Essays on the role of expectation dynamics, social influence and technology diffusion on efficiency, growth and inequality

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“*Das soziale Geschehen ist eine einheitliche Erscheinung. Aus seinem großen Strom hebt die ordnende Hand des Forschers die wirtschaftlichen Tatsachen gewaltsam heraus*”.

“The social process is really one indivisible whole. Out of its great stream the classifying hand of the investigator artificially extracts economic facts”. (Schumpeter, 1912, p. 1, transl. 1934)

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DOCTORAL DISSERTATION IN ECONOMICS

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Expectations and Social Influence Dynamics in Economics

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Contents

Chapter 1

Introduction

In recent years, the economy has suffered two major turmoils, namely the 2007 Great Recession and the COVID-19 induced economic crisis. The current global pandemic is unfolding its implications on an economic environment that was already showing several weaknesses. Increasing inequality, rising concentration, decreased business dynamism and lack of investment characterize modern advanced economies, especially the US[1]. Despite some of the mentioned features, particularly economic crises, having long marked the development of capitalistic economies, the economic system and its institutions are continuously evolving in an intertwined dynamics, providing constant challenges to researchers who aim at interpreting phenomena that can only be observed on their surface.

According to the approach known as "complexity economics" (Arthur, 2021; Hommes, 2006), the economy can be thought of as a complex system comprising heterogeneous agents, such as individuals and firms, interacting locally in specific institutional frameworks. Furthermore, differently from what is assumed in standard models based on the notion of full rationality, individuals are boundedly rational, meaning that they adopt heuristics and rules of thumb in order to adapt to a complex environment. According to this view, even the simplest microeconomic behavior, because of interactions, externalities and feedback effects, can generate complex and unexpected properties at the macroeconomic level. This conception of the economy, based on the notion of complexity, underlies heterogeneous agent models, which have been increasingly applied to a variety of topics in macroeconomic research (Dawid and Delli Gatti, 2018).

Thus far, my approach to the study of economics has been strongly shaped by this

[1] Cfr. Syverson (2019). On concentration: Crouzet and Eberly (2019), De Loecker et al. (2020); on decreased business dynamism: Decker et al. (2016); on lack of investment: Gutiérrez and Philippon (2016); on inequality: Piketty (2014), Karabarbounis and Neiman (2014), Atkinson (2015).

complexity perspective and I have become increasingly convinced that in order to unveil and fully understand the most recent economic developments, one has to combine a detailed granular analysis – which looks into what firms and individuals specifically do under different institutional environments, and how their behavior changes over time – with a study of the relevant macroeconomic tendencies. The insights gained from the analysis conducted at the microeconomic level are instrumental to the understanding of what happens at more aggregated levels and vice versa.

This thesis adopts multiple approaches aimed at capturing relevant mechanisms operating at the disaggregated level and then studying their implications at different levels of aggregation which, in turn, affect the microeconomic behavior of agents. In particular, based to varying degrees on the notion of complexity, the present dissertation reflects the intention of understanding a range of macroeconomic phenomena, namely the interaction between financial markets and the real economy, economic fluctuations and the tendency towards rising concentration, inequality and stagnation.

Concerning the behavior of individuals and, in particular, their decision making processes, empirical and theoretical research in various fields has demonstrated that decisions are the result of the integration of many elements, such as rational and emotional inputs, along with the causal models learned from the environment and the observation of the actions of others[2]. These subjective evaluations, which vary between individuals, result in the heterogeneity of opinions and actions.

These findings on heterogeneous beliefs have been increasingly incorporated in theoretical and empirical models aiming to assess their impact on the economy. However, quite often, these models focus solely either on the real economy or financial markets. Motivated by reasons of simplicity and tractability, this focus causes the interactions existing between beliefs and decisions formed in the two sectors to be somewhat neglected, when there is, in fact, considerable evidence pointing to the inter-linkages between expectations in the financial markets and firms' decisions (Cfr. Stein, 1996; Baker and Wurgler, 2002; Baker et al., 2003). Indeed, these studies stress that, particularly in a context of separation between ownership and control, firms' managers are induced to take into account shareholders' interests and expectations, causing finance and production to become increasingly integrated with each other (Davis, 2018).

This is reflected, on the one hand, as studied by Lazonick and O'Sullivan (2000), in the shift in US corporate strategy, which has occurred in the past decades, from an orientation towards retaining corporate profits and reinvesting in corporate growth,

[2]Cfr., among others, in psychoanalysis and psychology: Simon (1990), Gigerenzer and Todd (1999), Tuckett (2012), Lerner et al. (2015); in neuroscience: Bechara et al. (2000); in sociology: Smelser (1998).

to one where firms are induced to downsize labor and distribute corporate earnings to shareholders. In other words, corporate governance, especially in the US, has been increasingly inspired by the principle of shareholder value. On the other hand, another influence from shareholders on firms' activity is via investor sentiment, defined by Baker and Wurgler (2007) as "a belief about future cash flows and investment risk", which is able to influence multiple decisions by firms, such as those regarding dividend distribution, share buybacks and investment (e.g. Baker and Wurgler, 2004; Baker et al., 2009).

With respect to the impact of investor sentiment on firms' investment decisions, empirical research has identified various mechanisms potentially able to explain the relationship that exists between an optimistic investor sentiment and the firm's decision to invest. The factors that have been most studied are the equity issuance hypothesis, the catering theory and the purely behavioral channel[3]. In particular, the equity issuance hypothesis states that overvaluation of stock price implies that the firm can issue equity more easily and that this equity can be employed for investment purposes. Alternatively, the catering channel, introduced by Stein (1996), assumes that rational managers cater to shareholders' expectations, even if biased, in order to maximize the stock price, implying that, in the presence of overvalued stocks, managers are induced to over invest, and vice versa. This theory has also been tested for other firms' decisions, such as dividend payments and changing the corporate name. Finally, the purely behavioral channel indicates that overoptimism/over pessimism potentially influence the expectations of all economic agent, including shareholders and managers, who might act according to their biased beliefs.

Testing these theories empirically is not a trivial matter, for measuring investor sentiment requires the ability to disentangle the accurate firm's evaluation from beliefs not based on fundamentals. Typically, investor sentiment is measured by employing proxies derived from the likes of the market-to-book ratio, or the Tobin's Q, which are based on the firm's stock price and the book values of equity or assets[4]. On the other hand, innovative methods based on text analysis have recently been increasingly employed to measure investor optimism and pessimism. The purpose of these methods is to capture the prevalent attitude of agents towards the economy or specific firms, by applying text analysis to various sources, such as news stories. When read by large audiences, news articles can amplify and spread existing beliefs; therefore, measuring the tone employed in such news can provide information on investor sentiment (cfr. Tetlock, 2007; Tetlock et al., 2008).

[3]Cfr. Baker and Wurgler (2002), Stein (1996), Baker and Wurgler (2013).

[4]See, for example, Dong et al. (2006), Petmezas (2009).

I myself adopt this approach in the second chapter of this thesis, which aims at investigating the relationship between investor sentiment, measured by applying text analysis to firm-specific news by the media conglomerate Thomson Reuters, and merger and acquisition (M&A) activity. Firms increasingly employ M&As as a means of expansion alternative to investment; indeed, the last decades have seen an ever-increasing trend in the number and value of deals, making it highly important and relevant to comprehend the determinants of M&As (Brennan, 2016). Empirical literature in this field has illustrated that M&A activity occurs in clusters correlated with financial indexes, which provides support for the idea that there exists a strong interaction between financial market fluctuations and firms' decisions to pursue M&As[5]. In my paper, I find that investor sentiment is positively correlated with the probability of firms announcing acquisition deals. Furthermore, results indicate that the main factor accounting for the positive relationship is the purely behavioral channel, which posits that expectations of both managers and shareholders are potentially subject to bias.

The empirical results presented in the second chapter of this thesis highlight the key role played by heterogeneous beliefs in investment decisions, providing a strong motivation to investigate the issue theoretically. In the context of a real economy, one important feature of investment decisions, besides their dependency on expectations, is their complementarity. In particular, investment of one firm constitutes demand for other firms, and *vice versa*. This generates strategic complementarity and, as a consequence, a certain level of coordination of expectations is required in order for demand and supply to be in equilibrium. In a context of radical uncertainty, where individuals' expectations cannot be based solely on mathematical calculations but are partly influenced by subjective evaluations, frictions in coordination might emerge.

Indeed, one of the many contributions of Keynes (1936), if reformulated in terms of frictional coordination, indicates that macroeconomic outcomes partially depend on the ability of demand and supply agents to coordinate their expectations and decisions in a context of radical uncertainty. This idea has been further developed by Angeletos and coauthors in a series of papers[6], aiming at incorporating these specific Keynesian features in the Real Business Cycle (RBC) framework in order to study the impact of coordination issues on economic fluctuations. Their findings show that changes in the sentiments of individuals, even if unjustified by facts, lead to demand-driven economic fluctuations. This constitutes a novel result, as in RBC models the business cycle is generally driven by shocks to fundamental factors, such as technology, or households' preferences. However, given that the sentiment fluctuations are generated through

[5] See, among others, Rosen (2006), Gugler et al. (2012).

[6] E.g. Angeletos and La'O (2013), Angeletos et al. (2018), Angeletos et al. (2020).

exogenous shocks, the attention is essentially placed on the consequences of such sentiments on the economic system, rather than on their causes. In other words, the modelers remain agnostic about the endogenous formation of these sentiments, which is not explicitly addressed.

On the contrary, within the literature on heterogeneous agent models, the process of expectation formation and its impact on the economy has been extensively investigated[7]. Contributions in this field have included various formalizations of heterogeneous expectations, depending on the considered framework. Models focusing on expectations of future prices usually aim at capturing the role of fundamentalist, trend-following, and, to a lesser extent, optimistic and pessimistic agents (among others, Lux, 1995; Brock and Hommes, 1998). Moreover, a fairly extensive literature has developed models based on the New Keynesian framework incorporating optimistic and pessimistic beliefs of future output and inflation (e.g. De Grauwe, 2011; Anufriev et al., 2013).

However, despite the richness of the contributions in this field, a feature of expectation formation that has not been as extensively studied is the role of interactions among individuals and, in particular, how agents are induced to imitate each other's beliefs and actions. The importance of social influence in opinion formation finds strong support in many fields of research. In particular, it has been shown that the need to conform to others has both informational and normative motivations, the former arising from the goal to form a correct interpretation of reality and the latter from the desire for social approval[8].

The lack of reliable information and the need to guess the beliefs of others, which constitute the essential features of an economy characterized by frictional coordination, appear to amplify the role of social influence in the economic system. Therefore, in my view, these issues require further investigation. Indeed, I engage in this very task in the third chapter of the present thesis, by incorporating endogenously-emerging heterogeneous beliefs, which depend on social influence and economic outcomes, in the islands model proposed by Angeletos and La'O (2013) based on the notion of frictional coordination. The principal question addressed is whether social influence, i.e. the impact of other agents' beliefs on individual expectations, might act as a coordination device in the economy. The findings indicate that social influence has a non-monotonous impact on the efficiency of economic outcomes and, therefore, that it can improve the ability of agents to coordinate on better equilibria if within a certain range of values.

The second chapter of this thesis, while providing empirical motivation for the

[7]Cfr. the literature review by Hommes (2006).

[8]Cfr. Cialdini and Goldstein (2004), Flache et al. (2017).

analysis carried out in the third chapter, also led me to reflect on the recent trend of increasing concentration among firms. Indeed, the empirical analysis presented in the second chapter studies the mechanisms underlying how fluctuations in the market affect M&A activity, but the causes and implications of the ever increasing trend in M&A activity are left in the background. Yet, the increasing empirical relevance of the phenomenon suggests that significant transformations in industry concentration and market structure are taking place. In fact, M&As constitute one of the sources of rising concentration, for they imply, everything else being constant, that firms become larger and fewer[9]. Concentration levels since the early 1990s have witnessed an increase in more than 75% of US industries, where the Herfindahl-Hirschman Index has risen on average by 90% (Crouzet and Eberly, 2019; Grullon et al., 2019).

Along with a higher concentration, measured in terms of the number of firms active in specific sectors, advanced economies such as the US have witnessed an increase in ownership concentration. Fichtner et al. (2017) documents that, in the US, the three largest investment funds (BlackRock, Vanguard, and State Street), which adopt passive investment strategies, constitute the largest shareholder in 88% of S&P500 firms. Such dominant positions were particularly consolidated after 2008, when a significant amount of resources were shifted from active towards passive investment strategies. Although the implications of the increase of shares in the hands of passive investment funds on firms' corporate governance are still under debate[10], this evidence suggests that, in advanced economies, a tendency towards the 'centralization' of capital in the hands of fewer large investors is in operation[11].

Furthermore, it has been argued that the process of rising concentration has been accompanied by increasing markups (De Loecker et al., 2020) and stock prices, which partly account for the widespread rise in inequality observed in several countries[12]. Barkai (2020), for instance, stress that firms operating in more concentrated industries have experienced extraordinary high profit rates. Moreover, Gutiérrez and Philippon (2017) documents the decline in investment levels and innovation activity, which has especially occurred in concentrating industries and is connected to the long-lasting

[9] Cfr. Affeldt et al. (2021).

[10] In this respect, there are opposing views on incentives and possibilities to actively exert shareholder power. On the one hand, it is argued that since passive investors cannot exit from their investment in firms' stocks, they have little shareholder power. On the other hand, the impossibility of exiting itself increases the incentives to actively influence corporations. Fichtner et al. (2017) find that the three largest investment funds, which they call "the Big Three", follow a centralized corporate governance strategy employing coordinated voting efforts, although it also appears that they generally vote in line with firms' management.

[11] Hilferding (1910) presents an extensive analysis of the phenomenon of capital centralization that occurred in the twentieth century.

[12] See Stiglitz (2012) and Piketty (2014).

decline in average output growth, which decreased from 3.7% between 1947-1980 to 2.7% between 1980-2017 (Stiglitz, 2019).

The consequences of the enhanced market power stemming from rising concentration on production have been investigated by Sylos Labini (1967), while studying the transformation of the advanced economies during the twentieth century. According to Sylos Labini's view, the changing pricing behavior of firms which marked the transition from a competitive economy towards an oligopolistic market structure, has implications on production and growth. In particular, in the competitive economy, in the presence of more or less constant nominal earnings, technical progress manifests itself in decreasing prices, allowing the fruits of technical progress to be absorbed by increasing real demand levels. In an oligopolistic economy, prices instead acquire a downward rigidity[13]; hence, if nominal earnings adjust at a slower pace than prices, real demand might, in fact, decrease, contributing to a tendency towards stagnation, weak development and inequality. From this analysis, Sylos Labini concludes that in an oligopolistic economy technical progress, which renders part of the workforce unnecessary, has to be compensated for by additional sources of demand.

In Steindl (1976), the author studies the phenomenon of rising concentration and its implications on economic growth, by stressing the role of firms' capacity utilization. In particular, Steindl posits that larger firms, in order to push weaker competitors out of the market, adopt more aggressive strategies and increase their capacity utilization to produce more at lower prices. Hence, more competition might bring about higher concentration levels. However, once the economy crosses a certain level of concentration where even the weakest firms are quite large, it becomes more difficult for larger firms to continue to aggressively compete. Therefore, the sector might reach an equilibrium characterized by high concentration and low competition, whereby firms operate with lower rates of capacity utilization, bringing about a decline in investment.

In my view, these analyses, despite being conducted in the absence of any formal models, are of great value for understanding the long-run trends that have been characterizing the recent economic developments in advanced economies, namely rising inequality, higher concentration and the long-lasting decline in real output growth. According to the above-mentioned recent empirical research, these phenomena appear to be interrelated and a lively debate among economists is currently taking root on these issues; however, a comprehensive theoretical framework is yet to be developed (Syverson, 2019).

The fourth chapter of this thesis, which is coauthored with Enrico Turco, contributes

[13] The reason, according to Sylos Labini (1967), lies not only in higher concentration, but also in the process of unionization and product differentiation.

to filling this gap by combining insights provided by the macroeconomic analyses proposed in particular by Sylos Labini and Steindl with contributions in the literature on agent-based models and innovation. Our objective is to propose a theoretical framework able to account for rising concentration, increasing inequality and the decline in output growth, where higher market shares on the one hand reflect greater productivity and on the other imply greater market power, exploited through rising markups. For this purpose, we adopt an agent-based approach that allows us to investigate how the behavior of firms, under certain conditions, might affect the evolution of market structure towards an oligopolistic economy.

Overview of the thesis

This thesis addresses a range of issues in macroeconomics, namely, the relationship between the real economy and expectations formed in financial markets, endogenously emerging heterogeneous expectations, and the interaction among rising concentration, increasing inequality and the tendency towards stagnation. The approach adopted, based on the notion of complexity, combines the analysis of specific features and mechanisms characterizing the behavior of agents with the study of their impact on the economy.

In particular, the second chapter of this thesis investigates the relationship between firm-specific investor sentiment, measured by applying text analysis to news stories published by Thomson Reuters, and merger and acquisition deals announced by US-listed companies between 1997 and 2018. I find that a more positive investor sentiment increases the probability of firms announcing acquisitions but, by studying a number of potential reasons capable of explaining such a relationship, I do not find that the overvaluation hypothesis or the catering theory are able to account for the impact of investor sentiment on acquisition announcements. Instead, the results obtained by studying short- and long-run stock market reaction to merger announcements, and its relationship with investor sentiment, show a positive short-run correlation which is reversed in the long-run. These results provide evidence for the overoptimism theory of mergers, which states that, in periods characterized by more optimistic investor sentiment, managers are more induced to pursue acquisitions and that these are better perceived by the stock market, even though they perform worse in the long-run.

Chapter 3 incorporates endogenously emerging beliefs, with an emphasis on the role of social influence, into a stylized islands model, characterized by uncertainty and strategic complementarity generating frictional coordination. Individuals can have pessimistic, neutral or optimistic beliefs and can change these beliefs over time following a switching mechanism, driven by both economic outcomes and social influence. In such a framework, I study the emergent dynamics in order to assess the impact that social influence has on agents' coordination, economic stability and welfare. The results indicate that in the absence of social influence rational expectations are unstable and agents coordinate over time in a pessimistic and highly inefficient stationary state in which output and welfare are below the rational expectations equilibrium. As the importance of social influence grows, the steady state becomes even more pessimistic and, as it crosses a certain threshold, additional equilibria emerge and the economy may converge to the rational expectations steady state, in which welfare is highest, or to a much more optimistic equilibrium, which is not necessarily more efficient. Therefore, social influence might act as a coordination device, able to smooth the impact of uncertainty and individual incentives, with positive effects on welfare. The intuition is that, in the absence of social influence, firms are induced to lower their output in order to avoid excessive costs of production with respect to the unknown demand they will face on the market. As social influence takes values within a certain range, individuals are more likely to give less weight to individual incentives and imitate one another more, coordinating on better outcomes characterized by higher welfare.

By developing a macro agent-based model with endogenous technical change and heterogeneous vintages of machine tools, the fourth chapter[14] analyzes the underlying causes and consequences of the recent increase in market concentration. To address this question, we focus on the interplay of technical change and market power, and how this relates with income inequality and secular stagnation. In our view, the source of concentration lies in the fact that heterogeneous firms do not have equal access to capital-embodied innovations which we assume depends on the "knowledge gap", i.e., the difference between the degree of capital good's technical advancement and the firm's accumulated technological knowledge. The analysis shows that, in the absence of consistent knowledge spillovers and provided that capital goods remain considerably different from each other, technical progress generates systematic divergence in productivity across firms, leading to a reallocation of market shares towards more productive firms. Moreover, as the newly-emerging large firms seek to translate the enhanced market power into higher mark-ups, the resulting shift in the income distribution from wages to profits eventually undermines aggregate demand and growth. Yet, simulation experiments reveal that, in the absence of legal entry barriers, the imitation activity by capital good firms brings about a convergence among different techniques, which,

[14] Chapter 4 is the result of a joint work with Enrico Turco.

by reducing technological discontinuities, creates the conditions for a competitive and self-sustained growth process. Finally, a set of policy experiments is performed in order to shed light on those factors potentially able to halt the tendency towards stagnation.

The remainder of this thesis is organized as follows. The next section is titled 'Does Investor Sentiment Drive M&As?'; the work 'Endogenous Beliefs and Social Influence in a Simple Macroeconomic Framework' is presented in the third chapter. Finally, the analysis on 'Concentration, Stagnation and Inequality: an Agent-Based Approach' constitutes the fourth and final chapter. The above-mentioned chapters can be read independently, each providing an individual introduction, and conclusion. All referenced works appear in a common bibliography at the end of the thesis.

