timestep and sufficient supplies could be obtained, $Q_S(t+1) = Q^d_S(t)$.

- If $Q_S(t) > Q^d_S(t)$, firms in S have *overproduced.* In other words, one or more firms in S was unable to sell all of their goods.

In response to this, these firms will reduce their $E(\alpha^S_{i,t+1}|\phi)$ so that they will only produce at timestep $t+1$ the quantity they have managed to sell at timestep t. For example, if firm i overproduces at time t by 10 goods, it will adjust $E(\alpha^S_{i,t+1}|\phi)$ so that the next timestep it will reduce the number of goods it produces by 10: $q_i(t+1) = q_i(t) - 10$. Since only firms unable to sell all of their items reduce $E(\alpha^S_{i,t+1}|\phi)$, asymmetries in the expected α-value can occur between firms in a market.

- If $Q_S(t) < Q^d_S(t)$, market S has *underproduced*.

  In response to this, *all* firms will update their $E(\alpha^S_{i,t+1}|\phi)$ to meet that demand (i.e., so that $Q_S(t+1) = Q^d_S(t)$). Since all firms evaluate the market's collective demand, the individual $E(\alpha^S_{i,t+1}|\phi)$ realign (i.e. $E(\alpha^S_{i,t+1}|\phi) = E(\alpha^S_{j,t+1}|\phi)\ \forall i, j$ in S).

This model of agent expectations is an adaptive model rather than a rational model. That is to say, rather than evaluating the strategies of all other agents when updating their $E(\alpha^S_{i,t+1}|\phi)$, firms simply respond to their personal sale histories.

At $t = 0$, all firms are initialised with the same default value for expected demand. Therefore, markets at the bottom of the multi-market structures (i.e. those with a non-dynamic demand) maintain this initial value $F(\alpha)$ throughout the simulation. After initialisation, at $t > 0$, new entrants adopt the current average $E(\alpha^S_{i,t+1}|\phi)$ in their market (i.e., they take on the average market sentiment).

In pseudo-code representation, the only change takes place in the way in which a firm calculates its production quantity. Firms must also update their expected demand to reflect how many goods were sold in the previous timestep.

```
PRODUCE(market) {
        FOR firm f IN market {
          quantity q := f's expectation-adjusted Cournot quantity
          quantity s := f's current supplies stock
          IF s >= q {
            f produces q goods
          } ELSE {
            f produces s goods
          }
          IF q == 0 OR s == 0 {
            f exits the market
          }
        }
}
```

For comparison purposes, we also introduce the concept of *actual demand*: $A(\alpha^S)$. This is the value of α for a given market that, if adopted by all firms in the market, would produce the amount of goods demanded.

6.2 Simulation Behaviour

It is no longer the case that firms with the same production costs will produce the same quantity, since that amount is now linked to how much they sell. By extension, the cost of merging with a firm is no longer solely dependent on their production cost but their expected profit given how well they performed in the previous timestep.

In this section, we will investigate how the relationships discussed in the previous chapter change as a result of individual agent expectations.

6.2.1 Understanding $E(\alpha^S_{i,t+1}|\phi)$

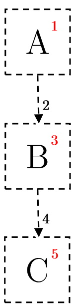


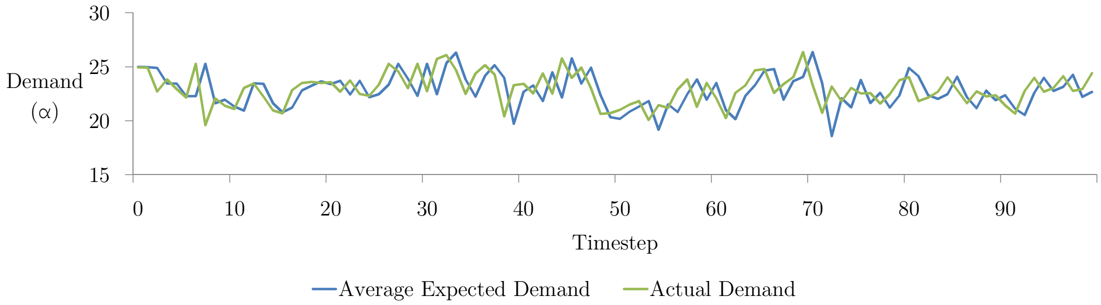
FIGURE 6.1: Chain

Trivially, since agent expectations are changed as a result of the relationship between supply and demand, there is no change in behaviour in the case of the single market model (i.e., with a constant α). If $E(\alpha^S_{i,t+1}|\phi) = F(\alpha)$ for all firms at initialisation, supply equals demand and so there is no difference in models. Since market entrants take on the average $E(\alpha^S_{i,t+1}|\phi)$ when they join a market, if expectations are varied initially, it may take some time for $E(\alpha^S_{i,t+1}|\phi) = F(\alpha)$ for all firms. If firms are underproducing initially, they quickly update $E(\alpha^S_{i,t+1}|\phi)$ (within the next timestep) to fill the required demand. If firms are overproducing, the change may be slower, but eventually all firms will adjust their $E(\alpha^S_{i,t+1}|\phi)$ to fill the required demand. Therefore, regardless of the starting configuration of expectations, after an intial period, all firms reach the same $E(\alpha^S_{i,t+1}|\phi)$. This is possible because the market receives an infinite supply, so market participants are not limited by how many goods they source as to how many they can produce.

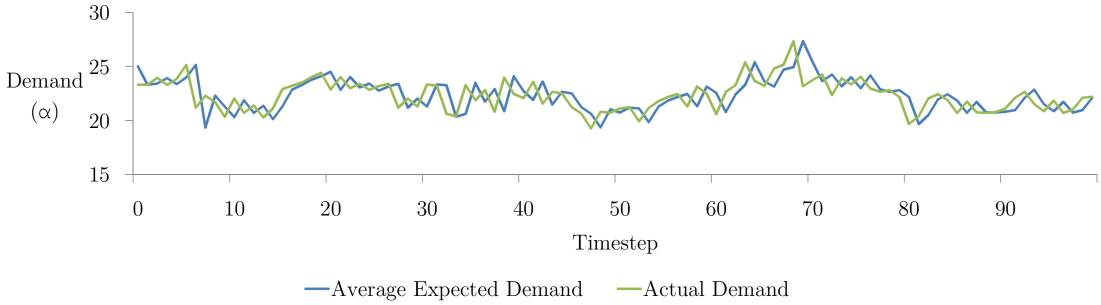
However, in connected markets, whenever demand changes, $E(\alpha^S_{i,t+1}|\phi)$ changes for one or more firms in S. When demand exceeds supply, all firms' $E(\alpha^S_{i,t+1}|\phi)$ are updated to the same value to reflect the increase in demand. However, when demand drops below supply, only firms who are affected by the drop (i.e., those who are unable to sell all of their goods) change their $E(\alpha^S_{i,t+1}|\phi)$ value.

In each multi-market structure, there is always some fixed, finite demand $F(\alpha)$ that markets produce for. For example, in the chain market (see Figure 6.1), market C has a fixed demand. Therefore, in any multi-market structure where no firms merge, or are randomly removed or added (i.e., firms are constant), the expected and actual demand in each market will equal this fixed demand.

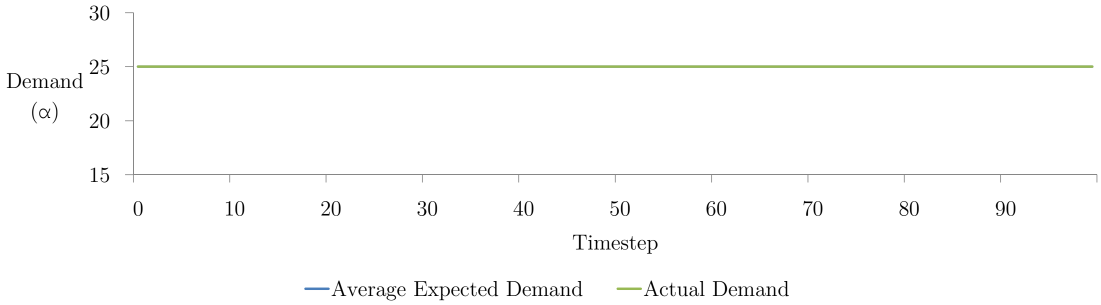
However, when a market's firm composition alters, the amount produced or demanded can change. In these situations, a market's average expected demand oscillates around $F(\alpha)$. This can be seen in Figure 6.2, which shows the average expected demand for the three markets in a chain configuration across a long simulation along with the actual demand placed on the market.



(A) Market A



(B) Market B



(C) Market C

FIGURE 6.2: Graphs showing the average expected demand and actual demand in a three-market chain structure across a simulation. Costs are drawn uniformly from a range between 3 and 5, $F(\alpha) = 25$ and $m = 10$.

As can be seen, there is a tendency for the average $E(\alpha^S_{i,t+1}|\phi)$ to oscillate below $F(\alpha)$. To understand this, consider how the quantity produced by a market changes over time: even with a fixed α-value, the total Cournot quantity produced by a market varies as the distribution of production costs and firm number changes. Therefore, when firms overproduce, they immediately reduce $E(\alpha^S_{i,t+1}|\phi)$, thereby lowering the average market

$E(\alpha^S_{i,t+1}|\phi)$. For the average to increase, the entire market must underproduce. Since this requires that all firms are selling all of their goods, it is less likely to occur than a single firm being unable to sell all goods. As such, the average $E(\alpha^S_{i,t+1}|\phi)$ oscillates just below $F(\alpha)$.