Chapter 2

Does Investor Sentiment Drive M&As?

2.1 Introduction

In this paper we investigate the relationship between investor sentiment, measured by applying text analysis to news stories published by Thomson Reuters, and merger and acquisition (M&A) deals performed by US-listed companies between 1997 and 2018. Investor sentiment can be defined as "a belief about future cash flows and investment risks that is not justified by the facts at hand" (Baker and Wurgler, 2007). According to a large number of studies discussed in the literature review, such beliefs might cause a firm's stock price to deviate from its fundamental level, generating a mispricing. Yet, measuring mispricing, as well as investor sentiment, is not an easy task. In fact, one needs to disentangle the portion of the firm's stock price reflecting relevant information from the other part reflecting beliefs not based on the firm's fundamentals. Studies generally rely on proxies based on the likes of market-to-book ratios and earnings per share[15]. However, a large literature has recently developed which aims at more directly capturing sentiment from the tone of news stories[16]. These studies apply text analysis to news from different sources and demonstrate that words expressing a positive or negative attitude account, beyond more traditional measures, for a large portion of price movements of stocks (and other assets) and that these price movements are reversed in the long-run, implying that they reflect sentiment rather than information.

We adopt this approach ourselves and measure investor sentiment by applying text

[15]With regard to non-firm-specific investor sentiment, a measure that is commonly employed is that developed by Baker and Wurgler (2007).

[16]Cfr., among others, Tetlock (2007), Tetlock et al. (2008), Garcia (2013) and Soo (2018).

analysis to a large sample of news articles published by the media conglomerate Thomson Reuters, with the assumption that the news reflects and amplifies certain beliefs and narratives about the economy and about individual companies. Indeed, Tuckett and Nikolic (2017) propose their Conviction Narrative Theory (CNT), where the role of narratives as ways to interpret and organize reality is emphasized, a simplified version of which was previously tested empirically by Tuckett et al. (2014). In particular, conviction narratives enable people to draw on the beliefs, causal models and rules of thumb that they learn from their environment, to identify opportunities that they deem worth acting upon and to feel sufficiently convinced about the anticipated outcomes to indeed act. The role of newspapers in sharing such narratives also depends on the size of the audience reached: the broader the coverage of the news source, the larger their impact on people's beliefs. Thomson Reuters, with over a thousand newspapers, 13 of which are in the top 15 newspapers by circulation globally, of course have a broad global reach. The company website provides the figure of 33 million unique monthly visitors to the website, with Thomson Reuters across all platforms being read each day by more than a billion people worldwide[17].

The investor sentiment measure is obtained as follows: once we have collected all the news articles written in English from 1996 to 2018, we link it to the US companies that are referred to therein, according to a number of criteria outlined below. Next, we compute the quarterly sum of the number of positive and negative words belonging to the dictionary developed by Loughran and McDonald (2012), which adapts The General Inquirer's Harvard-IV-4 classification dictionary[18] for economic contexts. According to numerous studies in psychology, such as the above-mentioned Tuckett and Nikolic (2017), distinguishing between rational and emotional elements of people's evaluations and choices is not meaningful, in that they are deeply interdependent, but here we nonetheless take the view that separating them is helpful in disentangling different economic theories. In fact, we ensure that our investor sentiment measure does not reflect information on firms' fundamentals[19]. The focus on words expressing a certain positive or negative attitude already allows us to avoid the incorporation of information bits; nevertheless, in order to obtain a variable which reflects as much as possible beliefs rather than information, we orthogonalize the measure with respect to a set of

[17] https://www.thomsonreuters.com/content/dam/openweb/documents/pdf/reuters-news-agency/fact-sheet/reuters-fact-sheet.pdf.

[18] This dictionary was developed by the Harvard University and contains a list of positive and negative words. It was used in the General Inquirer software, i.e. a program for processing natural language text with a focus on content analysis, developed in the 1960s at the Harvard Laboratory of Social Relations.

[19] We also conduct the analysis illustrated below by using a raw investor sentiment measure, and the results are similar in sign and significance.

firms' balance sheet information. Finally, since this sentiment index has both positive and negative values, and in our regressions the index is made to interact with other variables that can also take on negative values, we use the rank of the index value, which constitutes our investor sentiment measure.

Measuring investor sentiment and stock mispricing is interesting per se, in that their existence and implications call for alternatives to the Efficient Market Hypothesis (Fama, 1970). Indeed, by now there exists a broad consensus in the literature that investor sentiment can generate fluctuations in firms' stock prices[20] and this argument bears even more crucial implications if it is proven that such non-fundamental price fluctuations influence firms' decisions, hence affecting the real economy, rather than simply constituting a "sideshow" (Morck et al., 1990) confined to financial markets. The consequences of stock mispricing are addressed by a large number of authors; the literature on the determinants of M&As, in particular, has tried to shed light on the relationship between stock market movements and acquisitions. In fact, M&A activity occurs in clusters, also known as merger waves, which appear to follow financial indexes. Indeed, authors have found evidence of stock market movements correlating with several characteristics of such form of firms' investments. For example, Rosen (2006) documents the existence of a stock market momentum, finding that stock market reaction to a merger announcement is better in times of hot financial markets. Furthermore, Shleifer and Vishny (2003) and Rhodes-Kropf et al. (2005) offer theoretical models showing that the bidder firms' overvaluation relative to the target firm drives stock-financed acquisitions. The role of firms' overvaluation is also studied by Dong et al. (2006) and Gugler et al. (2012), who provide support for a positive correlation between the overvaluation of a firm's stock and the firm's likelihood of pursuing M&As.

In this paper we investigate potential explanations for the relationship between investor sentiment, measured as briefly illustrated above, and M&As. More specifically, we study what is the impact of investor sentiment on the probability of firms announcing a merger or an acquisition; in other words, whether a positive/negative belief about a specific company carries, respectively, a higher/lower probability of the firm announcing one or more M&As. We focus on announced mergers rather than completed deals because we are interested in the intention of companies to acquire other firms, rather than in the actual closing of a deal, which depends on a great number of additional factors. We find that, in different versions of the model, investor sentiment significantly (positively) affects the probability of firms announcing mergers or

[20] Cfr., among others, Baker and Wurgler (2007); Shiller (2015).

acquisitions. This implies that positive or negative attitudes towards the firm, reflected and/or amplified by the news, have an impact on the real activity of firms and, therefore, on the real economy. However, there might be different explanations for such a relationship, which we attempt to disentangle. First, let us assume that shareholders have biased expectations, unlike firms' managers, who have access to all the relevant information about their company and are rational. In this scenario, managers might be influenced by shareholders' biased expectations for various reasons. For example, the equity market timing hypothesis states that firms might exploit periods of overvaluation in order to issue equity at a more convenient price and exchange it for the real assets of other companies. Furthermore, the catering theory, which has not been studied in the M&A literature, suggests that firms' managers have incentives to cater to shareholders' expectations of the company's growth opportunities, even if those beliefs might be biased. Hence, in times of overoptimism, managers might pursue investment projects which are characterized by a negative net present value with the purpose of satisfying biased shareholders' expectations and maximizing the firm's stock price.

We investigate such potential factors and, according to our findings, both the equity market timing and the catering theories do not adequately explain the impact of sentiment on merger announcements. Indeed, we do not find evidence that managers rationally time their decisions based on shareholders' sentiment. There are various alternative hypotheses able to explain the positive relationship between investor sentiment and merger announcements. First, our measure of investor sentiment might capture relevant information about firms' growth opportunities rather than biased beliefs. In this case, the positive relationship would reflect the fact that higher investor sentiment implies the existence of growth opportunities that are exploited by firms acquiring other companies. Alternatively, the positive relationship between investor sentiment and M&A announcements might be explained by the overoptimism theory: positive investor sentiment, reflecting biased beliefs, is shared by investors and managers, who are willing to expand their business through M&As even though the firm's accurate evaluation would suggest otherwise. These hypotheses can be investigated by studying the short- and long-run stock market reaction to merger announcements (of completed deals) and their relationship with investor sentiment. In particular, the presence of a positive correlation between investor sentiment and short-run market reaction, which is reversed in the long-run, provides evidence for the overoptimism hypothesis, for it suggests that mergers announced in periods of high investor sentiment are evaluated better than others around announcement day, but that they perform worse in the long-run, when all the information has been incorporated and biases have been absorbed. This would imply that the higher probability of firms announcing more

M&As in periods of high investor sentiment is driven by overoptimism and constitutes over investment which in the long-run destroys value. Moreover, in the present framework, it would also point to our investor sentiment measure being able to capture beliefs rather than information. Alternatively, if the relationship between investor sentiment and stock market reaction is positive in the short-run and is not reversed in the long-run, this would indicate investor sentiment capturing growth opportunities, that are well exploited by managers and correctly evaluated by the market. This finding would be in line with the neoclassical theory of mergers that, as exposed in the literature review, states that acquisitions are generally made when there are potential synergies, and the market is characterized by rational expectations and thus able to correctly evaluate a transaction. Another option, if the relationship between the short-run stock market reaction and investor sentiment is negative, is that rational investors evaluate investment choices made by overoptimistic managers negatively. Finally, where there is no significant relationship between investor sentiment and stock market reaction, one possibility could be that our measure captures growth opportunities that can either be well or badly exploited by managers, regardless of the level of investor sentiment.

Hence, to address these points, we restrict the sample to those M&As that were completed and study the impact of investor sentiment on the market evaluation of the merger announcement both in the short-run and long-run. We find that the impact of investor sentiment on the market reaction to merger announcements is actually reversed in the long-run, pointing to the presence of overoptimism and suggesting, overall, that biased expectations on the part of both shareholders and managers might partly explain the occurrence of acquisitions.

2.2 Literature review

The present paper is related to a number of different streams of literature. First, it is closely linked with studies on the drivers of M&As and merger waves which have shed light on various possible determinants. The neoclassical theory of mergers (cfr. Andrade and Stafford, 2004; Jovanovic and Rousseau, 2002), for example, stresses the role of economic shocks driving acquisitions which are pursued when there exist potential synergies from the transaction. According to this view, acquisitions generally bring positive results to the merging companies and shareholders are able to distinguish good deals from bad ones, for they are not subject to biased expectations. Other authors emphasize the conflicting interests between shareholders and managers and show the importance of managerial objectives in influencing M&A activity (cfr. Jensen, 1986).

In particular, managers of firms with large free cash flows might engage in takeovers, rather than distribute resources to shareholders. This theory predicts that transactions driven by these motives might destroy, rather than create, value. Furthermore, the overvaluation of firms is studied by Shleifer and Vishny (2003), who stress the practice of companies of issuing more equity when it is overvalued, exchanging it for the real assets of other firms, in order to protect shareholders from the expected stock market downturn. For those authors, the managers of target firms have a short time horizon and are thus willing to accept the overvalued shares in order to gain from the stock market boom. Similarly, Rhodes-Kropf et al. (2005) support the view that the overvaluation of stocks is one of the drivers of merger waves, but posits a different reasoning for the targets' side, stating that the managers of targets are not able to distinguish overoptimism from rational expectations of future synergies. With regards to the behavioral channel, research by the likes of Gugler et al. (2012) and Petmezas (2009) provides evidence for the role of overoptimism in generating merger waves.

Broadening the view to the effects of misvaluation or investor sentiment on firms' decisions in general, we gain other interesting insights. Stein (1996), for instance, introduces the catering theory concerning investment decisions, which puts forward that managers are rational and aim at satisfying shareholders' expectations, regardless of their potential bias. For example, a firm stock price being overvalued might imply that investors are overoptimistic about its growth opportunities and this might drive managers, attempting to maximize the share price, to cater to this positive investor sentiment by pursuing investment projects characterized by a negative net present value, which nevertheless is positively perceived by investors, and *vice versa*. Stein (1996) argues that managers' incentives to cater are stronger under some circumstances, such as when firms are harder to value and, as a consequence, might be characterized by a misvaluation which lasts longer. The time horizon of shareholders or managers will potentially also influence the catering incentive; in particular, a shorter time horizon implies a stronger focus on results that occur when the eventual mispricing has not vanished yet, bringing about a larger incentive to cater. This theory has been tested for certain corporate decisions, such as for the dividend policy (Baker and Wurgler, 2004) and for firms' investment (Polk and Sapienza, 2008). Moreover, the above-mentioned equity market timing hypothesis has also been studied outside the literature focusing specifically on M&As. The idea, again, is that deviations in stock prices influence a firms' equity value, which constitute a significant source of financing. On this point, Baker and Wurgler (2002) show that, if the company's stock is mispriced, rational managers of equity-dependent firms find it more attractive to issue equity or buy back undervalued equity, eventually affecting the level of investment. Baker et al. (2003)

test this hypothesis directly and find evidence that stock market mispricing does indeed influence firms' investment through an equity issuance channel.

More generally, the study of investor sentiment links the present paper to the growing literature on heterogeneous expectations and biased beliefs, both in the real economy and in financial markets. Such works share the notion that individuals might not be entirely rational, as supported by evidence from other disciplines, such as psychoanalysis, psychology, neuroscience and sociology. In these fields, it is particularly stressed that individuals, when taking decisions, integrate their cognitive abilities with their emotional state. Furthermore, whilst relying on rational expectations implies complex reasoning, it is shown that, in a context of uncertainty and complexity, acting upon simple behavioral rules might be more convenient (cfr., among others, in psychoanalysis and psychology: Simon (1990), Gigerenzer and Todd (1999), Tuckett (2012), Lerner et al. (2015); in neuroscience: Bechara et al. (2000); in sociology: Smelser (1998)). In economics, Shiller (2015) constitutes an early example of studies taking into account such ideas and this is followed by various papers formalizing heterogeneous expectations, such as LeBaron et al. (1997), Brock and Hommes (1997, 1998), De Grauwe (2011) and others, which have been reviewed by Franke and Westerhoff (2017). In terms of empirical support for the role of heterogeneous expectations, the focus has been devoted both to survey data and laboratory experiments with human subjects. Among the former group, there are, for example, Gennaioli et al. (2016) and Bordalo et al. (2020), which show the importance of employing expectations data in order to understand corporate investment, planned and actual; these data, in fact, help explain such figures more than traditional measures of investment determinants. Furthermore, the results of these studies suggest the rejection of the rational expectations benchmark and instead provide support for the extrapolative nature of expectations, consistent with the presence of overoptimism in good times and over pessimism in bad times. Research that provides laboratory evidence for heterogeneous expectations in macroeconomics is surveyed in Assenza et al. (2014).

Finally, the proxy of investor sentiment that we build relates the present paper to those economic studies applying sentiment analysis to text sources, which are growing in number and importance. One important issue addressed in this field concerns the measurement of sentiment and its impact on economic variables. Tetlock (2007) is a pioneering example: the author applies sentiment analysis to The Wall Street Journal's (WSJ's) "Abreast of the Market" column on US stock market returns and provides evidence that measures of media content serve as a proxy for investor sentiment or non-informational trading by rejecting the hypothesis that media content contains new information about fundamental asset values. Tetlock et al. (2008), instead, investigate the impact of negative words found in The Wall Street Journal and in the articles from the Dow Jones News Service about individual S&P 500 firms. Their results, in contrast to the prediction of the former study, suggest that linguistic media content captures otherwise hard-to-quantify aspects of firms' fundamentals, which investors quickly incorporate into stock prices. In particular, media pessimism in firm-specific news is able to forecast low firm earnings. A similar study is Garcia (2013), in which the author investigates the effect of sentiment – the fraction of positive and negative words in two columns of financial news from The New York Times – on asset prices from 1905 to 2005, showing that stock returns are predicted by news content especially during recessions. Another interesting study is by Soo (2018), which aims at explaining the house price boom that occurred before the 2007 financial crisis. Soo's findings indicate that text content measures of local housing news has significant predictive power for future house prices, leading prices by nearly two years. Moreover, the author provides evidence that this result is not generated by news stories of unobserved fundamentals. Indeed, Tuckett et al. (2014) test what later became the Conviction Narrative Theory (Tuckett and Nikolic, 2017), by measuring shifts in the proportion of approach and avoidance words in news databases, and find that, during the period leading up to the 2017 financial crisis, there were unusual sentiment shifts, highlighting that the emergence of consensus over a narrative can be an important warning sign of impending financial system distress.

The present paper aims at contributing to these streams of literature, first by measuring the impact of investor sentiment on M&As, shedding light on the role of a number of potential factors that might explain the relationship, providing evidence for the overoptimism hypothesis. We accomplish this by also studying the impact of investor sentiment on market reaction to merger announcements. Importantly, we provide a measure of investor sentiment based on text analysis applied to a very large sample of firm-specific news stories supplied by the major news source Thomson Reuters.

2.3 Sentiment measure

We build our firm-level investor sentiment measure by applying text analysis to the database provided by Thomson Reuters[21], which stores all the major news agency's content from 1996. We consider only articles written in English on firms that are traded in at least one of the main US stock exchanges, namely the New York Stock Exchange, Nasdaq and NYSE American, and employ text analysis in order to match stories to

[21] A more detailed description of this and other data sets can be found in the Appendix.

those firms which are mentioned and discussed therein. Moreover, we only include articles that contain at least a few words from the dictionary developed by Loughran and McDonald (2012), in order to avoid such ones that consist solely of tables or lists with company names and quantitative information. Therefore, similarly to Tetlock et al. (2008), we only select news articles that:

- mention the firm's name at least twice either in the headline or body of the article;
- mention the firm's ticker at least once either in the headline or body of the article; and
- contain at least three words that are either positive or negative.

Furthermore, we only include news on those firm-year observations that appear in Compustat. Table 2.1 shows the number of articles per year included in our final news sample.

We measure investor sentiment on the selected news employing a bag-of-words method. In particular, we count the number of positive and negative words, based on the dictionary developed by Loughran and McDonald (2012). This list of words, including approximately 2,500 negative and 300 positive words, is a version of The General Inquirer's Harvard-IV-4 classification dictionary adapted for economic contexts by Loughran and McDonald (2012), which finds that a great number of words are capable of expressing a very different attitude depending on the context in which they are used.

We obtain our investor sentiment measure in the following way. First, we count the number of positive and negative words which appear in all the news stories published about a certain firm during the last quarter of every fiscal year and we compute:

$$Count_{i,t} = \frac{pos_{i,t} - neg_{i,t}}{length_{i,t}}, \tag{2.1}$$

where i and t indicate firm and quarter, respectively. Further, $pos_{i,t}$ and $neg_{i,t}$ are the total number of positive and negative words in all news articles published in quarter t on firm i and $length_{i,t}$ is the total number of words in those articles. We also compute $Count_{i,t}$ at the monthly and yearly frequency and provide two different versions, where one first computes the variable $Count_{i,t}$ for each article and then takes the average over a certain period of time and the other considers an unnormalized measure of positive and negative words: regression results are qualitatively similar in all cases.

Figure 2.1 illustrates the variable *Count*, measured at the monthly frequency and averaged across firms (indicated as Sentiment in the figure), and the monthly S&P index return obtained from CRSP, scaled by a factor of 100 for the purpose of comparison. We can see that the two move in a broadly similar way, except for the peaks before and after the 2007 financial crisis. Another significant period in the stock market history is that before 2000, characterized by the dot-com bubble; in the figure, the variable Sentiment seems relatively higher than the index return and both decline afterwards.

This measure of investor sentiment could capture both "a belief about future cash flow not based on facts at hand" and news that actually reflect growth opportunities. Whilst from a psychology point of view, such as that contained in the CNT, the distinction between rational and irrational elements contributing to opinion formation is somewhat problematic, for they are interdependent and hardly separable, we instead follow the line of thinking that such distinction is crucial for disentangling different economic theories such as the Efficient Market Hypothesis (EMH) from behavioral views of the functioning of financial markets. Therefore, our investor sentiment measure is orthogonalized with respect to certain firms' characteristics that proxy for future performance, as in Soo (2018). Table 2.2 shows the correlation between selected variables and we observe that the variable *Count* has a very low correlation with almost all other variables. Nevertheless, we regress *Count* on a set of balance sheet information included in the table and take the residuals which constitute the orthogonalized investor sentiment. Finally, in order to study interaction effects among such investor sentiment and other variables, we build for every year a percentile rank of the orthogonal sentiment, which is the variable *Sent* that appears in our regressions.

2.4 Data

We build our own dataset by combining six existing data sets. In particular, data on M&A deals are obtained from Zephyr Bureau van Dijk and stock market data are collected from the CRSP data set, whilst balance sheet and income data are derived from Compustat. As mentioned above, news data are taken from Thomson Reuters and, finally, data on managers' compensation are provided by ExecuComp. We drop any mergers where we cannot obtain CRSP and Compustat data for the bidder. Whereas Compustat (including ExecuComp) and CRSP can be combined through the match table provided by CRSP, the other datasets utilize different firms' identifiers. Hence, we combine the datasets by employing ISIN and CUSIP codes and by matching firms' names through text analysis – we describe this process in more detail in the Appendix.

Our analysis covers the years from 1997 to 2018.

Zephyr Bureau van Dijk provides a dataset which contains substantial information on M&As: we include those mergers or acquisitions where the acquiring company is US-listed. The great majority of observations are acquisitions, with only two deals in the sample being mergers – we use the two terms interchangeably. The dataset indicates the status of each deal, i.e. rumored, announced, completed or withdrawn. Whilst we exclude rumored M&As, we include those that have been completed as well as those that are announced and then withdrawn, for we are focused on the interest in acquiring another company, rather than in the actual completion of the deal. We eliminate those observations which are missing the announcement date or the acquired stake. We ignore outliers; any firm with a negative book value of equity or with a ratio of book value of equity to market value of equity over 10 is dropped. Our final sample of M&As contains 19,810 deals made by 2,437 companies included in Compustat, CRSP and in the final news dataset; table 2.3 shows how deals are distributed over the years.

In order to pursue a yearly analysis, we compute the number of deals made by each company per fiscal year. The explanatory variable of our interest is investor sentiment in the last quarter of the previous fiscal year with respect to the acquisition announcement. The focus of our study is the relationship, if any, between investor sentiment and the expressed interest of a firm in acquiring (or merging with) another company. Therefore, we ensure that, between our investor sentiment measure and the acquisition announcement date, there is a gap of at least one month, meaning that, if a M&A deal has been announced in the first month after the end of the firm's fiscal year, we attribute that deal to the previous fiscal year.

2.5 Investor sentiment and M&As

In this section we study the relationship between investor sentiment and M&A announcements by firms. The basic version of the equation that we estimate is the following:

$$Y_{i,t} = \beta_0 + \beta_1 Sent_{i,t-1} + \beta_2 CF_{i,t-1} + \beta_3 log(AT)_{i,t-1} + \beta_4 LEV_{i,t-1} + \eta_t + \mu_j + \epsilon_{i,t}, \quad (2.2)$$

where $Y_{i,t}$ is the probability of firm i announcing an acquisition or a merger in time t. The dependent variable is binary and can only take the values 0 or 1; thus, we estimate the relationship with a Probit model. *Sent* is our ranked orthogonalized sentiment measure, expressed as a percentage. Moreover, we include control variables which, according to the literature, help explain the occurrence of M&As. We consider that firms with larger cash flows might be less financially constrained and thus pursue acquisitions more easily. Hence, we include $CF_{i,t-1}$, which is firm i's cash flow. Moreover, $logAT_{i,t-1}$ is the logarithm of total assets, which proxies for firm size: large firms may be more likely to acquire other companies than small ones. Furthermore, a higher leverage might financially constrain firms; thus, we include $LEV_{i,t-1}$. Finally, we include industry dummies, μ_j, obtained from the three-digit SIC codes from Compustat, year dummies η_t and an error term. We expect: $\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 > 0$ and $\beta_4 < 0$.

Table 2.5 shows the marginal effects of the Probit model for different specifications. First of all, we find that a more positive sentiment is correlated with a higher probability of announcing an acquisition; this relationship is significant in all three models, the only difference being in the size of the effect, which is reduced by the inclusion of the industry and year dummies. In particular, in specification (1), an increase of one percentile in the sentiment ranking is associated with an increase of 4.2 percentage points in the probability of a firm making an acquisition, all other variables being at their average level. Moreover, less financially constrained and larger firms are more likely to announce mergers, while a higher leverage reduces such a probability. Adding time and industry fixed effects in model (2) reduces the marginal effects of investor sentiment, cash flow and leverage, while increasing the impact of the firm's size.

The literature investigating the determinants of mergers and acquisitions has studied the impact of overvaluation of firms by employing different proxies for mispricing and investor sentiment (cfr. Harford, 2005 and Gugler et al., 2012). These are, for instance, the market-to-book ratio, measuring the market and book value of equity, and the Tobin's Q, given by the ratio between the market and book value of the total assets. Both these measures aim at capturing how the market evaluation of a firm deviates from its fundamental value; however, the use of such proxies is somewhat problematic, in that it is difficult to separate mispricing from the correct anticipation of future growth opportunities – Tobin's Q is, in fact, often used in order to proxy for the latter. Nevertheless, we include both of these measures in model (3) in order to study whether the investor sentiment coefficient is reduced in size and significance after their addition. Interestingly, the results of model (3) suggest that the market-to-book ratio is not significant and the estimate is close to zero, whereas Tobin's Q is significant but has a small negative marginal effect. Thus, it appears that, in our sample, the measures perform poorly and that they also do not have any impact on the sentiment coefficient, which is still positive and significant. Nevertheless, their inclusion improves the predictive power of the model, as shown by the log likelihood and the AIC values.

The above-mentioned results suggest that there is a positive relationship between investor sentiment and the firm's probability of announcing one or more acquisitions.

This implies that more positive investor sentiment towards a specific company drives that company to pursue acquisitions, whilst a more negative attitude causes a firm to be less willing to consider M&As as a means of expansion. This analysis does not provide insights into why such a relationship exists, which is what we investigate in the next section.

2.5.1 What are the mechanisms at play?

As mentioned in the literature review, a number of theories have been developed on the mechanisms that exist behind the relationship between investor sentiment and M&As, such as the overvaluation hypothesis and the overoptimism on the part of either shareholders or managers. Moreover, with regard to the impact of mispricing on investment, Stein (1996) has introduced the catering theory. In what follows we explore these two potential explanations for the positive relationship between investor sentiment and the likelihood of a firm announcing a merger or an acquisition.

Overvaluation hypothesis

The overvaluation hypothesis, as mentioned, stresses that firms might exploit a positive mispricing of their stock in order to issue equity under more convenient conditions. Hence, we aim at taking into account the possibility that investor sentiment is positively correlated with acquisition announcements through the equity issuance channel. To do so, we include three proxies for equity issuance borrowed from Baker and Wurgler (2002), which should provide information on whether the effect of investor sentiment depends on equity issuance or not. In table 2.6, we estimate equation (2.2), with the addition of the ME-BE ratio and Tobin's Q; moreover, in model (1) we introduce EQISS.a, i.e. the ratio of the change in the book value of equity minus the change in retained earnings and total assets. The measure used in the second specification, EQISS.b, is similar, but the book value of equity is computed as stakeholders' equity plus deferred taxes and investment tax credit minus preferred stock (Davis et al., 2000). Finally, model (3) considers a cash flow measure of equity issuance, given by the difference between the sale and the purchase of common and preferred stock. From table 2.6, we observe that in models (1) and (2) equity issuance is significant and their coefficient is positive, meaning that higher equity issuance is correlated with the probability of pursuing acquisitions. This implies that it is likely that part of the acquisitions of the sample are financed by equity – Zephyr provides information on the means of payment and financing, but there are too many missing data that prevent its inclusion in the regression. In model (3), instead, the effect of equity issuance is significant but slightly negative. Importantly, we find that the marginal effect of investor sentiment is not affected at all by the inclusion of equity issuance variables, meaning that the two effects are distinct and separate.

Catering Theory

The catering theory posits that managers, who are rational, have incentives to cater – i.e. to satisfy – shareholders' expectations which can be biased. This implies that, as a consequence of stock mispricing, managers can over/under invest, if expectations are subject to overoptimism/over pessimism respectively. The extent of the incentives to cater depend essentially on the duration of the mispricing which, in turn, depends on how easy it is to evaluate a company, and on the time horizon of the shareholders. Hence, the relationship between investor sentiment and over/under investment should vary across firms. In particular, with regard to the former dimension, firms that are harder to evaluate might be characterized by a mispricing which lasts longer, for it takes more time for the correct evaluation to be incorporated by shareholders. Thus, such firms should exhibit a stronger relationship between investor sentiment and the probability of the announcement of acquisitions.

We employ four proxies for hard-to-value firms which have been studied in the literature: we consider that firms with high asset intangibility, low dividends, low profitability and young companies constitute hard-to-value firms (cfr. Baker and Wurgler, 2006; Kumar, 2009). With respect to the time horizon dimension, the idea is that a shorter time horizon on the part of shareholders or managers implies that the time when the mispricing is absorbed – because of the incorporation of the correct information – is less relevant for shareholders and managers. The latter group, in fact, might either have direct incentives to maximize the stock price or might be uninterested in the long time horizon. Similarly to Gibbons and Murphy (1992) and Gao (2010), we employ two proxies for this dimension, both obtained from the ExecuComp data set: one is a dummy variable indicating whether the CEO is younger than 63 years old, implying that he or she is at least three years from retirement, and, the other is the ratio of vested options to the total managers' compensation based on the average for the top five executives at the firm. In fact, newly granted stocks and options have to become vested in order to be sold or exercised. Thus, managers with a considerable amount of vested stocks and options might be more concerned about the firm's near-term stock price than those with a smaller amount. In order to build this proxy, we use the total compensation variable (TDC1), which includes salary, bonus, restricted stock granted and the Black-Scholes value of stock-options granted. The value of restricted stock and options that become vested in year t reads

$$ValueVestingEquity_t = UnvestedEquity_{t-1} + EquityGrant_t - UnvestedEquity_t, \quad (2.3)$$

where $UnvestedEquity_t$ is the value of unvested stock and options in year t and $EquityGrant_t$ is the value of newly granted stock and options. $VestingEquity$ is then obtained as $ValueVestingEquity$ divided by TDC1. Finally, we compute TH2 as TH2 = 1 - VestingEquity; a higher TH2 value indicates a longer horizon.

In order to study the interaction effect, we include interaction terms between investor sentiment and the above-mentioned proxies of hard-to-value and short time horizon companies in the regression. Since in a Probit model an insignificant interaction term does not necessarily indicate an insignificant relationship (cfr. Ai and Norton, 2003), we also study such relationships graphically but we do not present the related figures as they all confirm the regression results.

Table 2.7 illustrates the results of the regressions that specifically test the interaction effect between investor sentiment and dividends and between investor sentiment and asset tangibility. In model (1), we include a dummy indicating whether the firm pays low dividends, i.e. dividends that are less than or equal to the median amount of dividends paid. In our sample, the median dividends paid is zero; therefore, low-dividend firms are those which do not distribute dividends at all. In specification (2), we include an interaction term of investor sentiment with the actual dividends distributed by the firm. Models (3) and (4) take into account the level of asset tangibility and its interaction with investor sentiment. First of all, we observe that in all specifications, investor sentiment remains significant and positive. Moreover, concerning models (1) and (2), the two variables indicating the firms' dividend policies are insignificant in explaining the probability of a firm announcing an acquisition. As for the interaction terms, they are not significant either.

Specifications (3) and (4) in table 2.7 include asset tangibility, which significantly affects the probability of acquiring a company. In particular, firms with low asset tangibility are more likely to announce a merger or an acquisition. The coefficients of interaction terms between investor sentiment and the two specifications of asset tangibility are insignificant.

The two other proxies that we employ in order to test whether hard-to-value firms are more affected by investor sentiment in their acquisition decisions are firm age and profitability. Table 2.8 presents the results of four different specifications which include the interaction terms. Models (1) and (2) take into account the effect of firm age, whilst models (3) and (4) study firms' profitability. Model (1) includes a dummy indicating whether the firm is a young firm – i.e. younger than the median firm age. A young firm is less likely to pursue a merger or an acquisition; moreover, the interaction between investor sentiment and the dummy YoungFirm is non-significant. This result is confirmed by specification (2). Models (3) and (4) consider the profitability of firms; the former specification includes a dummy indicating whether the company is less profitable than the median firm, whereas the latter model includes the full distribution of profitability. Both models show that more profitable firms are more likely to pursue M&As and that the interaction between firms' age and investor sentiment and firms' profitability and investor sentiment is not significant.

Table 2.9 focuses on the role of time horizon. Model (1) includes a dummy, TH1, indicating whether the CEO of a company is younger than 63 years old. Model (2) includes a measure, TH2, of the options becoming vested over the total manager's compensation. TH1 does not have a significant impact on the probability of a firm making an acquisition; TH2, on the other hand, is positively associated with such a probability, implying that managers with a longer time horizon are more likely to acquire other companies. The two interaction terms are negative but non-significant, suggesting that, in our sample of M&A deals, investor sentiment and time horizon do not present interactions in influencing a firm's interest in acquiring other companies.

To sum up, our results suggest that investor sentiment is positively and significantly correlated with the probability of a firm announcing one or more acquisitions, which is confirmed across different specifications of the estimated model. Moreover, we find that equity issuance is positively correlated with such a probability. However, its inclusion in the regression does not affect the significance and size of investor sentiment impact, which, therefore, seems to exist independently from equity issuance. Furthermore, by employing proxies for hard-to-value and short-time horizon firms, we do not find evidence for the catering channel. Therefore, our results seem to provide an additional mechanism, beyond those just considered, that links investor sentiment to M&As. We explore this point in the next sections.

2.6 Effect of investor sentiment on the announcement return

One possible explanation for the positive relationship between investor sentiment and M&A activity, ignoring equity issuance and catering theories, is that a positive sentiment is an indicator of growth opportunities that are exploited by companies through mergers and acquisitions. In this case, investor sentiment would capture relevant information on firms' fundamentals. Alternatively, investor sentiment might reflect or amplify shareholders' and possibly managers' overoptimism, providing support for behavioral theories of mergers. These two potential explanations can be disentangled by studying the short-run and long-run stock market reaction to merger announcements and how such reaction varies depending on investor sentiment. Indeed, different theories generate differing predictions as to how stock return varies over time as a consequence of an acquisition announcement. For example, a positive relationship between the short-run return around the announcement date and investor sentiment is consistent both with the neoclassical theory – which stresses the role of economic shocks as M&A determinants and states that acquisitions generally create value because they reflect the presence of potential synergies between the companies involved – and with the overoptimism theory – which highlights that, in periods of positive sentiment, mergers might be perceived as better deals than they really are. However, these theories take an alternative view on the long-run reaction to merger announcements. In particular, if the stock market reaction is more positive in periods characterized by higher investor sentiment because the latter indicates growth opportunities that are exploited by managers and correctly evaluated by rational investors, then there should be no long-run reversal of the impact of investor sentiment. That is, investor sentiment before the announcement should not have a negative effect on the long-run stock market reaction because all the information is incorporated by shareholders at the time of the announcement. Instead, if such a long-run drift does exist, it should point towards the overoptimism hypothesis, as it suggests that the value created by deals made in periods of optimistic investor sentiment is perceived as being higher than it really is, as it emerges only in the long-run.

In order to compute the short- and long-run return of stocks, we use stock prices from CRSP; furthermore, we only consider completed acquisitions, ignoring withdrawn deals.

2.6.1 Short-run returns

The short-run return is computed as the average abnormal return of the stock over a window of five days around the announcement – we also consider a window of seven days, which does not change the results. More specifically, we follow Fuller et al. (2002) and Rosen (2006), and measure the cumulative abnormal average return (CAAR) over the five days surrounding the merger announcement as the difference between the return for the bidder and the return on the value-weighted market index:

$$CAAR_{i,t} = \sum_{t-2}^{t+2} R_{i,t} - R_t^{index}, \quad (2.4)$$

where $R_{i,t}$ is the return on the firm's stock on date t relative to the announcement date and R_t^{index} is the return on the index for that date.

For our sample of 1,087 deals the average CAAR using the value-weighted benchmark is 1.27%. The main variable we are interested in is investor sentiment, as we aim at investigating whether it has an impact on the stock market reaction. For this analysis we measure investor sentiment over a window of time starting four months before and ending one month before the announcement day; moreover, we consider the non-ranked orthogonalized investor sentiment expressed as a percentage, which we call $Sent2$. We include a few control variables that have been shown to influence the stock market reaction to acquisition announcements. In particular, we follow Rosen (2006) and add measures of merger and stock market momentum. With respect to the former, we take into account both the total number of mergers made in the year prior to a particular announcement, *n.mergers.total*, and the average five-day CAAR on merger announcements made in the same period, *CAAR.average*. With stock market momentum, we proxy this with *return.index* , i.e. the return on the value-weighted market index. Furthermore, bidder-specific merger activity might influence the short- and long-run reaction to acquisition announcements. Hence, we add the CAAR on the last merger by the bidding firm, provided that the announcement occurred in the prior three years, *L.CAAR*. Moreover, *n.mergers* is added to measure how active a firm is, measured as the number of acquisitions announced by the bidder in the prior three years. We also include *BHAR.average* – where BHAR stands for buy and hold average return – which is firms' long-term stock return computed according to equation (2.5), and the bidder market-to-book equity ratio, in order to qualify the financial health of the bidding company. We control for firm size by including $logAT$, i.e. the log of total assets. Finally, we control for two deal-specific factors: *proport.size* indicates the ratio between the size of the bidder and the target, and the dummy $diversifying$ states whether the transaction involves firms from two different industries, defined as the three-digit SIC code from Compustat. In the sample, 46.5% of all mergers are diversifying.

Table 2.11 shows the results of the CAAR analysis. We find that investor sentiment has a positive and significant effect on the short-run announcement return. In particular, a one percentage point increase in the sentiment boosts the CAAR for a bidding firm by 0.099 percentage points. This implies that announcing a merger in periods with high firm-specific investor sentiment leads to better market reaction than doing so in times characterized by low sentiment. As argued above, this can be consistent both with the neoclassical theory of mergers and with the behavioral view, depending on the long-run reaction. With regards to the other variables, the results provide evidence for the presence of merger and stock market momentum; in fact, both the coefficients of $CAAR.average$ and $return.index$ are positive and significant, whilst $n.mergers.total$ is insignificant. Hence, during hot merger and stock markets, a deal is more likely to be positively perceived by financial markets. Similarly for bidder-specific merger momentum, the CAAR on the previous merger boosts the current CAAR by 0.085 percentage points, whereas the number of mergers completed by the same firm in the previous year is not significant. Firm-specific market conditions do not indicate the presence of momentum; the negative coefficient of BHAR.average is consistent with Rosen (2006), where it is argued that one possible reason for such a relationship is hubris (Roll, 1986); i.e. managers of bidding firms that were recently successful might be induced to believe in their ability to create value in situations negatively judged by the market.

The amount of assets held by the firm is negatively correlated with the CAAR, which is consistent with earlier findings (cfr. Loderer and Martin (1997)). Furthermore, deal specific conditions do not have a significant effect on the short-run stock market reaction to acquisition announcements.

To sum up, the CAAR analysis offers the following insights: first and most importantly, investor sentiment has a positive impact on short-run market reaction to merger announcements; hence, we find evidence for investor sentiment momentum. Second, the results provide support for the presence of hot merger and stock market momentum.

2.6.2 Long-run returns

We turn to the long-run analysis, which can help us distinguish between the overoptimism hypothesis and the neoclassical theory of mergers. We employ the buy and hold average return (BHAR) measure of long-run performance after a merger announcement, which is similar to our short-run CAAR measure. We define the BHAR as the value of holding a long position in the stock of the bidding firm and a short position in a benchmark index, i.e. the CRSP value-weighted index, over the time horizon:

$$BHAR_{i,t} = \frac{\Pi_{t=1}^{T}(1 + R_{i,t})}{\Pi_{t=1}^{T}(1 + R_{t}^{index})} \tag{2.5}$$

The time window over which we measure the BHAR is the post-announcement period, as it starts three days after the announcement day and ends three years after that same announcement day. In our sample, the average BHAR is -3.51%. The results are similar to the time horizon that runs from two days prior to a merger announcement and has the same end date as the post-announcement period.

The BHAR regression results are provided in Table 2.12. The control variables are the same as those we use for the CAAR analysis. The coefficient on the investor sentiment is negative and significant, implying that an increase of one percentage point in the sentiment during the quarter before the acquisition announcement lowers the long-run return by 1.283 percentage points. This reversal of the relationship with respect to that in the short-run implies that acquisitions announced in periods of high investor sentiment perform worse, all else being equal, than those announced when beliefs are less optimistic, suggesting that investor sentiment reverses in the long-run, therefore providing support for the overoptimism hypothesis. Furthermore, this on the one hand indicates that investor sentiment reflects, at least partly, biased beliefs rather than information on firms' growth opportunities; on the other hand, it provides evidence that investors do not immediately correctly evaluate the value of deals, for they are subject to investor sentiment.