A firms' expected demand responds to the previous actual demand in market. Therefore, we might expect that $E(\alpha^S_{i,t+1}|\phi)$ is equal to $A(\alpha^S)$ at time t. Though this is often true, due to the dynamic nature of the market, this may not always be the case. After a firm has updated its expected demand in timestep t, several events may affect the actual demand for goods it receives in timestep $t+1$. In the case of two markets (supplier S and distributor D): market D then produces its goods and responds to sales where relevant; then market S may undergo a merger, react to entrants and random exits, and then produce goods based on their expected demands; and finally market D may undergo a merger, react to entrants and random exits before firms in D source their goods. In more complicated network structures, such as trees and lattices, even more processes must take place between timesteps.

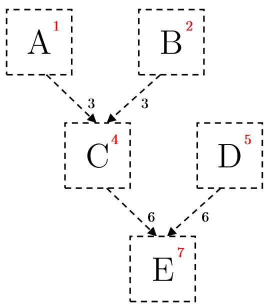


FIGURE 6.3: Inverted Tree

All markets in a given configuration demand goods to fill the final demand in base markets. However, note that we consider two concepts when referring to demand: the quantity of goods desired by a market, and the expected demand $E(\alpha^S_{i,t+1}|\phi)$. Therefore, dependent on the market configuration, a quantity able to satisfy the downstream demand might be produced by a market with a very low average $E(\alpha^S_{i,t+1}|\phi)$.

Trivially, in the case of base markets, such as market C in the chain structure, $A(\alpha^S) = F(\alpha)$. In all other cases, we find that $A(\alpha^S)$ oscilates close to this number.

Where markets share demand, such as such as markets A and B in the inverted tree structure in Figure 6.3, demand is split between the markets. Despite firms in downstream market C being indifferent to which market they source their goods from, the way in which demand is split between markets depends on the ability of those markets to fill the demand. For example, a market that overproduces is more likely to be able to sell goods, than those that underproduce. Therefore, an overproducing market is better equipped to fill more demand than an underproducing market. As already touched upon, the variation in demand is a direct consequence of the timestep delays in reacting to changing demand and the fundamental processes in the market (such as turnover of agents and mergers).

Although base markets, such as market C in the three-market chain, have a constant expected and actual α equal to their fixed demand, they still experience fluctuations in production. This is not surprising, since the ability to produce goods is a consequence of both demand and the supply of goods available. Therefore, changes in upstream markets affect the actual production in market C, but not its $E(\alpha^S_{i,t+1}|\phi)$.

6.2.2 The Relationship Between Waves and Links

After the introduction of agent expectations, whether or not a merger wave will occur or spread is no longer as simple as assessing firm number in relation to α. Therefore, a market that would previously have been declared stable may now incite merger activity.

Hypothesis 1: Individual agent expectations have little effect on overall merger activity.

The introduction of a firm's perceived level of demand may lead to situations in which a firm may want to merge when previously it would not. These occur when $E(\alpha^S_{i,t+1}|\phi)$ falls below $\alpha^S_{i,j}$, the maximum α-value for which a merger between i and j would be profitable in a given market. However, situations may also arise in which the opposite is true: firms do not want to merge when they previously would have. Therefore, we might expect that the introduction of individual agent expectations would have little effect on the overall merger activity.

Instead, we find that following the introduction of individual agent expectations there is a slight increase in merger activity. This is demonstrated in Figure 6.4, which compares the proportion of timesteps with merger activity for the two models. The data is taken from ten long duration simulations and suggests that agent expectations increase merger activity. Note that this is found to be the case regardless of the market configuration.

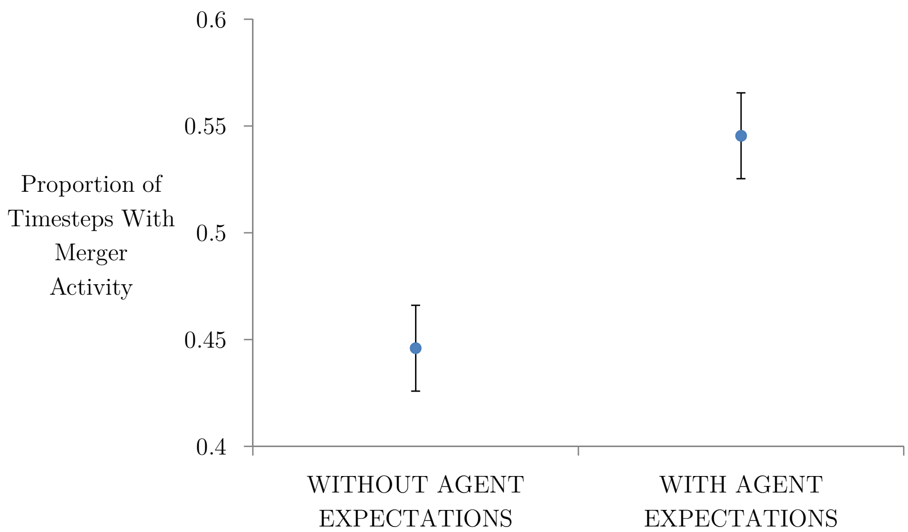


FIGURE 6.4: The average proportion of timesteps across market simulations without and then with agent expectations. The blue dot is the average across ten 1000-timestep simulations and the error bars show the standard deviation. These results are taken from market A from the chain market in Figure 6.1. Parameters are: $F(\alpha) = 25$, $c_{\min} = 3$, $c_{\max} = 6$ and at $t = 0$ $m = 10$.

To understand why, recall from the previous section how, with the exception of base markets whose $E(\alpha^S_{i,t+1}|\phi)$ values are constant, the average expected demand in a market oscillates around a value approximately equivalent to the demand it receives and, in the case of markets that share demand such as markets A and B in the inverted tree structure (Figure 6.3), has historically been able to produce for. This average level of demand was found to often be lower than $F(\alpha)$. Recalling Figure 5.2, a lower perceived demand increases the likelihood of merger activity.

Consider now the relationship between $\alpha_{\max}$ and the minimum value of individual expected demand in a market $E_{\min}(\alpha^S_{i,t+1}|\phi)$. If $E_{\min}(\alpha^S_{i,t+1}|\phi) \leq \alpha_{\max}$, at least one merger is desirable. Since $E_{\min}(\alpha^S_{i,t+1}|\phi)$ is lower in the model with agent expectations, merger activity increases.

Hypothesis 2: Agent expectations can be used to incite merger waves.

We might assume that since an agent's decision to merge is based on its perceived level of demand, changes in $E(\alpha^S_{i,t+1}|\phi)$ can be used to incite merger waves. This might correspond to a change in market sentiment by a group of firms in the real world, which goes on to incite waves. This is found to be the case in our model.

Recall that in the model, merger waves are periods in which some firms wish to merge (i.e., periods of merger desirability). Suppose we have a stable market in which no firms wish to merge. We can artificially lower $E(\alpha^S_{i,t+1}|\phi)$ for one firm to the point at which it would want to merge. Since mergers in our model are acquisitions of one firm by the other, it is not necessary for both the acquirer and target to find the merger desirable - the target is simply bought. Therefore, if we adjust the expectations of one or more firms we can incite merger activity.

Hypothesis 3: Changes in agent expectation can spread throughout a market and to other markets.

Since agent expectations are one of the causes of merger activity, it is interesting to question whether or not changes to expectations can spread between markets.

Trivially, since $E(\alpha^S_{i,t+1}|\phi)$ is dependent on the actual demand placed on a market, changes in supply do not affect it. Therefore, although reducing the supply to a market can reduce the number of participants and incite mergers that way (see previous chapter), it does not affect agent expectations. Any change in $E(\alpha^S_{i,t+1}|\phi)$ must be driven by downstream markets.

We know that any time there is an increase in the actual demand on a market, all firms update their expected demand to meet it. This is an immediate response by the market. Such a market then increases demand on its supplier markets, who similarly react by attempting to serve this demand.

However, despite expected demand being driven by actual demand, when there is a reduction in $A(\alpha^S)$, only affected agents (i.e., those who cannot sell all of their goods) reduce their expectations. In other words, a market is much less responsive to falling demand. Similarly, there is a delay in the effect on upstream markets. Nevertheless, markets do respond to negative changes in demand.

Overall, this suggests that merger desirability waves may now also be spread through markets by changes in agent expectation.

6.2.3 The Relationship Between Waves and Variance in Production Cost

It is interesting to consider the effect that individual agent expectations have on the relationship between merger waves and production cost. Recall that in the previous chapter we found that:

- Variance does not capture a relationship between production costs and waves;
- Waves reduce the variance in production costs in a market.

Hypothesis: There is no change in the relationship between waves and variance in production cost.

Since the nature of merger waves is unchanged, even though there is a slight increase in merger activity, we might expect to find the same relationship between waves and variance in production cost. However, this is not the case.

Figure 6.5 shows the variance in production cost before and after a series of waves across a simulation. As you can see, unlike in the previous model, waves do not necessarily reduce the variance in production costs in a market; the variance may now also increase.

To understand why this is happening, we must consider how mergers are incentivised. The cost of buying a target firm is a consequence of the target's expected profit. In the previous model, a firm's profit was easily determinable from its production cost; the lower the firm's production cost, the higher its profit is expected to be. However, in the current model, a firm with a low production cost might have a low expectation of its profits, since its expectation is updated based on sales. Therefore, it is less obvious which production costs will be removed from a market following a merger. As a consequence, the variance may increase following some merger waves, as well as decrease.

However, just as before, the variance, range, minimum and maximum values are not clear indicators of whether or not mergers will take place. This is found to be the case regardless of the market configuration.

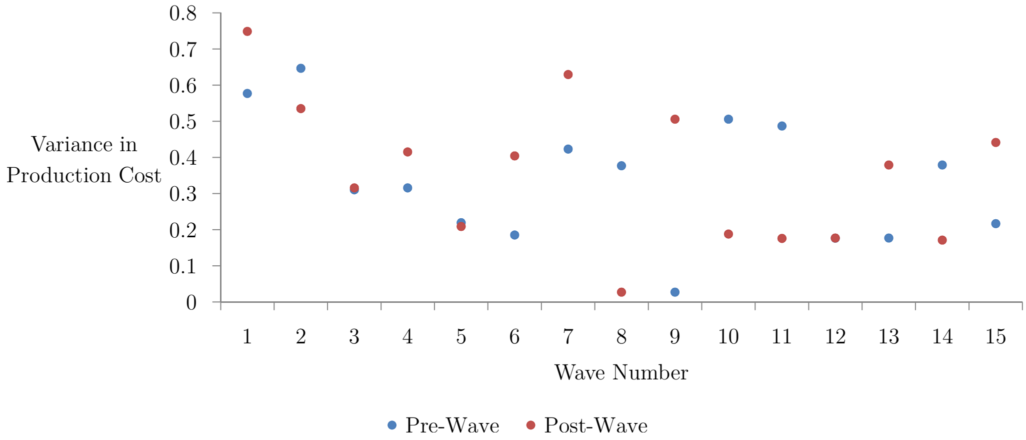


FIGURE 6.5: The pre- and post-merger variance in production cost for 15 waves within a 1000 timestep simulation. These results are taken from market A from the chain market in Figure 6.1. Parameters are: $F(\alpha) = 25$, $c_{\text{min}} = 3$ and $c_{\text{max}} = 6$, and at $t = 0$ $m = 10$.

6.2.4 The Relationship Between Survival and Production Cost

Given that the cost of merging with a firm is now a direct consequence of its previous sales, it is interesting to consider how the relationship between firm survival and production cost has changed. For instance, we might now assume that there is no longer a bias towards firms with a middle-to-lower production cost.

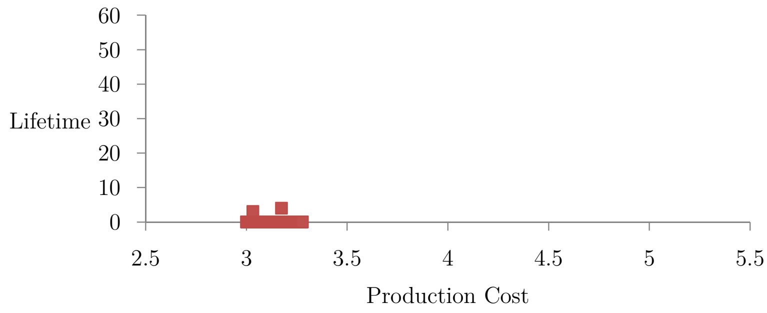
Recall that in the previous chapter we found that:

- Regardless of the supply-sourcing mechanism, middle-to-lower cost firms lived longer than higher cost firms;
- This relationship was maintained across markets in different configurations, with the relationship more distinguishable in those markets with a larger average market population;
- Regardless of whether or not a shock is applied to a market, merger targets have either a high or very low production cost.

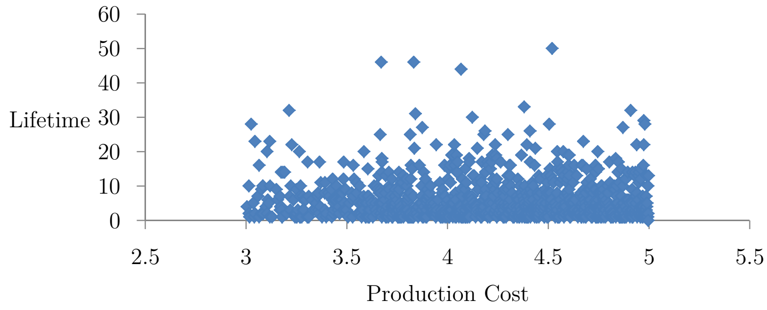
Hypothesis 1: Lower-cost firms are more likely to be merger targets than higher-cost firms.

As discussed in the previous section, in this extension to the model we see that firms that overproduce become cheaper to acquire than they would have been in the previous model. Therefore, we would expect an increase in the number of mergers targetting lower-cost firms. This is found to be the case.

If we compare the lifetimes of firms by their reason for exiting the market (i.e. through merging or through finishing production), we find a stark difference from the previous model. This is shown in Figure 6.6. Just as before, firms with a lower production cost find themselves the targets of mergers. However, unlike the previous model, higher cost firms do not.



(A) Merged Firms.



(B) Non-Merged Firms.

FIGURE 6.6: Production cost and agent lifetime categorised by firms who exit the market through mergers and those who are forced to leave through an inability to produce. These results are taken from market A from the chain market in Figure 6.1 over a 1000 timestep simulation. Costs are drawn from a range between 3 and 5, α is intialised to α_0 and $m = 10$.

Mergers with lower-cost targets are more likely to be motivated by a technological advantage for the acquirer, whilst higher-cost targets are more likely to be motivated by a reduction in competition. Therefore, we see that mergers for technological advantage are much more prominent in this model.

To understand why, consider the lower-cost firms. When they enter a market, they take on the average $E(\alpha^S_{i,t+1}|\phi)$, which causes them to produce an above average quantity of goods since their production costs are lower. It is therefore likely that they will be targeted by buyers, since buyer firms prefer to obtain all their goods from the smallest number of supplier firms. However, the random ordering of buyer firms makes it unlikely that the lower-cost firms will be able to sell all their goods. Therefore, they adjust their $E(\alpha^S_{i,t+1}|\phi)$, and expect a reduced profit. This makes them instantly more desirable as a merger target: not only are they cheaper to buy than they otherwise would have been, but they offer a technological advantage as well as a reduction in competition. Meanwhile, targetting mergers with higher-cost firms is less likely to offer the same payoff.

Following this, it is interesting to consider how this change affects the relationship between production cost and median lifetimes of firms.

Hypothesis 2: Firms with a middle-to-lower production cost no longer exhibit longer lifetimes than higher-cost firms.

In the previous model, there was a bias towards middle-to-lower cost firms, which enabled them to have longer lifetimes on average. This came about through their ability to produce more goods, and therefore be more likely not to exit the market through an inability to sell anything. The bias was shared between middle and lower cost firms, since lower cost firms also found themselves the targets of mergers; the second determinant of shorter agent lifetimes.

In the current model, a firm's lifetime is similarly closely linked to how much it sells. However, now firms reduce their production if they cannot sell all their produce, as well as exiting the market if they cannot sell any. And, once a low-cost firm reduces its production, it can become an affordable target for competitors. Additionally, as we have seen from above, higher-cost firms are less likely to be merger targets. Therefore, we might expect the lifetime of higher-cost firms to be increased, whilst that of lower-cost firms to be reduced. This is found to be the case.

Figure 6.7 shows how the bias that was evident in the previous model has changed (see Figure 5.15 for comparison). It shows the relationship between median agent lifetimes and production costs for the different configurations.

As can be seen, in all configurations - except the single market - there is now a firm bias towards higher-cost firms and against lower-cost firms. In the case of the single market, this is less pronounced, which is unsurprising since supply and demand are fixed in the model.

6.2.5 The Relationship Between Waves and Profitability

Previously, it was found that:

- As firm number decreases, average market profitability increases exponentially;
- The change in average profitability in a market has a multi-modal distribution;
- Merger activity does not affect this relationship.

The profit a firm makes is dependent on both its production and sales. Given that firms adjust their expected demand to respond to changes in sales, we may expect there to be an increase in market profitability since firms adjust their production quantities to reduce overproduction.

Note that profitability is based on the quantity of goods sold by an agent. Therefore, agents have reduced profitability if they cannot sell all of their goods.

Hypothesis: Introducing agent expectations increases the average profitability in a market.

Figure 6.8 shows the relationship between the average market profitability and firm number for agents with and without demand expectations. As we can see, just as in the previous models, the average market profitability decreases exponentially as firm number increases. However, we also find that the introduction of agent expectations increases the average market profitability as well as the standard deviation in this value.

To understand this, let us consider the oscillatory behaviour of production in the new model. Although firms adjust their production quantities in an attempt to reduce overproduction of goods, there is a delay in their decisions taking effect. As such, markets tend to oscillate between over- and under- production. During overproduction, the price of a good drops and firms receive a drop in their profit due to excess goods in the market; during underproduction, the price of the good increases, but firms then increase production to cater for demand. In the previous model, though profit was reduced by overproduction, firms made no move to adjust their production levels. However, now, the adjustment feedback leads to much more variation in the profitability of the market of fixed size.