Other coefficients that are revrsed with respect to the short-run analysis are that on the CAAR.average, which is of a larger magnitude than that in the CAAR regression, that on the value-weighted stock index over the twelve months prior to an announcement and that on the total number of mergers, *n.mergers.total*. Hence, acquisitions announced during a hot merger and stock market create less value than those announced during a cold market. With regards to firm-specific momentum variables, such has *n.mergers*, BHAR.average and L.ME-BE, these have negative and significant coefficients, but there is no strong evidence of reversal, as in the short-run analysis they were found to have a similar or non-significant impact.

2.7 Conclusion

In this paper we study the relationship between investor sentiment, measured by applying text analysis to news stories published by Thomson Reuters, on US-listed firms' decisions to announce M&A deals. We find that investor sentiment is positively correlated with the likelihood of firms announcing M&As. There are several possible explanations for such a relationship existing, one of them being the assumption that investors are not rational and that their biases cause stocks to be mispriced. Firms' managers, instead, are rational and time their decisions based on investor sentiment; this is what is predicted both by the overvaluation hypothesis and the catering theory. However, according to our findings, including proxies for these two mechanisms has almost no impact on the investor sentiment coefficient, suggesting that the latter has an independent effect. Therefore, we consider two alternative hypotheses: one is that investor sentiment actually captures future growth opportunities, rather than beliefs not based on facts at hand and the other is coherent with the overoptimism theory, which implies that managers as well as shareholders are not fully rational and that their beliefs are subject to investor sentiment. In order to distinguish these two theories, we explore the short-run and long-run stock market reaction to merger announcements, focusing in particular on the impact investor sentiment has on them. We find that investor sentiment is positively correlated with a better stock market reaction in the short-run, but that this relationship is reversed in the long-run, providing evidence for the overoptimism hypothesis, i.e. that managers are more inclined towards announcing M&As in times characterized by higher investor sentiment and that deals announced under these circumstances are better perceived by the stock market, even though, all else being equal, they perform worse in the long-run than those announced when investor sentiment is lower.

Appendix 2.A Data

In the Thomson Reuters data set, every observation is a "news story", composed of a large amount of information: besides the article's body and headline, we are able to obtain the time of publication, the language and the topic or subject, identified by Reuters Identification Codes (RICs). We select articles written in English about specific companies: their RICs contain a letter that provides information on the asset type, the company's ticker, followed by a letter indicating the stock exchange in which its stock is traded. For example, the company Apple is identified by R.AAPL.N, where R shows that it is a tradable asset, AAPL is the stock's ticker and N states that the stock is exchanged on the New York Stock Exchange. Moreover, a news story can be updated, corrected or modified in some way; this is indicated by the variable "takeSequence", for which we select only the last version of each story.

Compustat and ExecuComp's companies are matched with those covered by CRSP thanks to the matching table provided by the latter. In order to combine the above-mentioned data sets with Zephyr, we employ three methods: the conversion between the ISIN and CUSIP codes, matching companies' tickers and firms' names. In particular, the CUSIP, provided by Compustat, is entirely contained in the ISIN, obtained from Zephyr, which includes a prefix of two letters indicating the firm's country and a random digit at the end. Hence, we derive an expected CUSIP from the ISIN code and match the companies; for the remaining firms we employ the tickers. Both methods do not ensure exact matches; hence, we also check firms' names. Finally, we manually search for those companies for which we did not find match.

In order to match Thomson Reuters and Compustat companies, first, we single out those news stories referring to companies that are traded on at least one of the main US stock exchanges, namely the New York Stock Exchange, Nasdaq and NYSE American. Next, we combine firms from the two datasets through tickers. However, given that a ticker does not uniquely identify a stock, for it can be assigned to multiple companies over time, we extract firms' names from each news story and check whether they match with names provided by Compustat, ignoring certain words such as "Inc.", "Corp.", "The" and their variations. A further check is conducted when we require that firms' names appear in news stories at least a certain number of times, as mentioned in section 3.

Appendix 2.B Tables and figures

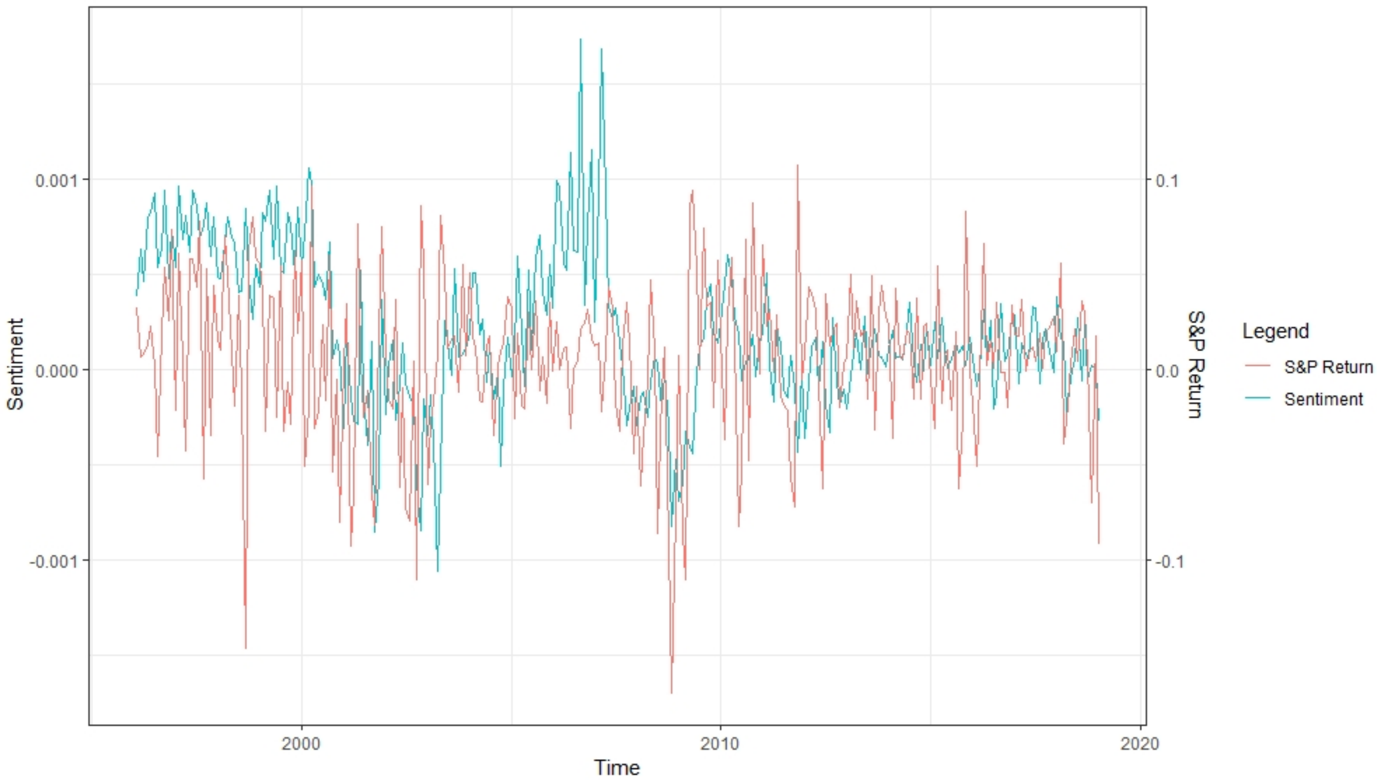


Figure 2.1: Sentiment index and S&P index return

Table 2.1: News stories distribution

	Median	Mean	Total number of news
1996	10.00	20.57	210982
1997	10.00	20.17	228207
1998	10.00	20.36	218422
1999	10.00	21.87	217535
2000	13.00	23.77	224644
2001	17.00	27.08	228358
2002	17.00	29.07	239260
2003	17.00	25.00	271122
2004	16.00	23.71	278469
2005	16.00	24.11	220562
2006	16.00	23.31	222871
2007	16.00	24.07	234577
2008	16.00	26.53	242791
2009	16.00	25.87	252206
2010	16.00	25.04	246222
2011	16.00	24.53	237693
2012	17.00	26.93	229766
2013	18.00	26.97	248707
2014	17.00	24.44	259016
2015	16.00	22.46	238905
2016	16.00	21.06	219086
2017	17.00	21.03	206015
2018	16.00	20.88	203494

Table 2.3: M&As per year

Year	N. of deals	N. of bidders	Max. n. of deals done by one firm
1997	70	60	4
1998	155	112	8
1999	235	136	16
2000	904	419	19
2001	901	438	19
2002	801	422	15
2003	765	405	14
2004	912	463	19
2005	1043	496	19
2006	1156	569	16
2007	1162	562	25
2008	985	479	25
2009	611	377	23
2010	913	486	16
2011	1063	567	23
2012	1148	607	41
2013	1043	574	41
2014	1319	731	38
2015	1265	703	38
2016	1079	643	34
2017	1204	732	34
2018	1076	668	40

Table 2.4: Descriptive Statistics for M&A determinants

	Median	Mean	Std. dev.
CF	0.23	0.36	1.09
AT	261.5	1967.7	7708.82
LEV	0.22	0.23	0.19
ME-BE	2.01	3.66	4.25
Tobin's Q	1.44	2.61	2.42
EQISS.a	0.23	14.21	73.12
Div	0.00	0.02	0.03
AssetTang	0.16	0.25	0.24
FirmAge (months)	130.0	197.7	204.48
Prof	0.07	0.01	0.06

CF is cash flow, given by income before extraordinary items plus depreciation and amortization, all divided by total assets. AT is total assets. LEV is leverage, given by the ratio of total assets minus book equity and total assets. ME-BE is the market-to-book equity ratio. Book equity is given by total assets minus total liabilities plus deferred taxes and investment tax credit minus preferred stock plus convertible debt. If preferred stock is missing, we use the redemption value. L.ME-BE is the beginning of year market-to-book ratio of equity; the market value of equity is obtained from CRSP as the product of shares outstanding and share price, eventually summed over the different classes of shares. Tobin's Q is given by the ratio of total assets minus book value of equity plus market value of equity and total assets. EQISS.a is the ratio of the change in the book value of equity minus the change in retained earnings and total assets. Div is dividends and is computed as total annual dividend per share times shares outstanding divided by book value of equity. AssetTang is given by total property, plant and equipment over total assets. FirmAge is computed as the number of months in which the firm appears in CRSP. Profitability is computed as the ratio of income before extraordinary items plus income taxes minus preferred dividends and book value of equity.

Table 2.2: Correlation table for selected variables

	Count	deal.yes	AT	L.AT	SS	L.SS	CF	L.CF	ni
Count									
deal.yes	0.05***								
AT	0.01	0.11***							
L.at	0.01	0.10***	0.99***						
SS	-0.02***	0.00	-0.04***	-0.04***					
L.SS	-0.01*	0.01*	-0.04***	-0.04***	0.45***				
CF	0.03***	0.03***	0.01*	0.01	-0.02***	0.04***			
L.CF	0.03***	0.04***	0.01**	0.01*	0.05***	-0.03***	0.34***		
ni	0.02***	0.14***	0.37***	0.34***	0.00	0.00	0.04***	0.03***	
L.ni	0.02***	0.14***	0.38***	0.36***	-0.01	0.00	0.03***	0.05***	0.71***

*p<0.1; **p<0.05; ***p<0.01. Count is the difference between the number of positive and negative words, appearing in news stories during the last quarter of each fiscal year. deal.yes is a dummy indicating whether a firm announces a merger or an acquisition. AT is total assets; L.AT is lagged total assets. SS is sales, L.SS is lagged sales. CF is cash flow, L.CF is lagged cash flow. ni and L.ni are net income and lagged net income.

Table 2.5: Marginal Effects

	Dependent variable:		
	P(Y=1)		
	(1)	(2)	(3)
L.Sent	0.042***	0.035***	0.036***
	(0.006)	(0.008)	(0.008)
L.CF	0.022***	0.013***	0.026***
	(0.005)	(0.005)	(0.008)
L.logAT	0.033***	0.036***	0.037***
	(0.001)	(0.007)	(0.007)
L.LEV	−0.047***	−0.037***	−0.050***
	(0.006)	(0.009)	(0.012)
L.ME-BE			0.00004
			(0.00003)
L.Tobin's Q			−0.0001*
			(0.0001)
Year Dummies	No	Yes	Yes
Industry Dummies	No	Yes	Yes
Constant			
Observations	51,878	51,878	49,785
Log Likelihood	-21,475.640	-19,457.520	-18,845.390
Akaike Inf. Crit.	42,961.280	39,495.040	38,274.780

*p<0.1; **p<0.05; ***p<0.01. L.Sent is lagged investor sentiment. We obtain it with the following procedure: we compute equation (2.2) on news published in the last quarter of every fiscal year and we orthogonalize it; i.e. we regress it on a number of firms' variables and take the residuals. Finally, in every year, we rank these residuals by percentiles. L.CF is the beginning of year cash flow, given by income before extraordinary items plus depreciation and amortization, all divided by total assets. L.logAT is the log of beginning of year total assets. L.LEV is the beginning of year leverage, given by the ratio of total assets minus book equity and total assets. Book equity is given by total assets minus total liabilities plus deferred taxes and investment tax credit minus preferred stock plus convertible debt. If preferred stock is missing, we use the redemption value. L.ME-BE is the beginning of year market-to-book ratio of equity; the market value of equity is obtained from CRSP as the product of shares outstanding and share price, eventually summed over the different classes of shares. L.Tobin's Q is given by the ratio of total assets minus book value of equity plus market value of equity and total assets – all values are beginning of year. Industry dummies are built from the three-digit SIC codes by Compustat.

Table 2.6: Marginal Effects

	Dependent variable:		
	deal.yes		
	(1)	(2)	(3)
L.Sent	0.035***	0.036***	0.038***
	(0.012)	(0.012)	(0.009)
L.CF	0.031***	0.030***	0.030***
	(0.012)	(0.011)	(0.011)
L.logAT	0.038***	0.038***	0.037***
	(0.012)	(0.012)	(0.007)
L.LEV	−0.056***	−0.056***	−0.051***
	(0.019)	(0.019)	(0.013)
L.ME-BE	0.00004	0.00004	0.00004
	(0.00004)	(0.00004)	(0.00004)
L.Tobin's Q	−0.0001*	−0.0001*	−0.0001*
	(0.0001)	(0.0001)	(0.0001)
EQISS.a	0.032***		
	(0.012)		
EQISS.b		0.029**	
		(0.012)	
EQISS.cashflow			−0.00001***
			(0.00000)
Constant			
Observations	48,709	48,794	44,630
Log Likelihood	-18,336.570	-18,380.270	-17,156.750
Akaike Inf. Crit.	37,259.140	37,346.540	34,895.510

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$. L.Sent is lagged investor sentiment. We obtain it with the following procedure: we compute equation (2.2) on news published in the last quarter of every fiscal year and we orthogonalize it, i.e. we regress it on a number of firms' variables and take the residuals. Finally, in every year, we rank these residuals by percentiles. L.CF is the beginning of year cash flow, given by income before extraordinary items plus depreciation and amortization, all divided by total assets. L.logAT is the log of beginning of year total assets. L.LEV is the beginning of year leverage, given by the ratio of total assets minus book equity and total assets. Book equity is given by total assets minus total liabilities plus deferred taxes and investment tax credit minus preferred stock plus convertible debt. If preferred stock is missing, we use the redemption value. L.ME-BE is the beginning of year market-to-book ratio of equity; the market value of equity is obtained from CRSP as the product of shares outstanding and share price, eventually summed over the different classes of shares. L.Tobin's Q is given by the ratio of total assets minus book value of equity plus market value of equity and total assets – all values are beginning of year. EQISS.a is the ratio of the change in the book value of equity minus the change in retained earnings and total assets. EQISS.b is the same as EQISS.a, except that the book value of equity is computed as stakeholders' equity plus deferred taxes and investment tax credit minus preferred stock. If stockholders' equity is missing, we use common equity plus preferred stock; otherwise, we take the difference between total assets and total liabilities. If deferred taxes is missing, we substitute it with zero. EQISS.cashflow is measured as sale of common and preferred stock minus purchase of common and preferred stock. Industry dummies are built from the three-digit SIC codes by Compustat.

Table 2.7: Marginal Effects

	Dependent variable:			
	deal.yes			
	(1)	(2)	(3)	(4)
L.Sent	0.035***	0.036*	0.036***	0.034***
	(0.012)	(0.019)	(0.014)	(0.013)
LowDiv	−0.051			
	(0.053)			
Div		0.195		
		(0.121)		
lowAsTan			0.023**	
			(0.010)	
AssetTang				−0.169***
				(0.057)
L.CF	0.031***	0.029*	0.033***	0.036***
	(0.012)	(0.016)	(0.013)	(0.013)
L.logAT	0.038***	0.037*	0.038***	0.038***
	(0.012)	(0.019)	(0.012)	(0.012)
L.LEV	−0.056***	−0.050*	−0.054***	−0.054***
	(0.019)	(0.027)	(0.019)	(0.019)
L.ME-BE	0.00004	0.00001	0.00003	0.00004
	(0.00004)	(0.00004)	(0.00004)	(0.00004)
L.Tobin's Q	−0.0001*	0.008*	−0.0001*	−0.0001**
	(0.0001)	(0.004)	(0.0001)	(0.0001)
EQISS.a	0.032***	0.022*	0.032***	0.031***
	(0.012)	(0.013)	(0.012)	(0.012)
L.Sent:LowDiv	0.048			
	(0.132)			
L.Sent:Div		−0.255		
		(0.172)		
L.Sent:lowAsTan			−0.002	
			(0.010)	
L.Sent:AssetTang				0.008
				(0.023)

Constant				
Observations	48,422	47,921	48,615	48,615
Log Likelihood	-18,215.030	-17,975.680	-18,289.650	-18,194.130
Akaike Inf. Crit.	37,018.070	36,539.370	37,169.300	36,978.250

*p<0.1; **p<0.05; ***p<0.01. L.Sent is lagged investor sentiment. We obtain it with the following procedure: we compute equation (2.2) on news published in the last quarter of every fiscal year and we orthogonalize it; i.e. we regress it on a number of firms' variables and take the residuals. Finally, in every year, we rank these residuals by percentiles. L.CF is the beginning of year cash flow, given by income before extraordinary items plus depreciation and amortization, all divided by total assets. L.logAT is the log of beginning of year total assets. L.LEV is the beginning of year leverage, given by the ratio of total assets minus book equity and total assets. Book equity is given by total assets minus total liabilities plus deferred taxes and investment tax credit minus preferred stock plus convertible debt. If preferred stock is missing, we use the redemption value. L.ME-BE is the beginning of year market-to-book ratio of equity; the market value of equity is obtained from CRSP as the product of shares outstanding and share price, eventually summed over the different classes of shares. L.Tobin's Q is given by the ratio of total assets minus book value of equity plus market value of equity and total assets – all values are beginning of year. EQISS.a is the ratio of the change in the book value of equity minus the change in retained earnings and total assets. LowDiv is a dummy variable indicating whether the firm pays no dividends. Div is dividends and is computed as total annual dividend per share times shares outstanding divided by book value of equity. Low AssetTang is a dummy variable indicating whether the firm has less tangible assets than the median firm, measured by AssetTang. The latter is given by total property, plant and equipment over total assets. Industry dummies are built from the three-digit SIC codes by Compustat.

Table 2.8: Marginal Effects

	Dependent variable:			
	deal.yes			
	(1)	(2)	(3)	(4)
L.Sent	0.036***	0.037***	0.026***	0.031*
	(0.012)	(0.011)	(0.009)	(0.017)
YoungFirm	−0.028**			
	(0.013)			
FirmAge		0.0001***		
		(0.00003)		
LowProf			−0.055***	
			(0.012)	
Prof				0.026*
				(0.015)
L.CF	0.029***	0.029***	0.019**	0.022*
	(0.011)	(0.009)	(0.008)	(0.013)
L.logAT	0.037***	0.033***	0.037***	0.039**
	(0.012)	(0.006)	(0.007)	(0.020)
L.LEV	−0.057***	−0.063***	−0.073***	−0.062*
	(0.019)	(0.015)	(0.016)	(0.032)
L.ME-BE	0.00003	0.00004	0.00004	0.00001
	(0.00004)	(0.00003)	(0.00004)	(0.0001)
L.Tobin's Q	−0.0001*	−0.0001*	−0.0001	0.008*
	(0.0001)	(0.0001)	(0.0001)	(0.004)
EQISS.a	0.033***	0.032***	0.047***	0.044*
	(0.012)	(0.009)	(0.012)	(0.024)
L.Sent:YoungFirm	0.003			
	(0.019)			
L.Sent:FirmAge		0.00001		
		(0.00002)		
L.Sent:lowprof			0.008	
			(0.011)	
L.Sent:Prof				0.010
				(0.014)

Constant				
Observations	48,816	48,816	46,934	46,224
Log Likelihood	-18,363.340	-18,238.430	-17,821.350	-17,695.110
Akaike Inf. Crit.	37,316.690	37,066.860	36,230.700	35,976.230

*p<0.1; **p<0.05; ***p<0.01. L.Sent is lagged investor sentiment. We obtain it with the following procedure: we compute equation (2.2) on news published in the last quarter of every fiscal year and we orthogonalize it; i.e. we regress it on a number of firms' variables and take the residuals. Finally, in every year, we rank these residuals by percentiles. L.CF is the beginning of year cash flow, given by income before extraordinary items plus depreciation and amortization, all divided by total assets. L.logAT is the log of beginning of year total assets. L.LEV is the beginning of year leverage, given by the ratio of total assets minus book equity and total assets. Book equity is given by total assets minus total liabilities plus deferred taxes and investment tax credit minus preferred stock plus convertible debt. If preferred stock is missing, we use the redemption value. L.ME-BE is the beginning of year market-to-book ratio of equity; the market value of equity is obtained from CRSP as the product of shares outstanding and share price, eventually summed over the different classes of shares. L.Tobin's Q is given by the ratio of total assets minus book value of equity plus market value of equity and total assets – all values are beginning of year. EQISS.a is the ratio of the change in the book value of equity minus the change in retained earnings and total assets. YoungFirm is a dummy variable indicating whether the firm has an age lower than the median one. FirmAge is computed as the number of months in which the firm appears in CRSP. LowProf is a dummy variable indicating whether the firm has a profitability lower than the median one; Prof is profitability and is computed as the ratio of income before extraordinary items plus income taxes minus preferred dividends and book value of equity. Industry dummies are built from the three-digit SIC codes by Compustat.

Table 2.9: Marginal Effects

	Dependent variable:	
	deal.yes	
	(1)	(2)
L.Sent	0.055**	0.064***
	(0.023)	(0.022)
L.CF	0.146***	0.168***
	(0.041)	(0.047)
L.logAT	0.068***	0.068***
	(0.015)	(0.015)
L.LEV	−0.110***	−0.114***
	(0.029)	(0.030)
L.ME-BE	0.0001	0.0001
	(0.0001)	(0.0001)
L.Tobin's Q	0.006***	0.010***
	(0.002)	(0.003)
EQISS.a	0.160***	0.187***
	(0.041)	(0.048)
TH1	0.001	
	(0.014)	
TH2		0.019**
		(0.009)
L.Sent:TH1	−0.006	
	(0.023)	
L.Sent:TH2		−0.017
		(0.014)
Constant		
Observations	24,879	25,172
Log Likelihood	-11,847.460	-11,860.630
Akaike Inf. Crit.	24,244.910	24,271.270

*p<0.1; **p<0.05; ***p<0.01. L.Sent is lagged investor sentiment. We obtain it with the following procedure: we compute equation (2.2) on news published in the last quarter of every fiscal year and we orthogonalize it; i.e. we regress it on a number of firms' variables and take the residuals. Finally, in every year, we rank these residuals by percentiles. L.CF is the beginning of year cash flow, given by income before extraordinary items plus depreciation and amortization, all divided by total assets. L.logAT is the log of beginning of year total assets. L.LEV is the beginning of year leverage, given by the ratio of total assets minus book equity and total assets. Book equity is given by total assets minus total liabilities plus deferred taxes and investment tax credit minus preferred stock plus convertible debt. If preferred stock is missing, we use the redemption value. L.ME-BE is the beginning of year market-to-book ratio of equity; the market value of equity is obtained from CRSP as the product of shares outstanding and share price, eventually summed over the different classes of shares. L.Tobin's Q is given by the ratio of total assets minus book value of equity plus market value of equity and total assets – all values are beginning of year. EQISS.a is the ratio of the change in the book value of equity minus the change in retained earnings and total assets. TH1 is the first dummy for time horizon, equal to 1 if the firm's CEO is younger than 63 years old. TH2 is computed as 1 minus the value of vesting equity over the total managers' compensation (TDC1 from ExecuComp). Value of vesting equity is the amount of options that become vested and is computed as the difference between unvested equity of the previous period and current unvested equity plus equity grant. Industry dummies are built from the three-digit SIC codes by Compustat.

Table 2.10: Descriptive Statistics for stock market reaction analysis

	Median	Mean	Std. dev
CAAR	2.14	1.27	1.02
BHAR	-4.24	-3.51	8.52
CAAR.average	2.57	1.93	1.62
n.mergers.total	155.0	126.6	76.90
return.index	19.83	14.94	13.17
L.CAAR	0.32	1.62	7.16
n.mergers	1.34	0.92	1.03
BHAR.average	-0.85	9.49	23.94
ME-BE	2.66	4.67	5.87
AT	656.82	2679.12	10545.3
Diversifying		46.51%	
Proport.size	0.25	0.375	0.36

CAAR is defined in equation (2.4). The announcement window runs from two days prior to an announcement to two days after the announcement. BHAR is defined in equation (2.5). The announcement window runs from three days after an announcement to three years after the announcement. L.Sent2 is lagged investor sentiment. We obtain it with the following procedure: we compute equation (2.2) on news published over a period running from four months before to one month before the merger announcement and we orthogonalize it; i.e. we regress it on a number of firms' variables and take the residuals. CAAR.average is the trailing 12-month average cumulative abnormal announcement return (CAAR), computed as the average CAAR for all sample mergers in the 12 months ending three days before an announcement. n.mergers.total is the number of sample mergers in the 12 months prior to an announcement. Return.index is the return on the value weighted CRSP index in the year ending three days before a merger announcement. L.CAAR is CAAR for the most recent merger, provided that the merger was announced in the three years prior to the current announcement. n.mergers is the number of acquisitions announced by the bidder in the three years prior to the announcement. BHAR.average is the return in the 12 months ending three days before an announcement. ME-BE is the beginning of year market-to-book equity ratio of the bidder, measured at the end of the year prior to the merger announcement. AT is total assets. Diversifying is a dummy indicating whether the target and the bidding firm are in different industries, obtained as the three-digit SIC code from Compustat. Proport.size is the ratio of target equity to bidder equity. If information on the target is missing, we use the variable on deal value from Zephyr.

Table 2.11: Results

	Dependent variable:
	CAAR
L.Sent2	0.099**
	(0.046)
CAAR.average	0.381***
	(0.136)
n.mergers.total	0.010
	(0.010)
return.index	0.009*
	(0.005)
L.CAAR	0.085**
	(0.039)
n.mergers	−0.0001
	(0.0004)
BHAR.average	−0.0005*
	(0.0003)
L.ME-BE	0.001
	(0.001)
L.logAT	−0.004***
	(0.001)
proport.size	−0.0001
	(0.001)
diversifying	−0.004
	(0.005)
Constant	0.036**
	(0.016)
Observations	1,087
R^2	0.017
Adjusted R^2	0.007
Residual Std. Error	0.063 (df = 1075)
F Statistic	2.395** (df = 11; 1075)

*p<0.1; **p<0.05; ***p<0.01. CAAR is defined in equation (2.4). The announcement window runs from two days prior to an announcement to two days after the announcement. L.Sent2 is lagged investor sentiment. We obtain it with the following procedure: we compute equation (2.2) on news published over a period running from four months before to one month before the merger announcement and we orthogonalize it; i.e. we regress it on a number of firms' variables and take the residuals. CAAR.average is the trailing 12-month average cumulative abnormal announcement return (CAAR), computed as the average CAAR for all sample mergers in the 12 months ending three days before an announcement. n.mergers.total is the number of sample mergers in the 12 months prior to an announcement. Return.index is the return on the value weighted CRSP index in the year ending three days before a merger announcement. L.CAAR is CAAR for the most recent merger, provided that the merger was announced in the three years prior to the current announcement. n.mergers is the number of acquisitions announced by the bidder in the three years prior to the announcement. BHAR.average is the return in the 12 months ending three days before an announcement. Bidder L.ME-BE is the beginning of year market-to-book equity ratio, measured at the end of the year prior to the merger announcement. L.logAT is the beginning of year log of total assets. The ratio of target-to-bidder size is the ratio of target equity to bidder equity. If information on the target is missing, we use the variable on deal value from Zephyr. Diversifying merger is a dummy indicating whether the target and the bidding firm are in different industries. Industry dummies are included in the regressions but not shown in the table.

Table 2.12: Results

	Dependent variable:
	BHAR
L.Sent2	-1.283^{***}
	(0.457)
CAAR.average	-3.289^{***}
	(1.170)
n.mergers.total	-0.0003^{***}
	(0.0001)
return.index	-0.247^{**}
	(0.083)
L.CAAR	0.311
	(0.287)
n.mergers	-0.005^{*}
	(0.003)
BHAR.average	-0.016^{**}
	(0.009)
L.ME-BE	-0.031^{***}
	(0.007)
L.logAT	0.007
	(0.010)
proport.size	−0.005
	(0.007)
diversifying	0.033
	(0.033)
Constant	1.273^{***}
	(0.118)
Observations	1087
R^2	0.047
Adjusted R^2	0.037
Residual Std. Error	0.493 (df = 1075)
F Statistic	5.286^{***} (df = 11; 1075)

*p<0.1; **p<0.05; ***p<0.01. BHAR is defined in equation (2.5). The announcement window runs from three days after an announcement to three years after the announcement. CAAR is defined in equation (2.4). The announcement window runs from two days prior to an announcement to two days after the announcement. L.Sent2 is lagged investor sentiment. We obtain it with the following procedure: we compute equation (2.2) on news published over a period running from four months before to one month before the merger announcement and we orthogonalize it; i.e. we regress it on a number of firms' variables and take the residuals. CAAR.average is the trailing 12-month average cumulative abnormal announcement return (CAAR), computed as the average CAAR for all sample mergers in the 12 months ending three days before an announcement. n.mergers.total is the number of sample mergers in the 12 months prior to an announcement. Return.index is the return on the value-weighted CRSP index in the year ending three days before a merger announcement. L.CAAR is CAAR for the most recent merger, provided that the merger was announced in the three years prior to the current announcement. n.mergers is the number of acquisitions announced by the bidder in the three years prior to the announcement. BHAR.average is the return in the 12 months ending three days before an announcement. Bidder L.ME-BE is the beginning of year market-to-book equity ratio, measured at the end of the year prior to the merger announcement. L.logAT is the beginning of year log of total assets. The ratio of target-to-bidder size is the ratio of target equity to bidder equity. If information on the target is missing, we use the variable on deal value from Zephyr. Diversifying merger is a dummy indicating whether the target and the bidding firm are in different industries. Industry dummies are included in the regressions but not shown in the table.

Chapter 3

Endogenous Beliefs and Social Influence in a Simple Macroeconomic Framework

3.1 Introduction

The role played by psychological factors in macroeconomics has been recently gaining increasing attention. Within general equilibrium literature, for instance, there is a growing number of models which incorporate the notion of animal spirits, i.e. waves of optimism and pessimism[22], as exogenous shocks to beliefs or confidence and show that they are able to produce economic fluctuations[23,24].

In such models, and more generally in macroeconomics, however, the notion that individuals' beliefs formation critically depends also on their interaction with each other, which is familiar in several fields, is not as much acknowledged. This hampers a thorough understanding of the macroeconomic implications of such interaction on several aspects such as output and welfare[25]. In fact, works in psychology and sociology have

[22]In Keynes' definition, animal spirits are "a spontaneous urge to action rather than inaction", thus, they specifically correspond to an enterprising or optimistic state, while the absence of animal spirits would resemble pessimism. However, in most recent literature, animal spirits is used to indicate waves of optimism or pessimism.

[23]Cfr., among others, Milani (2011), Angeletos and La'O (2013), Benhabib et al. (2015), Huo and Takayama (2015), Acharya et al. (2017), Angeletos et al. (2018).

[24]Moreover, there are heterogeneous agents models deviating from the rational expectations hypothesis which study the dynamics among beliefs and economic outcomes. Cfr. e.g. Hommes (2006); Franke and Westerhoff (2017).

[25]Few exceptions among economists are, for example, Keynes (1936), Shiller et al. (1984), Kindleberger and Aliber (1978).

carefully examined the role of social influence and its drivers, assessing its impact on individuals' opinion formation. For instance, previous studies have identified both informational and normative motivations to conform with others. The former, reinforced under uncertainty, are based on the goal to form a correct interpretation of reality; the latter deal with the desire of social approval. Moreover, perceived consensus matters: all else being equal, an individual will be more likely to adapt to the opinions and behavior displayed by the (local) majority than by the (local) minority[26].

Empirically, incorporating social influence in economic models has proved to better explaining certain patterns of the data. For example, Burnside et al. (2016) develop a model on booms and busts in the housing markets where agents with different beliefs can 'infect' each other with their forecasting rule, depending on their confidence level. Their model is shown to be able to match survey expectation data taken from Case et al. (2012) and data on self-assessed values of agents' homes from the American Housing Survey. Still in the housing market field, Bailey et al. (2018) combine data from online social networks with housing transaction data and provide strong evidence of an effect of social interactions on individuals' housing market expectations. Opinion dynamics based on social influence have been estimated in macroeconomic models as well. For example, **?** estimate a stochastic model of individual expectations partly driven by social influence employing data from the Ifo Business Climate Index for Germany. Their model is particularly able to reproduce the occurrence of abrupt large but rare swings in expectations. Another dataset measuring sentiment for German economy is the ZEW Business Climate Index, compiled by the Centre for European Economic Research. This has been employed by Lux (2009) to estimate a mechanism of switching between optimists and pessimists depending on a social interaction term. The results indicate that the model has significant explanatory power for the ups and downs of the above mentioned sentiment index. Moreover, the author finds a strong significance of the social interaction variable, which interestingly seems to be much more important for the goodness-of-fit of various specifications of the model than more standard macroeconomic variables.

The relevance of social influence in economics, highlighted by the above-mentioned studies, calls for a deeper understanding on a theoretical level of the role of social influence and its implications for the economic system. More specifically, social influence plays a crucial role in the presence of uncertainty. Indeed, the above-mentioned informational motivation to conform with others suggests that, in contexts characterized by uncertainty, individuals' need of relying on others in order to form an opinion and make

[26]Cfr. Cialdini and Goldstein (2004), Flache et al. (2017).

a decision is amplified. This is even more so if the outcomes of agents' decisions are interrelated with each other, meaning that the payoff associated with a certain action depends on others' actions, generating strategic complementarity. In such contexts, the economic system is also characterized by higher-order uncertainty and agents have to forecast each others' forecasts, increasing the complexity of interactions. Hence, when exploring the potential effects of social influence on agents' expectations and more generally on the economy, uncertainty and strategic complementarity are two key features that should be taken into account and incorporated in the model explicitly.

The present paper builds on such considerations and proposes a way to formalize endogenously emerging beliefs, i.e. optimism and pessimism, with an emphasis on the role of social influence, into a stylized Islands model, similar to that developed by Angeletos and La'O (2013). Such a model is purposely simple in order to maintain the reasoning as close as possible to that of standard neoclassical demand and supply functions, but, importantly, it incorporates uncertainty and strategic complementarity. In particular, producers are not aware of the demand they will face on the market and an increase in one's output acts as an incentive for others to raise production as well, and the other way round. Combined, these two features generate frictional coordination and a hierarchy of higher-order beliefs, which reminds a Beauty Contest type of game[27] that may lead individuals to lower their production well below the efficient level, hampering overall welfare. Agents may not be able to coordinate well their beliefs and behavior, eventually driving the economy to a bad equilibrium[28].

Within this framework, the trade off between social and individual objectives can be strongly shaped by the interaction among agents. However, the impact of social influence on uncertainty and coordination is yet to be understood.

Therefore, we incorporate an opinion model similar to that developed by Lux (1995), where agents can switch their belief over time depending on social influence. Different versions of this opinion model have been proved successful in matching expectations data, such as[29], among others, Alfarano et al. (2005), Lux (2012) and the abovementioned Lux (2009). Whereas the former two works focus on expectations formation in financial markets, the latter estimates a mechanism of switching between optimists and pessimists depending on a social interaction term. The empirical support for such

[27]The reference to such a game can be found in Keynes (1936).

[28]Lack of coordination may consist of the presence of multiple equilibria, as in the literature on sunspots (e.g. Cass and Shell (1983) and Azariadis (1981)), or in the coordination towards a bad equilibrium.

[29]For an extensive review of the literature on empirical validation of behavioural heterogeneous agents models, the reader is addressed to Lux and Zwinkels (2018). Moreover, Hommes (2018) reviews the literature of behavioral and experimental macroeconomics, including results from lab experiments on expectation formation.

opinion models suggests that the one that we adopt can provide valuable insights on the role of heterogeneous expectations and social influence in an economy characterized by frictional coordination.

Within this framework, we study the emerging sentiment dynamics and we assess the impact of social influence on agents' coordination, stability and efficiency of our simple trade economy. In particular, we pose the following questions. First, in the absence of social influence, does the economy converge to rational expectations (RE)? This is an important theoretical issue, because on the one hand it sheds light on the consistency conditions of the RE assumption, on the other it questions whether rational expectations necessarily generate higher profits for the individuals than other forecasting rules. Secondly, we study how optimism and pessimism endogenously evolve over time. Third, we assess the effects of social influence on the sentiment dynamics: does it bring about new steady states, or modify the existing ones? Also, what is the impact of social influence on profits, production and welfare? In case it has an impact on welfare, what is the mechanism behind it? Finally, to sum up the different insights, we explore the role of social influence as a coordination device, i.e. a mechanism that can improve agents' coordination and enhance economy's welfare, through its impact on sentiment dynamics.

More in detail, the economy is composed of islands that trade in every period in random pairs; at the moment in which they take their profit-maximizing production and employment decisions, islands do not know the island they have been matched with, along with her productivity and beliefs. Therefore, islands need to form expectations on the trading partner's output level and on her higher-order beliefs. In this respect, islands can have optimistic, pessimistic or neutral expectations and they can switch their type over time. The switching mechanism, briefly introduced above, depends on economic outcomes, i.e. the difference between average profits earned by each type, and on social influence, that is, the observation and, eventually, the imitation of others' sentiment. We assume that both of them are public knowledge: this might be interpreted as due to news media which, every period, publicly announce economic outcomes and the prevalent attitudes in the population.

We explore the system considering an economy populated by neutral and pessimistic islands alone, and one which involves optimistic agents, too. We find that when all islands are neutral, their expectations are rational, meaning that the hierarchy of higher-order beliefs collapses to the true fundamental and all islands expect what will be actually produced (on average). Moreover, in the absence of social influence, agents coordinate over time on a pessimistic and highly inefficient stationary state in which output is below the RE equilibrium; hence, RE are unstable. The reason of the coordination over the pessimistic steady state is that islands, in the absence of social influence, change belief based on the average profitability of each expectation rule, measured as average profits earned, and pessimistic islands make on average higher profits than neutral islands. This is so because pessimistic islands expect worse terms of trade and therefore their profit-maximizing production is lower, thus implying lower production costs and actually better terms of trade. In other words, agents' beliefs on the trading partner's output determine their (profit-maximizing) amount of production which influences negatively their terms of trade and positively their total costs; therefore, individuals have incentives to switch from the neutral belief to the pessimistic one in order to improve their terms of trade and sustain lower expenditures. Although there are some neutral islands that earn higher profits than some pessimistic ones, the probability of adopting one type of belief or the other depends on the relative average profits of the two groups. It is worth mentioning that this result simply emerges from relaxing the assumption of rational expectations and letting islands switch to the belief associated with the average higher profits.

As the importance of social influence in the individuals' belief switching process grows, this undesirable stable steady state becomes even more pessimistic, but as the social influence parameter crosses a certain threshold a second stable steady state emerges, in which agents coordinate on a much less pessimistic belief, eventually converging to the most efficient outcome. The intuition is that whereas lower levels of social influence reinforce the individuals' incentives towards the pessimistic belief, a stronger impact of social influence is able to counteract those incentives by pushing agents to imitate other expectation types as well. In the economy populated by all three types of beliefs, a higher impact of social influence generates also a new optimistic stable equilibrium, characterized by higher production but not necessarily higher welfare. Hence, social influence has a strong impact on the sentiment dynamics; extreme levels generate equal basins of attractions to those stable fixed points characterized by the entire predominance of either pessimistic, neutral or optimistic islands. In addition, social influence is able to balance the incentives to lower further and further output with respect to the trading partner. Concerning welfare, we find that the optimal outcome occurs under rational expectations, i.e. when all islands are neutral. The reason is that, whereas, as mentioned above, incorrect expectations imply higher profits – positively contributing to overall welfare –, they also entail a loss of utility born by neutral and optimistic islands that produce too much with respect to the realized terms of trade. Their excessive production imply an excessive amount of work by households, leading to high disutility. In other words, while some islands profit from uncertainty, others face losses that overcompensate the higher profits. This result points out the presence of a trade off between individual incentives and social outcomes, which social influence can resolve by helping agents coordinate on better stable steady states and neutralizing frictional coordination. The intuition is that social influence, by increasing the likelihood of agents sharing the same belief, reduces the higher-order uncertainty characterizing the economic system, lowering the resulting inefficiencies. However, social influence does not necessarily have a monotone effect on welfare: it can worsen the pessimistic equilibrium and, under certain conditions, an increase of the percentage of neutral or optimistic islands may bring about a reduction in welfare.