As expected, the overall average market profitability is increased following the introduction of agent expectations. This implies that the ability to respond to fluctuating demand is, on average, beneficial to the firms. Again, this is not surprising as, even with the timestep delay in responding to changes in demand, markets tend towards less waste (i.e., firms tend to produce fewer goods as $E(\alpha^S_{i,t+1}|\phi)$ fluctuates just below $F(\alpha^S)$ on average).

Perhaps unsurprisingly, the multi-modal distribution in the timestep change in profitability is no longer clearly identifiable. Figure 6.9 shows the smoother trend in the change in the average market profitability when looking at the cumulative distribution. Recall that, in the previous model, the multi-modal distribution was a consequence of the change in a market's composition between timesteps (i.e., the introduction and removal of firms). However, in the current model, the change in average market profitability can be much more dramatic between timesteps as agents vary their production in response to fluctuating demand.

6.3 Summary

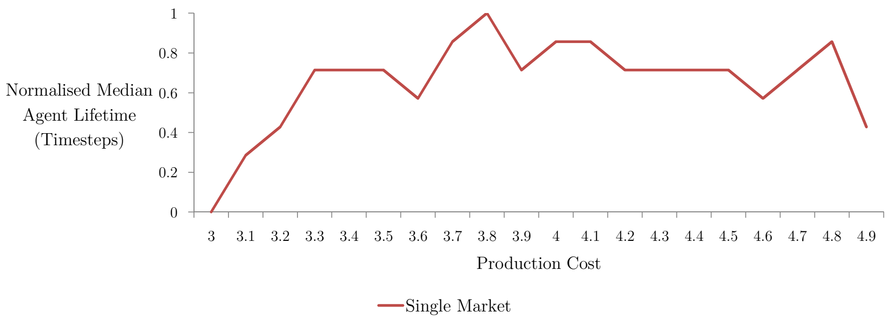
This chapter extended the multi-market model to enable firms to update their production in response to changing demand. This was found to have several effects on the behaviour of the model.

Although the introduction of agent expectations increases merger activity (see Figure 6.4), changes in expectation may also spread across supply-chain dependencies and act as a cause of merger waves. Since $E(\alpha^S_{i,t+1}|\phi)$ may be considered as an individual's market sentiment, this way of extending the model may provide another way of examining the behavioural theories of merger waves (such as the Managerial Discretion Theory (Shleifer and Vishny, 2003)).

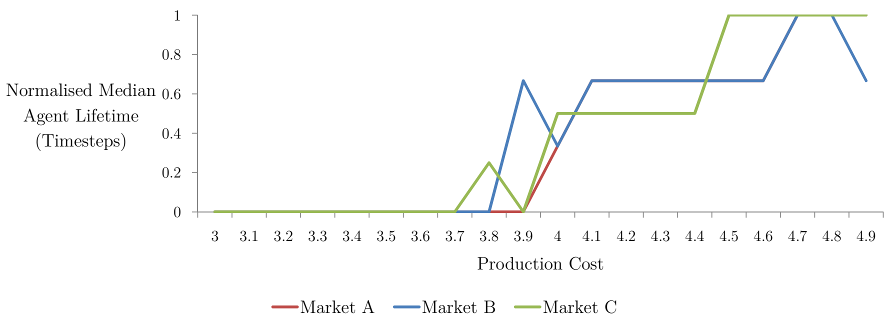
It was also found that:

- Lower cost firms now become the main target of mergers (see Figure 6.6). This is because they are more likely to overproduce, lower their expectations on demand, and therefore reduce the cost of merging with them. This could be seen as an example of a firm undervaluing its production advantage, or of other firms overvaluing the potential gain from a merger with such a firm.
- The market no longer favours firms with a lower production cost, but middle and higher-cost firms instead (see Figure 6.7). This is because they are less likely to overproduce or have reduced merger costs.
- The introduction of expectations increases the average profitability in a market and the variance in this profitability (see Figure 6.8). This is caused by the agent updating mechanism, as firms are able to respond to changing demand and tend towards less production waste.
- The relationship between waves and the variance in production cost is no longer discernible (see Figure 6.9), as is the multi-modal distribution of the change in average market profitability. Trivially, this is because the behaviour of a market is no longer simply a consequence of the cost configuration, but of $E(\alpha^S_{i,t+1}|\phi)$ as well. However, the average market profitability still decreases exponentially as firm number increases, since as the number of firms increases the profit in a market must be divided between more firms.

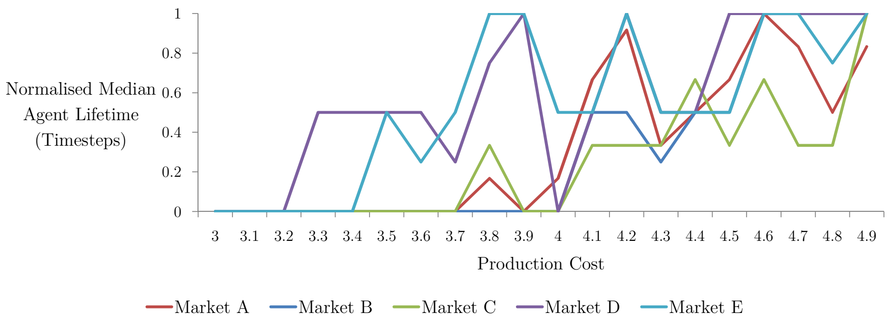
When agents have partial information about the state of a market, our model shows that waves can still occur randomly or be generated through shocks, and can spread between markets.



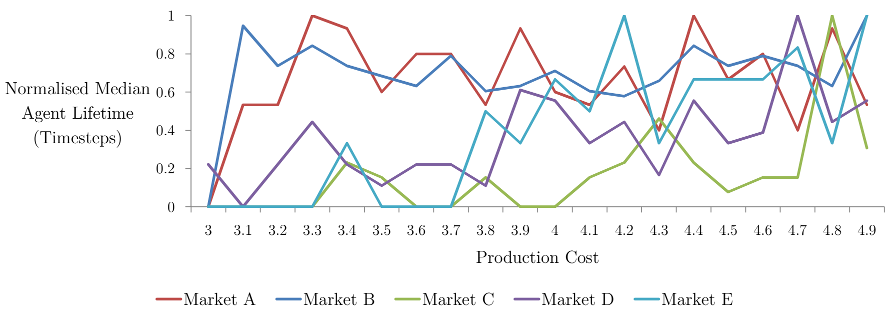
(A) Single Market.



(B) Chain

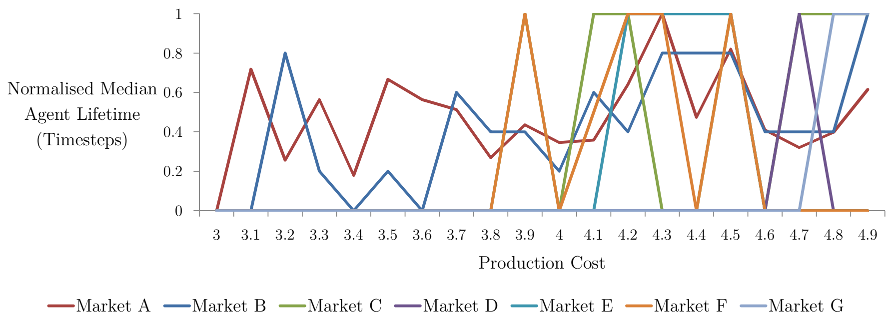


(C) Tree

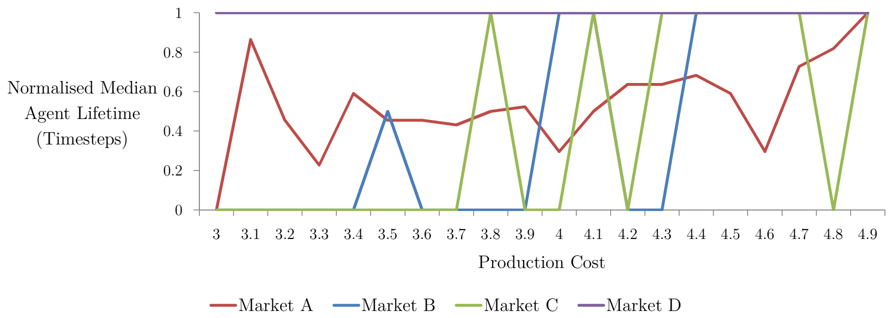


(D) Inverted Tree

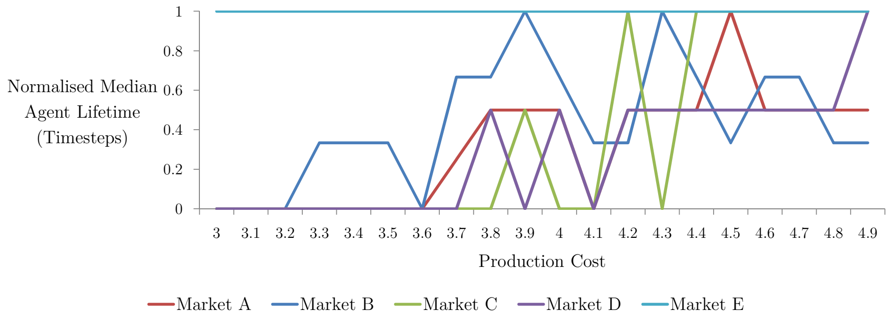
FIGURE 6.7: Median agent lifetime against production cost for markets across a 1000 timestep simulation. Costs are drawn from a range between 3 and 5, α is intialised to α_0 and $m = 10$.