These results can be interpreted from a policy perspective, suggesting that strengthening the social influence effect (e.g. fostering knowledge flows between islands) seem to be welfare improving.

The rest of the paper is organized as follows. The next section reviews the relevant literature; section 2 presents the basic structure of the model on which we incorporate endogenous beliefs along with a switching mechanism, discussed in section 3. Section 4 analyzes the sentiment dynamics, without and with social influence; section 5 assesses its impact on output and welfare. Section 6 concludes. Appendix A provides the derivation of some formulas presented in the paper; Appendix B includes the proofs of the propositions and in Appendix C the robustness of results with respect to parameter variations is studied.

3.1.1 Literature Review

Macroeconomic models incorporating psychological factors are growing in number and importance; regardless of the specific formalization, the notion that individuals may be not entirely rational is often taken into account. This idea finds strong support from other disciplines as well, such as, e.g., psychoanalysis, psychology, neuroscience and sociology. In these fields over time an extensive literature has developed on how individuals make decisions by integrating their cognitive abilities with their emotional state. Furthermore, in a context of uncertainty and complexity, agents might rely on simple behavioral rules, rather than complex mathematical reasoning (cfr., among others, in psychoanalysis and psychology: Simon (1990), Gigerenzer and Todd (1999), Tuckett (2012), Lerner et al. (2015); in neuroscience: Bechara et al. (2000); in sociology: Smelser (1998)).

In macroeconomics, several theories have been proposed to incorporate such insights, some focusing on the consequences of sentiment shocks, while others on their endogenous emergence. The present paper is related to them in multiple ways exposed below.

Within the former group, in the general equilibrium literature there is a number of works that develop the notion of fluctuations driven by non-fundamental uncertainty. For instance, Angeletos and La'O (2013), Huo and Takayama (2015), Acharya et al. (2017), Angeletos et al. (2018) formalize exogenous shocks on non-fundamental higher-order beliefs in unique equilibrium models which give a central position to frictional coordination, by including strategic complementarity and lack of common knowledge. We relate to this literature by incorporating such insights on coordination issues in our model. Moreover, Benhabib et al. (2015) show that in standard economies – without informational frictions, externalities, non-convexities or strategic complementarities in production – optimal decisions based on sentiments can generate stochastic self-fulfilling RE equilibria. Such works on extraneous uncertainty are rooted in a literature developed in the 1980s on multiple equilibria and sunspots fluctuations, which aimed at reintroduce the Keynesian narrative on animal spirits and multiple equilibria in standard Real Business Cycle models (cfr. e.g. Azariadis, 1981, Cass and Shell, 1983, Cooper and John, 1988, Benhabib and Farmer, 1994). Also, various versions of the islands model have been developed to analyze a number of different issues; for example, Angeletos et al. (2020) study how the endogeneity of information contained in macroeconomic statistics and market outcomes about the state of the economy impact on optimal monetary policy. Miao et al. (2020), instead, show how smooth aggregate consumption dynamics and highly volatile equity prices can coexist in an economy with dispersed information. Mentioned papers, in general, assume rational expectations, following the long tradition initiated by the seminal contribution of Muth (1961). An exception is provided by Milani (2011), which assumes that agents learn model coefficients over time and the learning process is affected by expectations shocks.

Endogenously emerging beliefs and heterogeneous expectations have also been discussed in the economics literature. One early example applied to financial markets is the Santa-Fe Artificial Stock Market (LeBaron et al., 1997), in which traders every period select an expectation rule among a large pool of rules, based on the market conditions that they observe and on a fitness measure of the rules. A simpler approach to formalize heterogeneous expectations is provided by the Brock-Hommes model (Brock and Hommes, 1997, 1998) in which there is a finite set of simple forecasting rules among which agents can choose – e.g. naive and rational expectations. Moreover, they introduce a switching mechanism among forecasting rules, which depends on the rules'(relative) performance measure. Another approach within the field of heterogeneous expectations, known as adaptive learning or statistical learning (e.g. Evans and Honkapohja (2012)), considers agents as using the perceived law of motion of the economy as a forecasting rule and trying to learn the optimal parameters with some learning mechanism, as new realizations become available (e.g. ordinary least squares, OLS, sample autocorrelation).

In the following papers, instead, the heterogeneous expectations approach has been used to explicitly model animal spirits, as waves of optimism and pessimism. Franke and Westerhoff (2017) provide an overview of some of these models. Examples are De Grauwe (2011), in which, as in the present paper, agents can be optimistic or pessimistic about future output and inflation with respect to the rational expectations benchmark. In Anufriev et al. (2013), the authors implement the heterogeneous expectations framework of Brock and Hommes (1997) in a frictionless DSGE model to study the role of heterogeneous expectations about future inflation. They consider a simple case in which agents can choose among three expectation rules – one fundamentalist, one with a positive bias and one with a negative bias.

Furthermore, the present work is related to the following papers which consider the role of social influence. In particular, our switching mechanism is grounded on that introduced by Lux (1995), which formalizes a financial market where booms and busts are driven by the change in the number of optimistic and pessimistic investors, explicitly driven by social influence. In particular, there are chartist and fundamentalist investors and the former group is composed by optimists and pessimists. The probability of an optimist becoming pessimistic and *vice versa* depends on the difference in the shares of the two types of beliefs. Seppecher and Salle (2015) develop a macroeconomic agent-based model which incorporates an opinion model where agents can be optimistic or pessimistic, depending on their economic conditions and on the majority belief. Their sentiment dynamics combined with the economic system is able to replicate the successions of stable and unstable macroeconomic regimes. In a distinct framework, the above-mentioned Burnside et al. (2016) studies the impact of social influence on booms and busts in the housing markets. Furthermore, the role of social influence has been investigated in network models which introduce communication among agents. For example, Panchenko et al. (2013) introduce network communications into a simple asset pricing model where agents may switch between heterogeneous beliefs according to their performance. They find that an important determinant of the system stability is the latency in the information transmission, which amplifies information inefficiencies, causing greater instabilities and higher deviations in the price dynamics. Also related is the literature on the genetic algorithm (cfr. e.g. Arifovic et al. (2000), Dawid (2011)), which allows the formalization of a learning population where agents take decisions by exchanging information with others, learning from them and also exploring new opportunities. Social learning, as formalized in such models, can be interpreted as generated by social interaction within a random network, which is a way in which the present model can be interpreted.

Whereas the literature briefly illustrated above mostly consist of theoretical studies, the relevance of heterogeneous expectations is supported by the broad empirical evidence produced by authors who have focused on the one hand on survey data and on the other on laboratory experiments with human subjects. Among the former group, the above mentioned works by Alfarano et al. (2005); Lux (2009, 2012) estimate switching models among different types of attitudes or expectation rules. Moreover, Gennaioli et al. (2016) and Bordalo et al. (2020) find that expectations data are able to give account for planned and actual corporate investment, more than traditional measures of investment determinants. Furthermore, they reject the rational expectations benchmark and, instead, provide support to the extrapolative nature of expectations, consistent with the presence of overoptimism in good times and over pessimism in bad times. These findings also point out the importance of analyzing expectations data in economics. Recently, laboratory experiments with human subjects have gained importance in the study of human behavior; Assenza et al. (2014) survey works on heterogeneous expectations in macroeconomics. One interesting example is Assenza et al. (2019), which fit a heuristic switching model of Brock and Hommes (1997), extended by Anufriev and Hommes (2012), to individual as well as aggregate experimental data in a New Keynesian framework. Such empirical works, both on survey data and on experimental evidence, support the notion of heterogeneous expectations, while challenging the assumption of full rationality.

Building on the above mentioned empirical evidence and theoretical works, we try to combine insights from the general equilibrium literature focusing on coordination issues, with contributions from the literature on endogenously emerging beliefs, in particular that on animal spirits. Furthermore, we relate to those studies that incorporate the notion of social influence in order to examine sentiment dynamics and its effect on economic dynamics. Our work proposes new lens through which study endogenous beliefs and social influence in macroeconomics, by focusing on the hampering effects of frictional coordination and conflicting incentives existing in the economy. We examine whether social influence, in a context of uncertainty, can smooth these mechanisms and help agents coordinate on more efficient steady states. Thus, our contribution to the literature is twofold: first, we incorporate endogenously emerging beliefs in a stylized macro model which sheds light on uncertainty and frictional coordination; secondly, we look at social influence in order to assess its deep implications on several aspects of the economy.

3.2 The Model

The model describes an economy composed by a large number n of heterogeneous islands with different productivities. Similarly to Angeletos and La'O (2013), each island is inhabited by a locally owned firm and a single household. The former produces one good employing labor and land; the latter earns a wage by supplying labor to the local firm. Households do not save anything and they want to consume both the local good and the 'foreign' goods: this gives rise to trade among islands. Trade takes place in pairs through random matching: each period, every island is randomly matched with another one and it trades only with the selected partner[30]. Strategic complementarity arises because of the positive relationship between producers' output: higher supply from one island entails higher demand for another island. Or, seen through another lens, islands want to improve their terms of trade which are affected positively by the trading partner's output; however, they are also negatively influenced by one's own production, thus bringing about an incentive not to increase too much production with respect to the trading partner's one.

Timing of events is key. When islands take their production decisions, they are not aware of the island they have been matched with, along with her productivity and output. In particular, suppose that every period t unfolds in two different sub-periods: the 'morning' and the 'afternoon'. In the morning the random trading pairs are drawn and islands take their production and employment decisions, prior to observing their exact match and the terms of trade. Therefore, supply is determined under incomplete information about demand and islands need to form expectations on the trading partner's output level. In the afternoon islands actually meet and trade their previously determined output: households choose their consumption level of the 'home' good and the 'foreign' good and market-clearing prices are determined. Crucially, production and inputs required are decided upon in the morning based on beliefs, while revenues are obtained in the afternoon when information is complete.

Our model presents a simple economy, in which firms choose optimally the level of profits-maximizing production, households choose their consumption maximizing their utility and, finally, market-clearing prices equate the marginal utility of the two goods.

[30] We can interpret the home consumers as either being indifferent among the goods of all other islands, or as liking only the good of their current random match.

3.2.1 Households' consumption on island i

The household on island i maximizes the following utility function:

$$U_i = \Sigma_{t=0}^{\infty}\beta^t[U(c_{it}, c_{it}^*) - V(l_{it})], \tag{3.1}$$

where $\beta \in (0,1)$ is the discount factor, $c_{it} \in \mathbb{R}_+$ and $c_{it}^* \in \mathbb{R}_+$ are the consumptions of, respectively, the 'home' good and the 'foreign' good in time t. $l_{it} \in \mathbb{R}_+$ is the labor supply and $V(l)$ is the disutility of labor. U and V are given by:

$$U(c, c^*) = \left(\frac{c}{1-\eta}\right)^{1-\eta}\left(\frac{c^*}{\eta}\right)^{\eta} \qquad \text{and} \qquad V(l) = \frac{l^{\epsilon}}{\epsilon}, \tag{3.2}$$

where $\eta \in (0,1)$ is the fraction of 'home' expenditure spent on the 'foreign' good and $\epsilon > 1$ is the Frisch elasticity of labor supply. The period t budget constraint for the household's utility maximization on island i is the following:

$$p_{it}c_{it} + p_{it}^*c_{it}^* \leq w_{it}l_{it} + r_{it}K + \pi_{it}, \tag{3.3}$$

where p_{it} and p_{it}^* are the prices of the 'home' good and the 'foreign' good, respectively. w_{it} is the wage, r_{it} the rental rate of land and π_{it} profits.

The first order conditions of the utility maximization[31] are $U_{c_{it}} = p_{it}$ and $U_{c_{it}^*} = p_{it}^*$. Moreover, trade between islands has to satisfy the trade balance condition, i.e. imports and exports have to be equal: $p_{it}^*c_{it}^* = p_{it}(y_{it} - c_{it})$, where y_{it} is the production of island i. In addition, all the production must be consumed, i.e. the market clearing condition must be satisfied: $c_{it} + c_{jt}^* = y_{it}$, where c_{jt}^* is the import in island j of the good produced on i. Combining these conditions, together with their corresponding version for i's trading partner j, we obtain the following results:

$$c_{it} = (1-\eta)y_{it}, \qquad c_{it}^* = \eta y_{jt} \qquad \text{and} \qquad p_{it} = y_{it}^{-\eta}y_{jt}^{\eta}. \tag{3.4}$$

From the above we can observe at the individual level the source of the strategic complementarity in our model. In particular, as shown in equation (3.4), a rise in y_{jt} increases the import of the 'foreign' good c_{it}^*, which raises the 'home' good's marginal utility and, in turn, its price. An increase in the price of island i's good can also be interpreted as an improvement of island i's terms of trade. In fact: $\frac{p_{it}}{p_{jt}} = \frac{y_{jt}}{y_{it}} = p_{it}^{\frac{1}{\eta}}$, which is an increasing function of p_{it}.

[31] After normalizing the local nominal prices so that the Lagrange multiplier $\lambda_{it} = 1$. See Angeletos and La'O (2013) for the proofs of the results in the present section.

3.2.2 Production on island i

Firms take production and employment decisions in the first stage of every period, when they still do not know the trading partner with which they have been matched with.

Island i's firm produces the local good, employing labor and land, with the following technology:

$$y_{it} = A_i l_{it}^{\Theta} k_{it}^{1-\Theta}, \tag{3.5}$$

where A_i is the local total factor productivity, which is formalized as a continuous random variable lognormally distributed[32]: $A_i \sim \log N(0, \sigma_A^2)$, with $\sigma_A > 0$. l_{it} and k_{it} are the labor and land input, respectively, and $\Theta \in (0,1)$ parametrizes the income share of labor. All islands are endowed with a fixed amount of land K.

Firms choose l_{it}, k_{it}, w_{it} and r_{it} optimally. In the labor market, the equilibrium wage is the wage which equates the marginal disutility of working with the marginal revenues of labor for the firm:

$$V'(l_{it}) = w_{it} = \mathbb{E}_{it}[p_{it}]\Theta \frac{y_{it}}{l_{it}}, \tag{3.6}$$

where $\mathbb{E}_{it}[p_{it}]$ is the expectation of island i on price p_{it}, which we will discuss in details later. The resulting optimal amount of labor input is given by $l_{it}^{*} = (\mathbb{E}_{it}[p_{it}]\Theta y_{it})^{\frac{1}{\epsilon}}$.

As regards land, in equilibrium $k_{it}^{*} = K$, i.e. firms employ the total amount of land disposable on each island; thus, we set $K = 1$.

By inserting the optimal amount of labor in (3.5) and recalling that $p_{it} = y_{it}^{-\eta} y_{jt}^{\eta}$ and, thus, $\mathbb{E}_{it}[p_{it}] = y_{it}^{-\eta}\,\mathbb{E}_{it}[y_{jt}^{\eta}]$, we obtain the equilibrium level of output for island i:

$$y_{it} = K_1^{\alpha} A_i^{\alpha} [\mathbb{E}_{it}(y_{jt}^{\eta})]^{\theta\alpha}, \tag{3.7}$$

where $K_1 \equiv (\Theta^{\theta})$, $\theta \equiv \frac{\Theta}{\epsilon} \in (0,1)$ and $\alpha \equiv \frac{1}{1-\theta+\eta\theta}$.

Equation (3.7) expresses that the equilibrium output of a producer is an increasing function of her productivity and of her expectation about the trading partner's output. In fact, higher productivity lowers the cost of producing and a higher supply by trading partners translates to higher demand for one's own production (or, equivalently, better terms of trade). $\eta\theta\alpha \in (0,1)$ represents the degree of the strategic complementarity. Equation (3.7) might be interpreted as the best response function in a two-player

[32] Whereas in the initial characterization of the model and in the section on the switching mechanism we describe the economy as being composed by a large number n of islands, here we approximate n to a continuum of islands, in order to simplify some computations in the next sections. For $n \to \infty$, the approximation error goes to zero.

game: the players are the islands within a match and their actions are the amount of production. Nevertheless, this is a macro model in which islands are infinitesimal price takers and the complementarity is an outcome of competitive market interactions.

3.3 Endogenous beliefs and switching mechanism

Production decisions depend on islands' expectations about their match, i.e. $\mathbb{E}_{it}(y_{jt}^{\eta})$.

This is where we want to capture the idea of 'animal spirits', that is, optimism and pessimism, being driven not only by economic variables but also by social influence.

3.3.1 Three types of endogenous belief

We consider three types of beliefs: neutral, optimistic and pessimistic. First, we formally define the former which will be used as a benchmark to define the others[33]. In particular, every island knows that the equilibrium output level expressed by equation (3.7) indicates the production behavior of all agents in the economy. Therefore, they form their expectations precisely of equation (3.7) – as applied to another generic island –, which is made of two parts. On the one hand there are the technology related terms[34]; on the other hand, there is the other island's belief of her partner's output level. By assuming that the former are common knowledge[35], the remaining unknown term of which the island has to form expectations is her trading partner's beliefs, which involves an infinite hierarchy of higher-order beliefs. In order to find a neutral expectation benchmark, we assume that an island i has neutral expectations when her n-order belief is correct. Indeed, for any order n, this assumption allows the hierarchy of beliefs to collapse to the true fundamental. Hence, the neutral belief benchmark reads:

$$\mathbb{E}_n(y_{jt}^{\eta}) = K_1^{\eta\gamma}\,\mathbb{E}(A_i^{\eta\alpha})^{\frac{\gamma}{\alpha}} \tag{3.8}$$

where the subscript n stands for neutral, $\gamma \equiv \frac{1}{1-\theta}$ and $\frac{\gamma}{\alpha} \in (1,\infty)$[36].

The optimistic and pessimistic beliefs are defined as follows:

$$\mathbb{E}_{it}(y_{jt}^{\eta}) = \begin{cases} \mathbb{E}_n(y_{jt}^{\eta})(1+\delta) & \text{if } i \text{ is optimistic}(i=o) \\ \mathbb{E}_n(y_{jt}^{\eta})(1-\delta) & \text{if } i \text{ is pessimistic}(i=p) \end{cases} \tag{3.9}$$

[33] Here we just provide an intuition of how we define the neutral belief benchmark; see Appendix 3.A.2 for the full formal derivation.

[34] These include: K_1, α and $\mathbb{E}(A_i^{\eta\alpha})$.

[35] The values of K_1 and α are known, whereas with regard to islands' productivity, the distribution of A_i is common knowledge, rather than its specific realizations.

[36] $\frac{\gamma}{\alpha} \equiv \frac{1-\theta+\eta\theta}{1-\theta}$.

where $\delta \in (0,1)$ represents the degree of optimism or pessimism. Although the degree of optimism and pessimism of agents is likely to vary over time, or based on the encounters made, we assume an exogenously fixed δ for reason of simplicity.

The idea behind the deviation of δ from the neutral belief is that an optimistic (pessimistic) island i thinks that the trading partner j overestimates (underestimates) her own belief. In other words, an optimistic (pessimistic) island is an island which believes that her future trading partner will be optimistic (pessimistic) and therefore will produce more (less) than the neutral benchmark; as a consequence, island i will in turn produce more (less). In fact, we observe what follows.

Output for the three types of islands By substituting equation (3.9) into (3.7), we obtain the optimal output for the different types of island:

$$y_i = \begin{cases} K_1^\gamma A_i^\alpha \, \mathbb{E}[A_j^{\eta\alpha}]^{\theta\gamma} & \text{if } i \text{ is neutral } (i = n) \\ K_1^\gamma A_i^\alpha \, \mathbb{E}[A_j^{\eta\alpha}]^{\theta\gamma}(1+\delta)^{\theta\alpha} & \text{if } i \text{ is optimistic } (i = o) \\ K_1^\gamma A_i^\alpha \, \mathbb{E}[A_j^{\eta\alpha}]^{\theta\gamma}(1-\delta)^{\theta\alpha} & \text{if } i \text{ is pessimistic } (i = p) \end{cases} \tag{3.10}$$

We can observe that, also with regard to production, optimists' and pessimists' output are positive and negative deviations, respectively, from the output of a neutral island. The size of this deviation is $(1+\delta)^{\theta\alpha}$ for the optimists and $(1-\delta)^{\theta\alpha}$ for the pessimists, where $\theta\alpha$ is the weight given by an island to the expectation of the trading partner's deviation from the neutral benchmark.

It is interesting to note the following proposition about the neutral belief.

Proposition 1 *When every island in the economy is neutral, the neutral belief $\mathbb{E}_n(y_j^\eta)$ corresponds to the expected output of neutral islands $\mathbb{E}(y_n^\eta)$. Therefore, in this case, neutral islands have rational expectations.*[37]

$$\mathbb{E}_n(y_j^\eta) = K_1^{\eta\gamma} \, \mathbb{E}(A_i^{\eta\alpha})^{\frac{\gamma}{\alpha}} = K_1^{\eta\gamma} \, \mathbb{E}(A_i^{\eta\alpha})^{\eta\gamma\theta} \int_0^{+\infty} A_i^{\eta\alpha} dF(A_i) = \mathbb{E}(y_n^\eta), \tag{3.11}$$

where on the left hand side there is the neutral belief and on the right hand side there is the expected value of neutral islands' production[38].

Therefore, all islands being neutral reminds an economy under complete information in which all agents share the same information about one another, there is no higher-order uncertainty and beliefs only depend on true fundamentals.

[37] See section 3.B.1 for a proof.

[38] The same proposition does not hold for the neutral belief on y_j, which, when all islands are neutral, does not equal $\mathbb{E}(y_n)$.

By contrast, an economy populated by different belief types, can be thought as being under incomplete information, in which islands face uncertainty about one another's beliefs and actions. As a result, coordination is imperfect and islands make mistakes in their evaluations of others' beliefs.

Proposition 1 does not hold for the other types of island; in fact, from equation (3.10) we obtain optimists' and pessimists' expected production[39]:

$$\mathbb{E}(y_i^\eta) = \begin{cases} \mathbb{E}(y_n^\eta)(1+\delta)^{\theta\alpha\eta} & \text{if } i \text{ is optimistic}(i=o) \\ \mathbb{E}(y_n^\eta)(1-\delta)^{\theta\alpha\eta} & \text{if } i \text{ is pessimistic}(i=p), \end{cases} \tag{3.12}$$

which shows that optimistic (pessimistic) islands systematically overestimate (underestimate) optimists' (pessimists') expected production[40]. The reason lies in the degree of strategic complementarity.

Profits Profit function of an island i trading with an island j in period t is given by[41]

$$\pi_{ij} = y_i^{1-\eta}(y_j^\eta - \mathbb{E}_i(y_j^\eta)) \tag{3.13}$$

and thus depends on the type and productivity of i and j. Equation (3.13) is key to understand islands' motivations to lower their beliefs as it shows how uncertainty and strategic complementarity shape individual incentives. In particular, i's belief on the trading partner's output enters in equation (3.13) with a negative sign. The intuition is that production takes place in the morning while ignoring future terms of trade and, therefore, the determination of input requirements and thereby total wages depend on beliefs. Simultaneously, low expectations on j's output allow island i to improve her terms of trade. Therefore, what islands expect the trading partner's output to be has a negative impact on their profits and here the incentive to lower each one's own beliefs arises.

In a certain period t, an island can meet all the three types of trading partners and with each of them it will earn different profits. The population of our economy is made of neutral, pessimistic and optimistic islands, each with its own share of population: n_n, n_p and n_o, respectively[42]. Thus, expected profits of an island i are given by the sum of the expected profits that it earns trading with each expectation type multiplied

[39] Recalling from Proposition 1 that $\mathbb{E}_n(y_j^\eta) = \mathbb{E}(y_n^\eta)$

[40] The reason is that $\theta\alpha\eta \in (0,1)$, which implies $1+\delta > (1+\delta)^{\theta\alpha\eta}$ and $1-\delta < (1-\delta)^{\theta\alpha\eta}$.

[41] See section 3.A.3 for its derivation.

[42] Population shares vary over time; however, in the equations below, we ignore the subscript t to lighten notation.

by its shares. Considering a neutral i, her average profits are given by

$$\begin{aligned}\mathbb{E}(\pi_{n,t}) = \mathbb{E}\left(y_n^{(1-\eta)}\right)\mathbb{E}(y_n^{\eta})\Big[& n_p\left[(1-\delta)^{\theta\eta\alpha}-1\right] \\ & +n_n\left[1-1\right] \\ & +n_o\left[(1+\delta)^{\theta\eta\alpha}-1\right]\Big]\end{aligned} \tag{3.14}$$

Similarly, we derive average profits of pessimists and optimists[43].

In what follows we use the notation $\bar{\pi}_{r,s}$ to indicate the average profits of islands of type 'r' trading with islands of type 's', with $r, s = \{p, n, o\}$.

Expected profits of neutral islands trading with neutral islands It follows from (3.13) and $\mathbb{E}_n(y_j^{\eta}) = \mathbb{E}(y_n^{\eta})$ that neutral islands earn zero expected profits when matched with another neutral agent, i.e.

$$\bar{\pi}_{n,n} = 0. \tag{3.15}$$

The reason is that, when an island correctly guesses the trading partner's output distribution, their interaction is similar to that among agents in a perfectly competitive economy and, thus, firms will produce until their marginal cost equals the expected price – which, under rational expectations, is known – which, in turn, equals firms' average costs, driving profits to zero. Under incomplete information, instead, there are opportunities for positive profits depending on islands' beliefs, as shown in equation (3.13). Of course, the profits earned by each island individually can diverge from the expected profits of their type, mainly because of their productivity level as well as that of their trading partner.

3.3.2 Switching mechanism

We capture the sentiment dynamics in the economy through a switching model of beliefs similar to Lux (1995), which, as mentioned in the Introduction, has been successfully estimated in different frameworks, both in financial markets and with data on business sentiment. In particular, when applied to sentiment measures (e.g. Lux (2009)), it sheds light on the importance of social interaction in determining fluctuations among optimism and pessimism.

We are interested in the dynamics of the shares of the different types of island,

[43]See section 3.A.4 in Appendix A.

that is, $\dot{n}_p$, $\dot{n}_n$ and $\dot{n}_o$. Since we are working with an infinitely large population, the random effects disappear and we obtain a deterministic formulation of the dynamics of the inflows and outflows into and from the different attitudes. For instance, the share of pessimistic islands evolves as follows:

$$\dot{n}_p = n_n q_{np} + n_o q_{op} - n_p q_{pn} - n_p q_{po}, \tag{3.16}$$

where q_{np} and q_{pn} are the transition rates from the neutral belief to the pessimistic belief and *vice versa*, respectively. The idea is that the share of pessimistic islands in one period is given by the inflows from the two other types into the pessimistic group, minus the outflows from the pessimistic attitude to the two other types. Likewise, the evolution of the share of neutral and optimistic islands are defined.

With regards to the transition rates[44] from one attitude to another, they depend on the one hand on the economic payoffs of the different types and, on the other, on the observation of the others' beliefs – as mentioned, both of them are public knowledge. For example, q_{pn}, the transition rate from the pessimistic to the neutral belief, reflects the fact that the higher the difference of expected profits made by neutral and pessimistic islands, or the higher the difference between the shares of the neutral and pessimistic beliefs, the more likely it is that a pessimistic island turns neutral. Therefore, q_{pn} is positively related to $\mathbb{E}(\pi_{n,t}) - \mathbb{E}(\pi_{p,t})$ and to $n_n - n_p$. These same variables enter with a negative sign into q_{np}, the transition rate from the neutral to the pessimistic belief.

Furthermore, the transition rates include a parameter for the speed of switching, v, which captures changes of attitude due to factors not taken into account by the model[45]. In what follows we use $\bar{\pi}_{r-s,t}$ to identify the difference between the expected profits made by r and those made by s. Hence, a general transition rate from type r to type s reads:

$$q_{rs}(n_p, n_n, n_o) = v \exp(a_0 \bar{\pi}_{r-s,t}(n_p, n_n, n_o) + a_1(n_s - n_r)) \quad \text{for } r \rightarrow s, \tag{3.17}$$

where $r, s = \{p, n, o\}$.[46]

[44]For reasons of analytical tractability we use a continuous time formulation of the switching model, which is interpreted as the limit of the discrete time version with the length of a period Δt going to zero. See section 3.A.5 of the Appendix for the derivation of our continuous dynamics model from its discrete time version.

[45]The inclusion of $v > 0$ guarantees that some changes in the beliefs happen even when the difference between expected profits of the two types and the difference between their shares equal zero: $q_{rs}(z) = q_{sr}(z) = v > 0$

[46]With regards to this functional relationship, it implies that the relative changes of the transition

The coefficient a_0 represents the strength of the impact of the difference between the two types' expected profits on the transition rates. The higher a_0, the more importance is given by the islands to the profits earned by each type. a_1 is the impact of the composition of the different beliefs in the economy on the transition rates. This parameter measures the importance of social influence in the model. The higher a_1, the more attention islands give to others' attitude and the more likely it is that each island imitates the predominant belief. When a_0 and a_1 are 0, the transition rates in both directions equal v, which means that they are determined only by the speed of switching.

3.4 Sentiment dynamics

3.4.1 No social influence

As a benchmark we first study the sentiment dynamics in the absence of social influence.

Since restricting the attention to two types increases the analytical tractability of the model, as a first step we consider an economy composed only by neutral and pessimistic islands.

Pessimistic and neutral expectations

In an economy with two types of belief, the composition of the population can be expressed by an 'opinion index', that is, the difference between the share of neutral and pessimistic islands: $x = n_n - n_p$. $x \in [-1, 1]$; therefore, if $x = 0$, the economy is in a balanced situation, $x > 0$ represents an economy characterized by a predominance of neutral islands and $x < 0$ implies that more islands are pessimistic. The extreme cases are $x = -1$, where all islands are pessimistic, and $x = 1$ where all islands are neutral and, importantly, all agents in the economy have rational expectations.

In order to analyze the dynamics of the population shares of such an economy, we can explore the dynamic behavior of x in a one-dimensional system. Considering that $\frac{x+1}{2} = n_n$ and $\frac{1-x}{2} = n_p$, we can write it as follows:

$$\dot{x} = (1 - x)q_{pn} - (1 + x)q_{np}. \tag{3.18}$$

rates with respect to the variables mentioned above are linear and symmetrical, following Haag and Weidlich (1983) and Lux (1995). This means that, considering a general transition rate $q_{rs}(z)$ from a belief 'r' to a belief 's', which depends on a variable z, we want that $\frac{dq_{rs}(z)/dz}{q_{rs}(z)} = Az$ and $\frac{dq_{sr}(z)/dz}{q_{sr}(z)} = -Az$, for some constant A.

The transition rates can be expressed as functions of x as well:

$$\begin{aligned} q_{pn}(x) &= v\exp(a_0\bar{\pi}_{n-p,t}(x) + a_1 x) && \text{for pessimistic to neutral;} \\ q_{np}(x) &= v\exp(-a_0\bar{\pi}_{n-p,t}(x) - a_1 x) && \text{for neutral to pessimistic.} \end{aligned} \tag{3.19}$$

If we plug (3.19) in (3.18)[47], we obtain the following differential equation:

$$\dot{x} = 2v[\tanh(a_0\bar{\pi}_{n-p}(x) + a_1 x) - x]\cosh(a_0\bar{\pi}_{n-p}(x) + a_1 x). \tag{3.20}$$

Absence of social influence implies that $a_1 = 0$ and the switching mechanism is driven only by the difference in the average profits made by neutral and pessimistic islands, which is shown in figure 3.9 in Appendix C for different parameter constellations.

Difference between expected profits of neutral and pessimistic islands The difference between the average profits of neutral and pessimistic islands, $\bar{\pi}_{n-p}(x)$, is a linear function of x and it is given by

$$\begin{aligned} \bar{\pi}_{n-p,t}(x) = \mathbb{E}\left(y_n^{(1-\eta)}\right)\mathbb{E}(y_n^{\eta})\Bigg[& \frac{1-x}{2}\left[(1-\delta)^{\theta\eta\alpha} - 1\right] \\ & + \frac{x+1}{2}\left[1-1\right] \\ & - \frac{1-x}{2}(1-\delta)^{\theta(1-\eta)\alpha}\left[(1-\delta)^{\theta\eta\alpha} - (1-\delta)\right] \\ & - \frac{x+1}{2}(1-\delta)^{\theta(1-\eta)\alpha}\left[1-(1-\delta)\right]\Bigg]. \end{aligned} \tag{3.21}$$

From this we obtain the following proposition:

Proposition 2 *For $\delta > 0$, expected profits of pessimistic islands are always higher than those of neutral islands.*

$$\bar{\pi}_{n-p}(x) < 0, \qquad \text{for any } x. \tag{3.22}$$

In fact, the profit function of equation (3.13) shows that, in order for the profits to be positive, the belief of i should be lower than j's expected output. Consider the case in which island i is pessimistic and trades with j which is neutral: we have that $\mathbb{E}_n(y_j^{\eta}) > \mathbb{E}_n(y_j^{\eta})(1-\delta)$. This means that pessimists on average are better off than

[47] Recall that $\exp(y) - \exp(-y) = \sinh(y)$, $\exp(y) + \exp(-y) = \cosh(y)$ and $\frac{\sinh(y)}{\cosh(y)} = \tanh(y)$.

neutral islands because they underestimate neutral islands' expected production. This allows them to simultaneously improve their terms of trade and reduce their costs by producing less. In a sense, even though islands are price takers which behave optimally given their belief, pessimists act as they were monopolists able to shift the price in their favor. This is possible only in the presence of higher-order uncertainty, which creates room for making positive profits. Here lies the basis of the trade off between individual and social outcomes emerging in the presence of uncertainty, as we will deepen in section 3.5. Interestingly, the same happens also when a pessimist trades with another pessimist: $\mathbb{E}_n(y_j^\eta)(1-\delta)^{\alpha\theta\eta} > \mathbb{E}_n(y_j^\eta)(1-\delta)$, which is always true because $\eta\theta\alpha$ is smaller than one. In other words, the latter result implies that pessimistic islands are 'too pessimistic', since they systematically underestimate even the pessimists' production[48]. Again, individual islands' profits can diverge from the average profits of their type thanks to their productivity level and that of their trading partner. Finally, it is worth noting that the fact that pessimists are on average better off than neutral islands simply emerges from letting islands switch between different types of belief based on their relative profitability.

Figure 3.1 illustrates the sentiment dynamics of (3.20) in the absence of social influence, for different levels of a_0 and for the parameters shown in table 3.1, which are consistent with a more sophisticated version of the present model – without endogenous beliefs and with capital accumulation –, presented by Angeletos and La'O (2013) as a variant of the Real Business Cycle model[49]. All the dynamics and variables presented in the main body of the paper are studied under this set of parameters. In Appendix C the robustness of results with respect to parameter variations is studied.

Steady state Without social influence, (3.20) is continuous and monotonically decreasing; in $x = -1$ it is positive and in $x = 1$ it is negative, therefore the solution exists, it is unique and it is globally stable. In particular, the fixed point is given by:

$$\tanh(a_0 \bar{\pi}_{n-p}(x)) = x, \tag{3.23}$$

[48]For $\delta \geq 0$, $\bar{\pi}_{n-p}(x)$ is an non decreasing function of x: although both types of island are better off – *ceteris paribus* – by meeting a neutral island rather than a pessimistic one, the advantage for neutral islands exceeds that for pessimistic ones. Thus, when all islands in the economy are neutral, that is, for $x = 1$, the absolute value of the difference of expected profits of neutral and pessimistic islands is minimized.

[49]These parameters are also consistent with King and Rebelo (1999), except for δ, η and v. In their model, $\eta = 1$, δ and v are not included since they assume rational expectations and do not have differential equations. From these parameters it follows that: $K1 \equiv (\Theta^\theta)(K^{(1-\Theta)}) = 0.869$, $\alpha \equiv \frac{1}{1-\theta+\eta\theta} = 1.194$, $\gamma \equiv \frac{1}{1-\theta} = 1.481$ and the degree of strategic complementarity $\eta\alpha\theta = 0.194$.

Table 3.1: Parameters of the model

Parameter	Value
K	1
Θ	0.65
ϵ	2
$\theta \equiv \frac{\Theta}{\epsilon}$	0.325
η	0.5
δ	0.3
σ	0.038
v	0.5

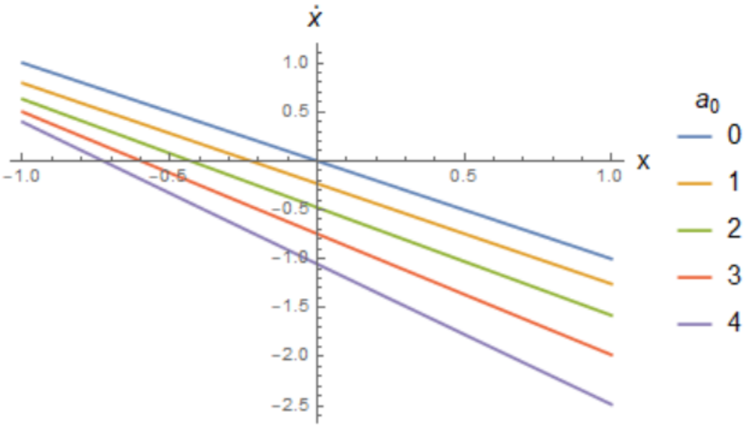


Figure 3.1: Dynamics of $\dot{x}$ without social influence. See the equilibrium points in table 3.2.

which implies $a_0 = 0$ and $x = 0$. Otherwise, if $a_0 \neq 0$, it must hold that $\frac{e^{a_0 \bar{\pi}_{n-p}(x)} - e^{-(a_0 \bar{\pi}_{n-p}(x))}}{e^{a_0 \bar{\pi}_{n-p}(x)} + e^{-(a_0 \bar{\pi}_{n-p}(x))}} = x$, which has no analytical solution. We can see from figure 3.1 that for $a_0 = 0$ the economy is in a balanced situation and the dynamics is driven by v alone, which is the speed of switching, whose idea is to incorporate those reasons for switching not included in the model.

For $a_0 \geq 0$, the dynamics will converge to a pessimistic equilibrium, far from the rational expectations steady state. Therefore, we have the following proposition:

Proposition 3 *Rational expectations are not stable in our trade economy characterized by strategic complementarity and uncertainty.*

The reason for this shift away from $x = 1$ lies in the fact that, for $a_0 \neq 0$, islands take into account that the pessimistic islands on average make higher profits than the neutral ones, the reason being the better terms of trade and the lower costs of pessimists[50].

[50]Furthermore, even for $a_0 = 0$, $x^* = 1$ is unstable because of the transition rates which are symmetric and linear in their relative changes with respect to each other. Therefore, in the absence of factors (unequally) influencing the switching between the different expectation types, the system

Table 3.2: Equilibrium points of the dynamics shown in figure 3.1.

	Equilibrium points	Derivative at the equilibrium
$a_0 = 0$	$x^* = 0$	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1
$a_0 = 1$	x^* = -0.2259	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0248
$a_0 = 2$	x^* = -0.4305	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.1046
$a_0 = 3$	x^* = -0.5991	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.2445
$a_0 = 4$	x^* = -0.7274	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.4523

Proposition 3 is interesting in that it shows the instability of rational expectations when taking into account heterogeneous beliefs in a context characterized by frictional coordination. Moreover, it sheds light on the fact that under frictional coordination, individuals might be better off by having a pessimistic attitude and thus avoiding new investment which involves a cost and is too risky in an uncertain environment. It is possible that by switching from a pessimistic to a neutral attitude, increasing as a consequence her production level, an island earns higher profits, depending on her productivity level and on that of her trading partner; nevertheless, there is a considerable risk of making losses, given that on average neutral agents are worse off than pessimists. Hence, it is interesting to understand under which conditions agents are prone to abandon their pessimistic state and increase their production; as we will see below, social interaction plays a crucial role in determining different and potentially better equilibria. It is worth mentioning that the fact that expected profits of neutral islands are negative only depends on the deviation δ of the pessimistic expectation from the neutral benchmark which, however, seems to be a quite straightforward and general way to define the different beliefs. The convergence towards pessimistic fixed points, hence, simply emerges as a consequence of allowing agents to switch belief based on the expected profits of each type.