(E) Lattice



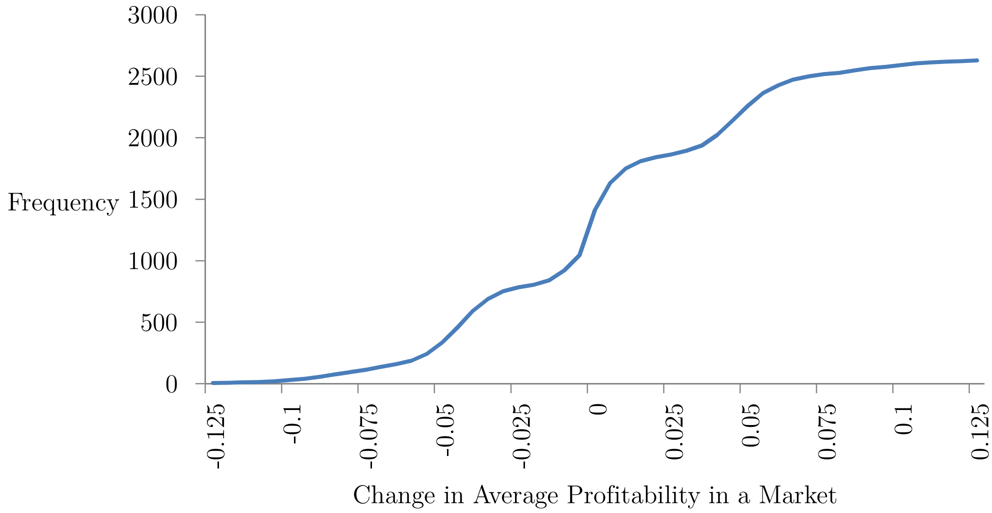
(F) Loop



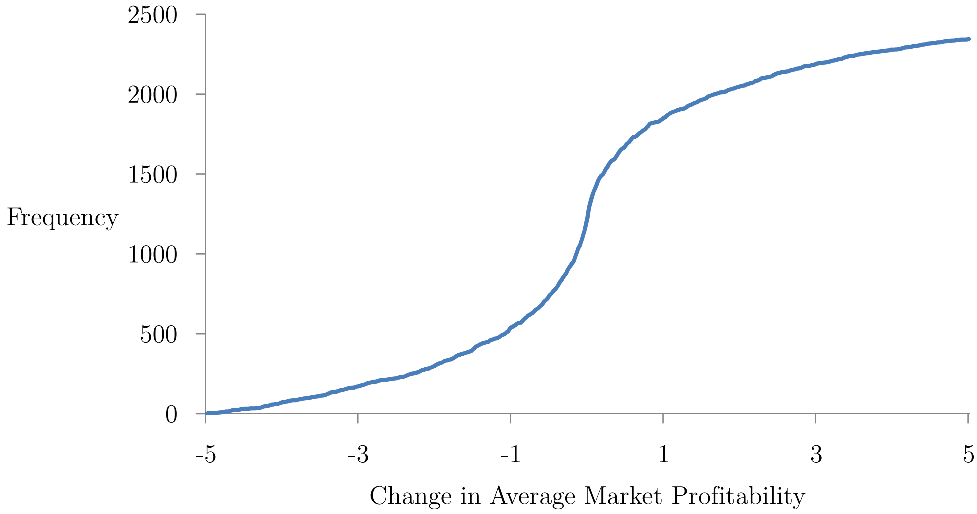
(G) Star

FIGURE 6.7: Median agent lifetime against production cost for a markets across a 1000 timestep simulation. Costs are drawn from a range between 3 and 5, α is intialised to α_0 and $m = 10$.

FIGURE 6.8: The average (bar) and standard deviation (error bars) in average market profitability against firm number for markets without and with agent expectations. Data is taken from five 1000 timestep simulations for market B in the three-market chain structure. Costs are drawn from a range between 7 and 10, $F(\alpha) = 25$ and $m = 10$.



(A) Without Agent Expectations.



(B) With Agent Expectations

FIGURE 6.9: The cumulative distribution of change in average market profitability for a market first (A) without and then (B) with agent expectations. Data is taken from a 2500 timestep simulations for market B in the three-market chain structure. Costs are drawn from a range between 7 and 10, $F(\alpha) = 25$ and $m = 10$.

Chapter 7

Conclusion

This thesis set out to gain a greater understanding of the causes and effects of merger waves by using agent-based modelling. In the past ten years, agent-based modelling has become an increasingly widespread tool for exploring economic phenomena. However, it has yet to fully explore models of mergers and competition.

Understanding the causes and effects of mergers is increasingly important as global consolidation grows, which many believe is increasing global systemic risk (Mishkin, 1999; De Nicolo and Kwast, 2002). Therefore, merger regulation is under increasing scrutiny as it attempts to balance national and international competitive interests.

This thesis set out to fulfil the following three aims:

1. To demonstrate how agent-based modelling can be used to create dynamic models of merging capable of simulating merger wave phenomena;
2. To test the theories of merger wave causes;
3. To develop a better understanding in the role of dependencies between markets.

This final chapter will summarise the main findings in this thesis, discuss the extent to which our research aims were met, and propose ways in which this work might be continued in the future.

7.1 Main Findings

Chapter 2 consolidated a large corpus of empirical and theoretical research into merger waves to find that:

- Merger waves may be caused by neoclassical shocks (such as regulatory changes), behavioural shocks (such as misvaluations) or arise randomly.
- Merger waves are often clustered together by industry, with dependencies between industries acting as pathways enabling them to spread.

It was also found that empirical investigations into the effects of mergers often reached different conclusions, even when using the same dataset. However, some findings, such as the payoff rivals experience following a merger, were widely accepted.

An overview of merger regulation revealed that mergers are regulated on a case-by-case basis, their relative importance signalled by size. However, successful regulation remains an ongoing point of economic and political contention.

It was shown that, although agent-based models are increasingly popular in predictive analysis and 'what-if' simulation, they are often difficult to validate.

Chapters 3 and *4* demonstrated how agent-based modelling could be used to simulate a competitive market based on two existing static models: Neary (2007) and Qiu and Zhou (2005). The model was used to investigate theories surrounding the causes of merger waves. It was found that:

- For mergers to occur, the level of demand in a market has to be below a certain threshold amount ($\alpha_{\max}$) and at least one firm must operate with a different production cost to the others.
- Merger waves can occur endogenously in the model, or be prompted by shocks to supply or demand consistent with neoclassical and behavioural theories of merger wave generation.
- Such waves are significantly different from those generated by a null model, supporting the view that there are waves in merger activity (Gartner and Halbheer, 2009).

It was also found that, in the multi-cost market, agents that acted strategically (i.e., those who considered an extended future payoff from merging) were more likely to want to engage in mergers. It was also suggested that merging increased the probability of firms surviving in a competitive market.

Chapter 5 developed the model in *Chapter 4* by connecting multiple markets through supply chains; the goods produced in one market became the supply for another. It was found that:

- In support of the literature, supply chain dependencies enable merger waves to spread between markets (see Ahern and Harford, 2013).

- A wave can be generated in multiple markets simultaneously by the same exogenous cause, or generated in a single market, which then can spread through to other markets.
- The susceptibility of a market to distruptions in other markets depends on the structure of its dependencies to supplier and distributor markets.
- The position of a market within a supply chain affects the average lifetime of firms within that market.
- Merger targets have either high or low production costs.
- Merger waves reduce the variance in production costs between firms in a market.

These findings were further explored in *Chapter 6*, which developed the model to enable agents to dynamically respond to changes in demand by updating their production quantities. The primary findings of this chapter were that agent expectations increased merger activity, could act as a further cause of merger waves, and enable changes in expectation to spread across supply chains.

Though the results supported some of the trends that had previously been identified in *Chapter 5*, such as the effect a market's position within a supply chain has on its susceptibility to disruptions in other markets, many were altered. Unlike before, it was found that:

- It was rare for higher cost firms to be the targets of mergers; the vast majority being lower cost firms.
- Firms with a lower production cost tended to have shorter lifetimes than those of middle to higher cost.
- There was no clear relationship between merger waves and the variance in production cost.
- The multi-modal distribution of the change in average market profitability was no longer clear.

Additionally, the average profitability of a market was increased following the introduction of agent expectations.

Differences between models act as a way of determining which behaviours are traits of the model and which are the consequences of design choices. Therefore, the differences in behaviour between *Chapters 5* and *6* highlight areas for further investigation.

7.2 Implications and Limitations

This thesis has constructed an agent-based model able to support a number of theories and findings about the causes and effects of merger waves. Part I suggested that merger waves are caused by an 'imbalance' in firm production costs that are unsupportable by a given market condition. In other words, changes in supply, demand or firm composition could generate a wave. Part II extended this by adding further that the type of good produced by a market (complementary or substitutable) and its configuration of dependencies on other markets might put it at an increased risk of experiencing a wave.

Given the unpredictable nature of real-world merger waves, regulators may wish to minimise their impact. Our research suggests the following:

- To lessen the probability of merger waves, supply and demand must be kept at sustainable levels;
- Firms sourcing substitutable goods from multiple markets are less susceptible to fluctuations in supply and demand than those sourcing complementary goods;
- The behaviour of firms operating in markets that act as bottlenecks in supply chains are more likely to have a significant impact on connected markets.

However, the extent to which specific policy implications might be identified is restricted given the model's limitations. We now present a discussion of these limitations and how they might be overcome.

General Limitations

- *Abstractness*:

  Throughout its development, a number of design choices had to be made in order to construct the final multi-market model. For instance, which existing theories to base it on, how to implement a supply chain dependency, how to conceptualise mergers, etc. To many, the characterisation of a firm, itself a complex entity, as a simple utility function, which differentiates itself from other firms solely based on its production cost, might seem an extreme oversimplification of the real world. However, in order to develop any model, abstractions are necessary.

  The question of abstractness was an ongoing issue throughout the research. As documented, in an attempt to reduce the effect of certain design choices, where possible alternatives were often explored. For example, the investigation into myopic or pseudo-strategic decision-making agents in Part I was an effort to investigate the consequences of simplification. Similarly, the study introducing agent expectations in the multi-market model (Chapter 6) acted as a robustness test for the model's findings.

- *Real-world Relevance*:

  In addition to its abstract nature, the model produced is not currently calibrated to any real world specification. For example, although we might specify the flow of goods through multiple connected markets, we do not explicitly model a collection of markets on, say, the manufacture of timber goods in Canada. This acts as a substantial limitation to the real-world relevance of the model in its current form.

  However, given the model's ability to support a number of existing theories regarding merger behaviour, themselves derived from empirical investigations, we believe such calibration to be a reasonable next step in this research (see Future Work).

Model Limitations

- *Defining a Merger Wave*:

  In our model, at most one merger may take place in a timestep. Therefore, the traditional definition of merger waves, which are characterised by the change in the volume of merger activity over time, cannot be used. Instead, merger desirability was used (i.e., the number of firms that want to merge rather than the number of firms that merge). This may draw into question the extent to which merger wave behaviour is being considered; in a merger wave, a particular merger is only considered once, whereas a merger may be desirable for many timesteps.

  The alternative to using merger desirability as a wave measure was to allow more than one merger to occur in a single timestep. However, since the desirability of a merger depends on the market configuration, merger decisions are interdependent. As such, a particular merger may only be considered desirable as long as another merger does not take place, or a number of desirable mergers may involve the same firm. This raises a number of modelling questions, such as how to determine which mergers are permitted during a timestep.

  Despite this, when investigating merger desirability in our model, two distinct modes of activity were clearly visible. In other words, there was a clear regime-switching behaviour similar to those that characterise real-world merger waves.

- *Modelling Competition*:

  The competition modelled in this research is based on a Cournot competition. In a Cournot competition, firms compete to produce a homogeneous good; each firm must determine the quantity of goods it will produce. This was adopted largely due to its use in Neary (2007) and Qiu and Zhou (2005), the two papers on which the initial single market model was built. However, there are alternatives. For instance, a Bertrand competition, in which each firm must set the price at which to sell their goods (Dutta, 1999).

It is proposed as future work to investigate the effect that alternative ways of modelling competition might have on the characterisation of merger waves. Although we do not know what the effects would be, we would expect our core findings to remain the same; that the model can exhibit merger waves, that these waves can be generated by shocks to markets, and that waves can spread between markets.

- *Conceptualising Agents*:

  Agent-based modelling provides a wealth of techniques for representing complex entities. Although we experimented with myopic and pseudo-strategic agents, and introduced agent expectations, the agents used in our model are simple. In reality, firms adapt and evolve over time to changing landscapes. However, our simple agents were still able to exhibit interesting behaviour, such as merger waves.

  It is proposed as future work that the use of intelligent, learning agents are investigated. Given that real-world firms change strategies over time, it would be interesting to see the effect that learning agents has on the behaviour of the model. For example, we might expect that firms live longer on average or a more profitable, since they may be better equipped to respond to changing demand.

- *Generalisation of Wave Causes*:

  Throughout our investigation, we consider endogenous and exogenous (behavioural and neoclassical) shocks. These are very generally defined. We do not, for example, consider a specific theory and investigate its exact outcome on the behaviour of the model. For example, we group behavioural theories together under the concept of 'demand shocks', rather than investigating the Managerial Hypothesis Theory in more detail. This is proposed as future work.

- *Intermarket Dependencies*:

  The model presented in Part II considers only one type of market interdependency: supply chains. However, the choice of using supply chains to model interconnections was not made arbitrarily. Supply chains are often clear, objective and well-documented in real-world systems, unlike, for example, political pressures that develop dependencies between markets. Therefore, there is the potential to calibrate such dependencies in our model to a particular group of real-world markets to test behavioural outcomes in the future.

  The literature on modelling supply chains is vast. Our implementation, therefore, is greatly simplified. However, the purpose of introducing supply chains was to determine their effect on the spread of waves between markets. This was successfully demonstrated.

  It is proposed as future research that the supply chain dependencies are investigated in more detail, and additional dependencies between markets modelled.

7.3 Future Work

Following on from the discussion above, we now elaborate on proposed future work.

Creating a predictive model.

Having established a model capable of replicating several theoretical merger traits, it would be interesting to calibrate the model using real world data. Such a model could then be used in a similar manner to the EURACE (2006) and CRISIS (2011) models in the development of future regulation. The first step would be to obtain time series data for a particular industry, including details about mergers, competitors, entrants, demand and supply, etc. A portion of this data would then be embedded within the model's framework.

Chapter 2 indicated a number of empirical starting points from which to develop the model. For instance:

- Merged firms receive a negative effect on post-merger share price compared to other firms in the same industry.
- The larger the acquiring firm, the more negative the effect of the merger.
- Mergers have a positive effect on the share price of rivals in the same industry.
- The closer the rival to the merging firm, the greater the effect of the merger.

Extending the theoretical model.

Of continued interest is the effect of dynamic evolving networks in agent-based models (e.g. Jackson, 2003). There are a number of existing network models that consider the spread of contagion. Given that merger waves are said to spread through industry dependencies, such models could be useful in investigating their transmission and determining whether or not it is possible to prevent any of the negative effects of merger waves.

An alternative extension could be the development of more realistic or intelligent agents. For example, agents could be designed with learning capabilities or be given the capacity to innovate, reducing costs. Again, there is a large literature on economic intelligent agents (see van den Bergh et al., 2002; Holland and Miller, 1991).

Developing our understanding of complexity in merging.

Understanding the complex consequences of merging between autonomous agents can offer implications for disciplines beyond economics. For example, many biological processes such as cell fusion involve a number of identical entities autonomously uniting.

Similarly, studies in other disciplines could offer insight into economic merger behaviour. Therefore, it would be useful to develop a unifying framework under which the study of the dynamic effect of simple merging processes could be explored, along with the aggregate dynamics of the overall system.

7.4 Concluding Remarks

This thesis set out to gain a greater understanding of the causes and effects of merger waves by using agent-based modelling. Though in its current form the model has some limitations, the research has demonstrated how a simple competition model can reveal complex aggregate behaviour that is consistent with empirical merger investigations. It has also supported the growing use of agent-based modelling in understanding economic phenomena, which enabled us to create a networked model capable of investigating the dynamic effect of merger activity. This was previously unseen in the literature.

It is hoped that in the long term, this research will be further developed and calibrated using real-world data, and act as a useful tool in determining future merger regulation.

Appendix

Available on request are:

- **Spatial Mobility in the Formation of Agent-Based Economic Networks**
  Submitted to the 17th International Conference on Computing in Economics and Finance (CEF 2011), and was presented in June 2011.
- **Competition and Cascades in the Financial Markets**
  Submitted to the 18th International Conference on Computing in Economics and Finance (CEF 2012), and was presented in June 2012.
- **Competition and Cascades in the Financial Markets**
  Published in Wiley's Intelligent Systems in Accounting, Finance and Management journal in December 2012.
- **Stabilising Merger Waves**
  Submitted to the 19th International Conference on Computing in Economics and Finance (CEF 2013), and was presented in July 2013.

Bibliography

Agrawal, A. and Jaffee, J. F. (2000). The post-merger performance puzzle. *Advances in Mergers and Acquisitions*, (1):7–41.

Agrawal, A., Jaffee, J. F., and Mandelker, G. N. (1992). The post-merger performance of acquiring firms: A re-examination of an anomaly. *Journal of Finance*, 47(4):1605–1621.

Ahern, K. R. and Harford, J. (2013). The importance of industry links in merger waves. *Journal of Finance, forthcoming.*

Akhavein, J. D., Berger, A. N., and Humphrey, D. B. (1997). The effects of megamergers on efficiency and prices: Evidence from a bank profit function. *Review of Industrial Organization*, 12(1):99–139.

Akhigbe, A., Borde, S. F., and Whyte, A. M. (2000). The source of gains to targets and their industry rivals: Evidence based on terminated merger proposals. *Financial Management*, 29(4):101–118.

Alexandridis, G., Fuller, K. P., Terhaar, L., and Travlos, N. G. (2013). Deal size, acquisition premia and shareholder gains. *Journal of Corporate Finance*, 20:1–13.

Anthes, G. H. (2003). Agents of change: Software agents tame supply chain complexity and optimise performance. `http://www.computerworld.com/s/article/77855/Agents_of_Change`.

Arthur, W. B. (1999). Complexity and the economy. *Science*, 284(5411):107–109.

Arthur, W. B. (2005). Out-of-equilibrium economics and agent-based modelling. Working Paper 2005-09-037, Santa Fe Institute.

Asquith, P. (1983). Merger bids, uncertainty, and stockholder returns. *Journal of Financial Economics*, 11(14):51–83.

Asquith, P., Bruner, R. F., and Mullins, D. W. (1983). The gains to bidding firms from merger. *Journal of Financial Economics*, 11:121–139.

Bator, F. M. (1958). The anatomy of market failure. *The Quarterly Journal of Economics*, 72(3):351–379.

Beinhocker, E. (2007). *The Origin of Wealth: Evolution, Complexity, and the Radical Remaking of Economics.* Random House Business.

Bendeck, Y. M. and Waller, E. R. (2007). Bank acquisition announcements and intra-industry effects. *Journal of Business and Economics Research*, 5:15–22.

Bernad, C., Fuentelsaz, L., and Gomez, J. (2010). The effect of mergers and acquisitions on productivity: An empirical application to spanish banking. *Omega*, 38(5):283–293.

Bernile, G., Lyandres, E., and Zhdanov, A. (2011). A theory of strategic mergers. *Review of Finance*, 16:517–575.

Bianchi, C., Cirillo, P., Gallegati, M., and Vagliasindi, P. A. (2007). Validating and calibrating agent-based models: A case study. *Journal of Computational Economics*, 30:240–264.

Blume, L. E. and Easley, D. (2008). Market competition and selection. In Durlauf, S. N. and Blume, L. E., editors, *The New Palgrave Dictionary of Economics*, volume 2nd Edition. Palgrave Macmillan.

Bradley, M. and Jarrell, G. (1988). Comment. *Knights, Raiders and Targets*, pages 252–259.

CC (2013). The Competition Commission. `http://www.competition-commission.org.uk`.

Chu, T.-Q., Drogoul, A., Boucher, A., and Jucker, J.-D. (2012). Towards a Methodology for the Participatory Design of Agent-Based Models. In *Principles and Practice of Multi-Agent Systems*, pages 428–442. Springer Berlin Heidelberg.

Clougherty, J. A. and Duso, T. (2008). The impact of horizontal mergers on rivals: Gains to being left outside the merger. *Journal of Management Studies*, 46(8):1365–1395.

CRISIS (2011). Complexity Research Initiative for Systemic InstabilitieS. `http://www.crisis-economics.eu/`.

Dafny, L. S. (2005). Estimation and identification of merger effects: An application to hospital mergers. Working Paper 11673, National Bureau of Economic Research.

Dawnay, E. and Shah, H. (2005). Behavioural economics: Seven principles for policy makers. Discussion paper, New Economics Foundation.

De Nicolo, G. and Kwast, M. L. (2002). Systemic risk and financial consolidation: Are they related? IMF Working Paper 02/55, International Monetary Fund.

Durlauf, S. N. (2012). Complexity, economics and public policy. *Politics, Philosophy and Economics*, 11(1):45–75.

Dutta, P. (1999). *Strategies and Games: Theory and Practice.* MIT Press.

Eckbo, B. E. (1983). Horizontal mergers, collusion, and stockholder wealth. *Journal of Financial Economics*, 11:241–273.

Ehrhardt, G. C. M. A., Marsili, M., and Vega-Redondo, F. (2006). Phenomenological models of socioeconomic network dynamics. *Physical Review E*, 74(3):036106.

EURACE (2006). The EURACE Project. `http://www.eurace.org/`.

Farmer, J. D. and Foley, D. (2009). The economy needs agent-based modelling. *Nature*, 460:685–686.

Filbien, J.-Y. and Kooli, M. (2011). Gains to merging firms and their rivals: Evidence from canada. In *Proceedings of the International Conference of the French Finance Association*, Montpellier, France.

Firth, M. (1980). Takeovers, shareholder returns, and the theory of the firm. *Quarterly Journal of Economics*, 94(2):235–60.

Franks, J. R., Harris, R. S., and Titman, S. (1991). The post-merger shareprice performance of acquiring firms. *Journal of Financial Economics*, 29:81–96.

Gaffeo, E., Gallegati, M., and Gostoli, U. (2012). An agent-based proof of principle for walrasian macroeconomic theory. CEEL Working Papers 1202, Cognitive and Experimental Economics Laboratory, Department of Economics, University of Trento, Italia.

Gartner, D. L. and Halbheer, D. (2009). Are there waves in merger activity after all? *International Journal of Industrial Organization*, 27:708–718.

GDE (2011). Global dependency explorer. `http://cephea.de/gde`.

Gorton, G., Kahl, M., and Rosen, R. J. (2009). Eat or be eaten: A theory of mergers and firm size. *Journal of Finance*, 64(3):1291–1344.

Gowrisankaran, G. (1999). A dynamic model of endogenous horizontal mergers. *RAND Journal of Economics*, 30:56–83.

Gual, J. (2007). Time to rethink merger policy? *Competition Policy International*, 3(1).

Gugler, K., Mueller, D. C., and Weichselbaumer, M. (2008). The determinants of merger waves: An international perspective. Discussion Paper 08-076, Zentrum for Europische Wirtschaftsforschung.

Gugler, K., Mueller, D. C., Yurtoglu, B. B., and Zulehner, C. (2003). The effects of mergers: An international comparison. *International Journal of Industrial Organisation*, 21:625–653.

Harford, J. (2005). What drives merger waves? *Journal of Financial Economics*, 77(3):529–560.

HayGroup (2007). Dangerous liaisons: M & A - The integration game. White paper, The Hay Group. `http://www.haygroup.com/`.

Haynes, M. and Thompson, S. (1999). The productivity effects of bank mergers: Evidence from the uk building societies. *Journal of Banking and Finance*, 23(5):825–846.

Higson, C. and Elliot, J. (1998). Post takeover returns: The UK evidence. *Journal of Empirical Finance*, 5(1):27–46.

Holland, J. H. and Miller, J. H. (1991). Artificial adaptive agent in economic theory. *The American Economic Review*, 81(2):365–370.

Hombert, J., Pouyet, J., and Schutz, N. (2009). Anticompetitive Vertical Mergers Waves. Working Paper 55, Department of Economics, Paris School of Economics.

Horgan, J. (1995). From complexity to perplexity. *Scientific American*, 272:74–79.

Horn, H. and Persson, L. (2001). Endogenous mergers in concentrated markets. *International Journal of Industrial Organization*, 19(8):1213–1244.

Horn, H. and Stennek, J. (2007). The political economy of EU merger control: Small vs. large member states. *Contributions to Economic Analysis*, 282:259–285.

Jackson, M. O. (2003). A survey of models of network formation: Stability and efficiency. Technical Report 0303011, The Economics Working Paper Archive.

Jarrell, G. A. and Poulsen, A. B. (1989). The returns to acquiring firms in tender offers: Evidence from three decades. *Financial Management*, 18(3):12–19.

Jordan, P. R., Kiekintveld, C., and Wellman, M. P. (2007). Empirical game-theoretic analysis of the TAC supply chain game. In *Proceedings of the 6th international joint conference on Autonomous agents and multiagent systems*, pages 1188–1195, Richland, SC. International Foundation for Autonomous Agents and Multiagent Systems.

Jovanovic, B. and Rousseau, P. L. (2002). The Q-theory of mergers. Working Paper 8740, National Bureau of Economic Research, Inc.

Kleijnen, J. P. C. (1995). Verification and validation of simulation models. *European Journal of Operational Research*, 82(1):145–162.

Kleinert, J. and Klodt, H. (1983). Causes and consequences of merger waves. Working Papers 1092, Kiel Institute for the World Economy.

Lambrecht, B. M. (2004). The timing and terms of mergers motivated by economies of scale. *Journal of Financial Economics*, 72:41–62.

Lichtenberg, F. R. and Siegel, D. (1987). Productivity and changes in ownership of manufactoring plants. *Brookings Papers on Economic Activity*, 3:643–673.

Lipton, M. (1979). Takeover bids in the targets boardroom. *International Journal of Industrial Organization*, 27:708–718.

Lipton, M. (2006). Merger waves in the 19th, 20th and 21st centuries. The Davies Lecture, Osgoode Hall Law School, York University. September, 2006.

Loderer, C. and Martin, K. (1992). Postacquisition performance of acquiring firms. *Financial Management*, 21(3):69–79.

Magenheim, E. B. and Mueller, D. C. (1988). Are acquiring firm shareholders better off after an acquisition? In *Knights, Raiders and Targets*, pages 171–193. Oxford University Press.

Maksimovic, V., Phillips, G., and Yang, L. (2011). Private and public merger waves. Working paper, University of Maryland, NBER and UCLA.

Malatesta, P. H. (1983). The wealth effect of merger activity and the objective functions of merging firms. *Journal of Financial Economics*, 12(1-4):155–181.

Malmendier, U., Moretti, E., and Peters, F. (2011). Winning by losing: Evidence on overbidding in mergers. Discussion Papers 11-101/2/DSF25, Tinbergen Institute.

Malmendier, U., Moretti, E., and Peters, F. (2012). Winning by losing: Evidence on the long-run effects of mergers. Working Paper 18024, National Bureau of Economic Research.

Mandelker, G. (1974). Risk and return: The case of merging firms. *Journal of Financial Economics*, 1:303–335.

Mantravadi, P. and Reddy, A. V. (2008). Post-merger performance of acquiring firms from different industries in india. *International Research Journal of Finance and Economics*, 22:192–196.

Marks, R. (2012). Analysis and synthesis: Multi-agent systems in the social sciences. *The Knowledge Engineering Review*, 27:123–136.

Matos, N., Sierra, C., and Jennings, N. (1998). Determining successful negotiation strategies: An evolutionary approach. In *Proceedings of the International Conference on Multi Agent Systems, 1998.*, pages 182–189.

McGowan, L. and Cini, M. (1999). Discretion and politicization in EU competition policy: The case of merger control. *Governance: An Internationl Journal of Policy and Administration*, 12(2):175–200.

Min, H. and Zhou, G. (2002). Supply chain modeling: Past, present and future. *Computers & Industrial Engineering*, 43(12):231–249.

Mishkin, F. S. (1999). Financial consolidation: Dangers and opportunities. *Journal of Banking & Finance*, 23(2-4):675–691.

Moeller, S. B., Schlingermann, F. P., and Stulz, R. M. (2004). Firm size and the gains from acquisitions. *Journal of Financial Economics*, 73(2):201–228.

Mueller, D. C. (1985). Mergers and market share. *Review of Economics and Statistics*, 47(2):259–267.

Mullin, G. L., Mullin, J. C., and Mullin, W. P. (1995). The competitive effects of mergers: Stock market evidence from the US steel dissolution suit. *The RAND Journal of Economics*, 26(2):314–330.

Neary, J. P. (2007). Cross-border mergers as instruments of comparative advantage. *Review of Economic Studies*, 74(4):1229–1257.

Nilssen, T. and Sorgard, L. (1998). Sequential horizontal mergers. *European Economic Review*, 42(9):1683–1702.

Niu, J., Cai, K., Parsons, S., Gerding, E., and McBurney, P. (2008). Characterizing effective auction mechanisms: insights from the 2007 TAC market design competition. In *Proceedings of the 7th international joint conference on Autonomous agents and multiagent systems - Volume 2*, AAMAS '08, pages 1079–1086, Richland, SC. International Foundation for Autonomous Agents and Multiagent Systems.

Norback, P.-J. and Persson, L. (2007). Investment liberalization: Why a restrictive cross-border merger policy can be counterproductive. *Journal of International Economics*, 72(2):366–380.

Ormerod, P., Trabatti, M., Glass, K., and Colbaugh, R. (2007). Explaining social and economic phenomena by models with low or zero cognition agents. In *Complexity Hints for Economic Policy*, New Economic Windows, pages 201–210. Springer Milan.

PA (2011). The PA Statistics Yearbook 2011. `http://www.publishers.org.uk`.

Pergler, M. and Lamarre, E. (2009). Upgrading your risk assessment for uncertain times. McKinsey Working Papers on Risk 9, McKinsey.

Qiu, L. D. and Zhou, W. (2005). Merger waves: A model of endogenous mergers. *RAND Journal of Economics*, 38(1):214–226.

Rau, P. R. and Vermealen, T. (1998). Glamour, value and the post-acquisition performance. *Journal of Financial Economics*, 49(2):223–253.

Ravenscraft, D. J. and Scherer, F. M. (1989). The profitability of mergers. *International Journal of Industrial Organization*, 7(1):101–116.

Resende, M. (1996). Mergers and acquisitions in the UK: A disaggregated analysis. *Applied Economics Letters*, 3(10):637–40.

Resende, M. (1999). Wave behaviour of mergers and acquisitions in the UK: A sectoral study. *Oxford Bulletin of Economics and Statistics*, 61(1):85–94.

Resende, M. (2008). Mergers and acquisitions waves in the UK: A markov-switching approach. *Applied Financial Economics*, 18(13):1067–1074.

Review, T. T. (2009). A regulatory response to the global banking crisis. Discussion Paper DP 09/2 ref. 003299, FSA.

Rezitis, A. N. (2008). Efficiency and productivity effects of bank mergers: Evidence from the Greek banking industry. *Economic Modelling*, 25(2):236–254.

Rhoades, S. A. (1998). The efficiency effects of bank mergers: An overview of case studies of nine mergers. *Journal of Banking and Finance*, 22(3):273–291.

Rhodes-Kropf, M., Robinson, D. T., and Viswanathan, S. (2005a). Valuation waves and merger activity: The empirical evidence. *Journal of Financial Economics*, 77(3):561–603.

Rhodes-Kropf, M., Robinson, T., and Viswanathan, S. (2005b). Valuation waves and merger activity: The empirical evidence. *Journal of Financial Economics*, 77(3):561–603.

Roth, A. E. (2002). The economist as engineer: Game theory, experimentation and computation as tools for design economics. *Econometrica*, 70:1341–1378.

Russell, S. and Norvig, P. (2010). *Artificial Intelligence: A Modern Approach*. Prentice Hall.

Shleifer, A. and Vishny, R. W. (2003). Stock market driven acquisitions. *Journal of Financial Economics*, 70(3):295–311.

Shughart, W. F. and Tollison, R. D. (1984). The random character of merger activity. *Journal of Economics*, 15(4):200–209.

Sloman, J. and Hinde, K. (2007). *Economics for Business*. Prentice Hall.

Sorensen, D. E. (2000). Characteristics of merging firms. *Journal of Economics and Business*, 52(5):423–433.

Stephanou, C. (2009). Smaller but safer? CrisisResponse Note 3, The World Bank Group.

Swarminathan, J. M., Smith, S. F., and Sadeh, N. M. (1998). Modeling supply chain dynamics: A multiagent approach. *Decision Sciences*, 29(3):607–632.

TAC (2013). The trading agent competition. `http://tac.sics.se/`.

TAC/AA (2013). TAC Ad Auctions. `http://aa.tradingagents.org/`.

Tarullo, D. K. (2011). Industrial organization and systemic risk: An agenda for further research. Conference on the Regulation of Systemic Risk, Federal Reserve Board.

Tesfatsion, L. (2000). Agent-based computational economics: A brief guide to the literature. Working paper, Department of Economics, Iowa State University.

Tesfatsion, L. (2005). Agent-based computational economics: A constructive approach to economic theory. Working paper, Department of Economics, Iowa State University.

Town, R. J. (1992). Merger waves and the structure of merger and acquisition time-series. *Journal of Applied Econometrics*, 7(S1):S83–S100.

Toxvaerd, F. (2008). Strategic merger waves: A theory of musical chairs. *Journal of Economic Theory*, 140:1–26.

Treasury, H. (2010). A new approach to financial regulation: Judgement, focus and stability. Technical Report CM7874, HM Treasury.

Tuch, C. and O'Sullivan, N. (2007). The impact of acquisitions on firm performance: A review of the evidence. *International Journal of Management Reviews*, 9(2):141–170.

van den Bergh, W. M., Boer, K., de Bruin, A., Kaymak, U., and Spronk, J. (2002). On intelligent agent-based analysis of financial markets. Technical report, Faculty of Economics, Erasmus University, Rotterdam.

Various (2013). Economic integration. `http://en.wikipedia.org/wiki/Economic_integration`.

WB (2013). The world bank. `http://data.worldbank.org`.

Wellman, M. P., Reeves, D. M., Lochner, K. M., and Suri, R. (2005). Searching for Walverine 2005. In *Agent-Mediated Electronic Commerce. Designing Trading Agents and Mechanisms*, volume 3937 of *Lecture Notes in Computer Science*, pages 157–170. Springer Berlin Heidelberg.

Windrum, P., Fagiolo, G., and Moneta, A. (2007). Empirical validation of agent-based models: Alternatives and prospects. *Journal of Artificial Societies and Social Simulation*, 10(2):8.

Wooldridge, M. (2009). *An Introduction to MultiAgent Systems*. Wiley.

Yeung, C. S. K., Poon, A. S. Y., and Wu, F. F. (1999). Game theoretical multi-agent modelling of coalition formation for multilateral trades. *IEEE Transactions on Power Systems*, 14(3):929–934.

Zedan, C. (2012). Competition, cascades and connectivity: A multi-market model of endogenous mergers. Presentation at 18th Annual Conference on Computing in Economics and Finance, Prague, Czech Republic. July 2012.

Zedan, C., Ianni, A., and Bullock, S. (2011a). Competition and cascades in the financial markets: An agent-based nework model of endogenous mergers. Presentation at 5th International Conference on Computational and Financial Econometrics, London, UK. December 2011.

Zedan, C., Ianni, A., and Bullock, S. (2011b). Connection, competition and contagion in the financial markets. Poster at 1st Student Conference in Complexity Science, Winchester, UK. August 2011.

Zedan, C., Ianni, A., and Bullock, S. (2012a). Competition, cascades and connectivity: Modelling the economy as a complex system. Poster at University of Southampton 2012 Postgraduate Research Showcase, Southampton, UK. May 2012.

Zedan, C., Ianni, A., and Bullock, S. (2012b). Competition, cascades and connectivity: Modelling the economy as a complex system. Poster at 2nd Student Conference in Complexity Science, Gloucester, UK. August 2012.

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

Zedan, C., Ianni, A., and Bullock, S. (2013b). Stabilizing merger waves. Poster at 3rd Student Conference in Complexity Science, Oxford, UK. August 2013.

Zedan, C., Ianni, A., and Bullock, S. (2013c). Stabilizing merger waves: An agent-based network model of market stability. Poster at University of Southampton 2013 Postgraduate Research Showcase, Southampton, UK. May 2013.

Zedan, C., Ianni, A., and Bullock, S. (2013d). Stabilizing merger waves: An agent-based network model of market stability. Presentation at 19th Annual Conference on Computing in Economics and Finance, Vancouver, Canada. July 2013.