Pessimistic, neutral and optimistic expectations

In an economy which includes optimistic islands as well, the population composition can be represented by the shares of optimists and of pessimists: n_o and n_p, respectively. n_n, instead, is given by $1 - n_p - n_o$. The transition rates are of the form shown in

converges to a balanced equilibrium where the shares of neutral and pessimistic islands are equal[51].

equation (3.17) with $a_1 = 0$ and the dynamics of n_p and n_o is given by:

$$\begin{aligned}\dot{n}_p &= (n_n)v\exp(-a_0\bar{\pi}_{n-p,t}(n_p,n_o)) + n_o v\exp(-a_0\bar{\pi}_{o-p,t}(n_p,n_o))\\ &\quad - n_p v\exp(a_0\bar{\pi}_{n-p,t}(n_p,n_o)) - n_p v\exp(a_0\bar{\pi}_{o-p,t}(n_p,n_o));\\ \dot{n}_o &= (n_n)v\exp(a_0\bar{\pi}_{o-n,t}(n_p,n_o)) + n_p v\exp(a_0\bar{\pi}_{o-p,t}(n_p,n_o))\\ &\quad - n_o v\exp(-a_0\bar{\pi}_{o-n,t}(n_p,n_o)) - n_o v\exp(-a_0\bar{\pi}_{o-p,t}(n_p,n_o)).\end{aligned} \tag{3.24}$$

Figure 3.2 shows the isoclines of such a system for different levels of a_0. The equilibrium points are listed in table 3.3.

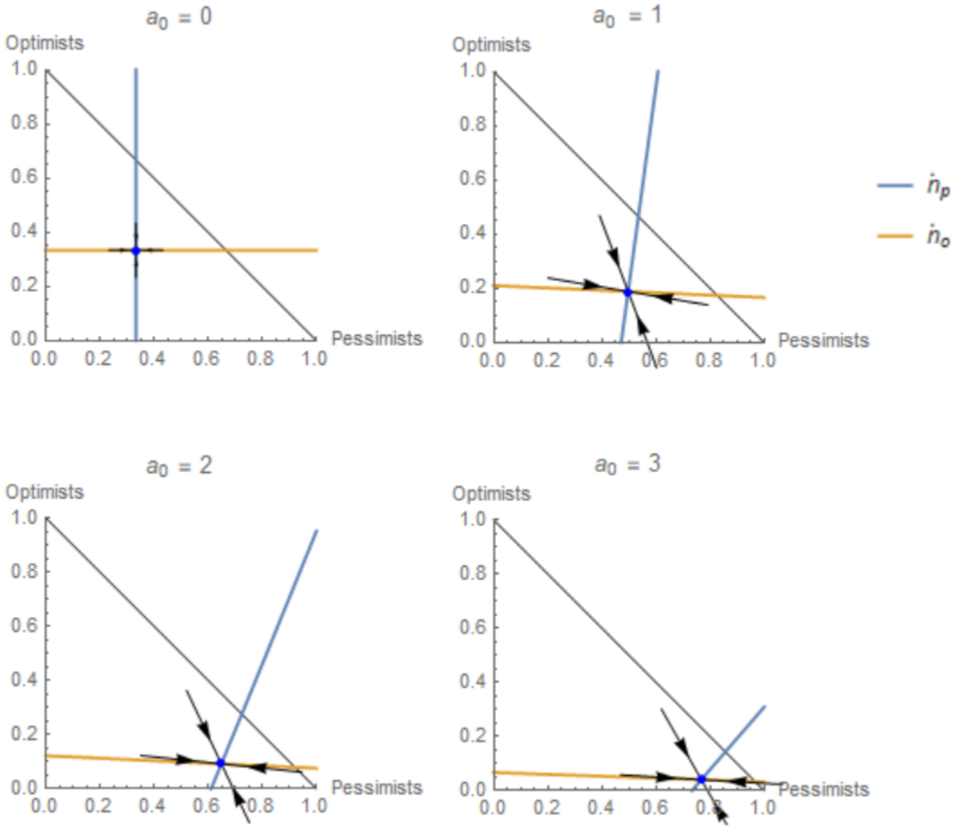


Figure 3.2: Phase portrait of the dynamics for the parameters listed in table 3.1, without social influence and for different a_0's. Inward arrows indicate the stable manifolds.

In the absence of social influence, the two-dimensional system behaves similarly to the one-dimensional dynamics. With no sensitivity to economic outcomes, the system converges to a situation in which the same number of islands are neutral, optimistic and pessimistic. As a_0 increases, more and more islands become pessimistic. The fixed

Table 3.3: Equilibrium points of the dynamics shown in figure 3.2.

	Equilibrium points	Eigenvalues	Eigenvectors
$a_0 = 0$	$(n_p^*, n_o^*) = (0.3333,\ 0.3333)$	λ_1 =-1.5	$v_1 = (0,\ 1)$
		λ_2 =-1.5	$v_2 = (1,\ 0)$
$a_0 = 1$	$(n_p^*, n_o^*) = (0.4974,\ 0.1879)$	λ_1 =-1.8139	$v_1 = (-0.3524,\ 0.9359)$
		λ_2 =-1.3610	$v_2 = (0.9860,\ -0.1666)$
		λ_2 =-1.3438	$v_2 = (0.9948,\ -0.1015)$
$a_0 = 3$	$(n_p^*, n_o^*) = (0.7667,\ 0.0408)$	λ_1 =-3.4151	$v_1 = (-0.4925,\ 0.8703)$
		λ_2 =-1.4233	$v_2 = (0.9983,\ -0.0577)$

point of the system is stable, as clear from the negative eigenvalues. The reason for the convergence to a situation dominated by pessimistic islands lies in expected profits of the different types. In particular, as shown in the two types setting, pessimistic islands earn higher expected profits than neutral ones, which holds true in the three expectations framework as well. Analogously, expected profits of neutral islands are greater than those of optimists, as clarified in what follows.

Difference between expected profits of optimistic and neutral agents The difference between expected profits of an optimistic and a neutral island, $\bar{\pi}_{o-n}(p, o)$, is given by

$$\begin{aligned}\bar{\pi}_{o-n,t}(n_p, n_o) = \mathbb{E}\left(y_n^{(1-\eta)}\right)\mathbb{E}(y_n^{\eta})\Big[& n_n(1+\delta)^{\theta(1-\eta)\alpha}\left[1-(1+\delta)\right] \\ & + n_o\,(1+\delta)^{\theta(1-\eta)\alpha}\left[(1+\delta)^{\theta\eta\alpha}-(1+\delta)\right] \\ & - n_n\left[1-1\right] \\ & - n_o\left[(1+\delta)^{\theta\eta\alpha}-1\right]\Big].\end{aligned} \tag{3.25}$$

It is worth noting the following proposition:

Proposition 4 *For $\delta > 0$, expected profits of a neutral island are always greater than those of an optimistic island.*

$$\bar{\pi}_{o-n}(n_p, n_o) < 0, \qquad \text{for any } n_p \text{ and } n_o. \tag{3.26}$$

In fact, first line of equation (3.25) shows that expected profits of an optimistic island trading with a neutral one are negative. Moreover, the expected profits of an optimist trading with another optimist are negative, too, because of the degree of strategic complementarity. In general, optimists overestimate expected output of every type of island and, thus, earn the lowest expected profits. It follows that expected profits of pessimists are also higher than those of optimists.

3.4.2 Dynamics with social influence

Let us consider the case in which islands observe what others think and do and eventually imitate them. In formal terms, this implies $a_1 > 0$, that is, social influence is positive and affects the transition rates.

Pessimistic and neutral expectations

The dynamics of an economy populated by pessimistic and neutral islands is given by

$$\dot{x} = 2v[\tanh(a_0\bar{\pi}_{n-p}(x) + a_1 x) - x]\cosh(a_0\bar{\pi}_{n-p}(x) + a_1 x), \tag{3.27}$$

which is shown in figure 3.3, for $a_0 = 1$. The equilibrium points of the different dynamics shown here are listed in table 3.4

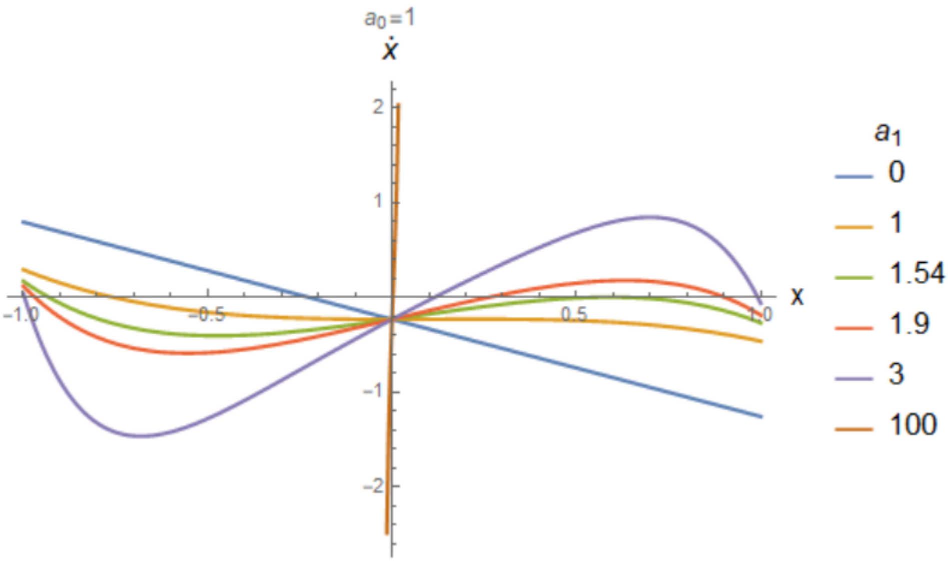


Figure 3.3: Dynamics of the economy with different levels of social influence; with the parameters shown in table 3.1.

Table 3.4: Equilibrium points of the dynamics shown in figure 3.3.

	Equilibrium points	Derivative at the equilibrium
$a_1 = 0$	x^* = -0.2259	$\frac{d(\dot{x})}{dx}\vert_{x^*}$ = -1.0248
$a_1 = 1$	x^* = -0.7560	$\frac{d(\dot{x})}{dx}\vert_{x^*}$ = -0.8720
$a_1 = 1.5357$	x_1^* = -0.9302 x_2^* = 0.5893	$\frac{d(\dot{x})}{dx}\vert_{x^*}$ = -2.1593 $\frac{d(\dot{x})}{dx}\vert_{x_2^*}$ = 0.0000
$a_1 = 1.9$	x_1^* = -0.9688 x_2^* = 0.2613 x_3^* = 0.9029	$\frac{d(\dot{x})}{dx}\vert_{x_1^*}$ = -3.5613 $\frac{d(\dot{x})}{dx}\vert_{x_2^*}$ = 0.7998 $\frac{d(\dot{x})}{dx}\vert_{x_3^*}$ = -1.5088
$a_1 = 3$	x_1^* = -0.9968 x_2^* = 0.1149 x_3^* = 0.9918	$\frac{d(\dot{x})}{dx}\vert_{x_1^*}$ = -12.3168 $\frac{d(\dot{x})}{dx}\vert_{x_2^*}$ = 1.9753 $\frac{d(\dot{x})}{dx}\vert_{x_3^*}$ = -7.4532
$a_1 = 100$	x_1^* = -1 x_2^* = 0.0053 x_3^* = 1	$\frac{d(\dot{x})}{dx}\vert_{x_1^*} = -2.3856 * 10^43$ $\frac{d(\dot{x})}{dx}\vert_{x_2^*}$ = 99.0514 $\frac{d(\dot{x})}{dx}\vert_{x_3^*} = -8.4157 * 10^42$

Steady states The dynamics shown in equation (3.27) is a continuous function of x, which takes positive values for $x = -1$ and negative values for $x = 1$; therefore, it has at least one solution. It is not analytically solvable whether and for which values the dynamics is monotonically decreasing.

We can study its behavior by analyzing its representation in figure 3.3, where $a_0 = 1$ and a_1 varies as shown. The blue line represents the case in which there is no social influence; here the solution is unique, x^* = -0.23, the fixed point is globally stable and the economy is made of 38.71% neutral islands and 61.30% pessimistic islands. By increasing the importance of social influence at $a_1 = 1$, the unique stable equilibrium shifts to the left, leading even more islands to become pessimistic. Hence, social influence, in this case, amplifies the number of pessimistic islands. The reason is that in the absence of social influence, islands, as illustrated above, prefer to adopt a pessimistic attitude which protects them from the risks involved in increasing production. Low values of a_1 strengthen this dynamic, for the few neutral agents observe that the majority is pessimistic and,hence, decide to imitate the prevailing sentiment.

However, if we increase social influence to 1.5357, as the green line of figure 3.3 shows, the negative stable equilibrium shifts even more to the left and we observe a qualitative change in the dynamics. In fact, a new equilibrium arises, $x_2^* = 0.59$, which is a critical point in which a fold bifurcation occurs. Indeed, we observe that with $a_1 = 1.9$, the system has three equilibria: one which is negative and locally stable, where almost all islands are pessimistic; on the positive x-axis, there are two equilibria. One of them is unstable, the other one, $x_3^* = 0.9029$, characterized by 95.15% neutral islands, gets closer to the rational expectations scenario and is locally stable. This type of dynamics states that, assuming that the economy is initially made of half neutral and half pessimistic islands, over time more neutral islands will turn pessimistic until the latter type constitutes 98.44% of the population. However, if the initial situation is characterized by, e.g., 70% neutral islands, over time the economy will be composed almost only of them.

With further increments in a_1, the dynamics does not change qualitatively anymore; in fact, with $a_1 = 3$, there are again three fixed points of the same nature as in the previous case. With a growing social influence, what changes is that two locally stable fixed points converge towards the uniform states $x^* = -1$ and $x^* = 1$ respectively, and the unstable fixed point, which is the boundary of the basins of attraction of the stable ones, moves towards $x^* = 0$, as shown by part of the dynamics under $a_1 = 100$ in figure 3.3.

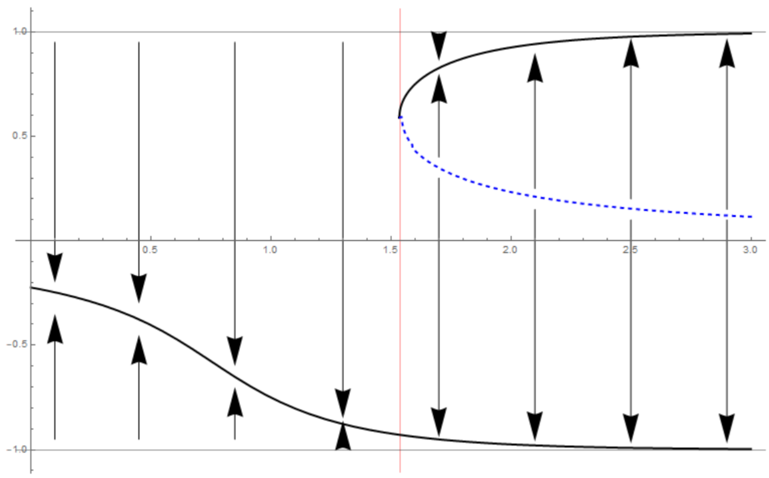


Figure 3.4: Bifurcation Diagram of the system with the parameters shown in table 3.1 and $a_0 = 1$.

The fold bifurcation can be observed more clearly in the bifurcation diagram in figure 3.4, where the black lines show how stable steady states evolve with the social influence parameter. The blue dotted line illustrates the development of the unstable fixed point. The red vertical line shows the critical value of a_1, around 1.5357, where two new steady states arise. This figure represents clearly the possible convergence of agents to the rational expectations steady states, defined by $x = 1$.

The takeaway from this analysis is that social influence has a strong and non monotone impact on the sentiment dynamics: whereas low levels strengthen the individual incentives implied by the model to produce less and avoid the risk of making losses, as interactions grow in importance, such an incentive is compensated by the will to imitate other (potentially neutral) islands. This sheds light on the potential of social influence to help agents in coordinating on better steady states, which eventually converge to the RE scenario. Hence, social influence has the effect of reducing the level of higher-order uncertainty embedded in the economic system; with lower higher-order uncertainty, producers manage to abandon their pessimistic attitude and expand production.

Pessimistic, neutral and optimistic expectations

In an economy with three types of belief and a positive social influence, the dynamics of the population shares are of the form of equation (3.17) with $a_1 > 0$. The phase portrait of this system, for $a_0 = 1$ and $a_1 = 1$, is shown in figure 3.5. There is a unique stable steady state; here, the economy is composed of 79.66% pessimistic islands, 7% optimistic islands and the rest is neutral. Therefore, social influence shifts the steady state towards an economy with more pessimists, as occurs in an economy composed of two types only. The dynamics with higher levels of social influence is shown in figure 3.6, the steady states are listed in table 3.13 in Appendix C.

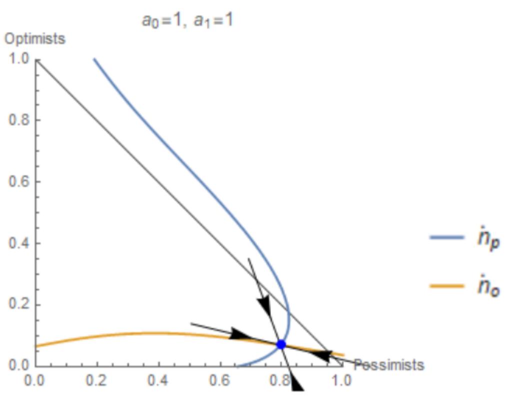


Figure 3.5: Dynamics of the two-dimensional system for the parameters listed in table 3.1, for $a_0 = 1$ and $a_1 = 1$. Inward arrows indicate stable manifolds.

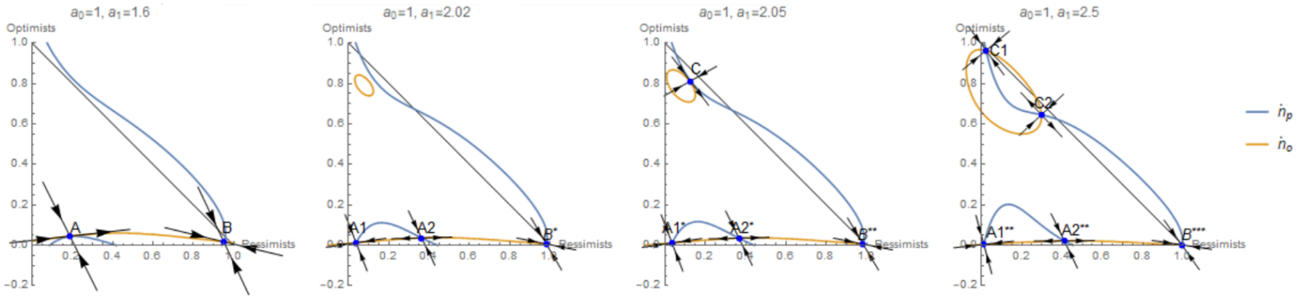


Figure 3.6: Dynamics of the two-dimensional system for the parameters listed in table 3.1, for different levels of social influence and $a_0 = 1$. Inward and outward arrows indicate stable and unstable manifolds, respectively.

With a social influence parameter of 1.6, while the steady state characterized by a predominance of the pessimistic belief shifts towards the right, a new fixed point emerges, $A = (0.1873,\ 0.0455)$, characterized by a majority of neutral islands. This effect corresponds to that emerging in the one-dimensional system. The value $a_1 = 1.6$ is a bifurcation point: as the importance of social influence grows, a fold bifurcation occurs and A splits in two fixed points. In particular, for $a_1 = 2.02$, the two new steady states are a stable fixed point and a saddle node which separates the basins of attraction of the other two stable steady states. The former implies a predominance of neutral islands. Expanding social influence to $a_1 = 2.05$, the dynamics qualitatively changes again and we observe another fold bifurcation. In particular, a fourth steady state emerges at $C = (0.1256,\ 0.8118)$, which is the first steady state characterized by a predominance of optimistic islands. The other two stable points keep shifting towards the extreme scenarios in which all islands are either pessimistic or optimistic; this is the effect that any increment in the level of social influence has on them. At the saddle point $A2^*$, there are more pessimistic islands than in $A2$, which implies that the basin of attraction to $A1^*$ is larger: a higher number of initial scenarios leads to the almost-rational expectations case.

Figure 3.7 shows the dynamics for higher levels of social influence; table 3.14 in Appendix C illustrates its fixed points. More specifically, $a_1 = 3.12$ is another bifurcation point and implies that, for higher values of a_1, the fixed points become seven: subsequent increments in a_1 do not change the dynamics anymore. The limit scenario is characterized by three stable nodes, where all islands are either neutral, pessimistic or optimistic. The other four fixed points divide the simplex in the different basins

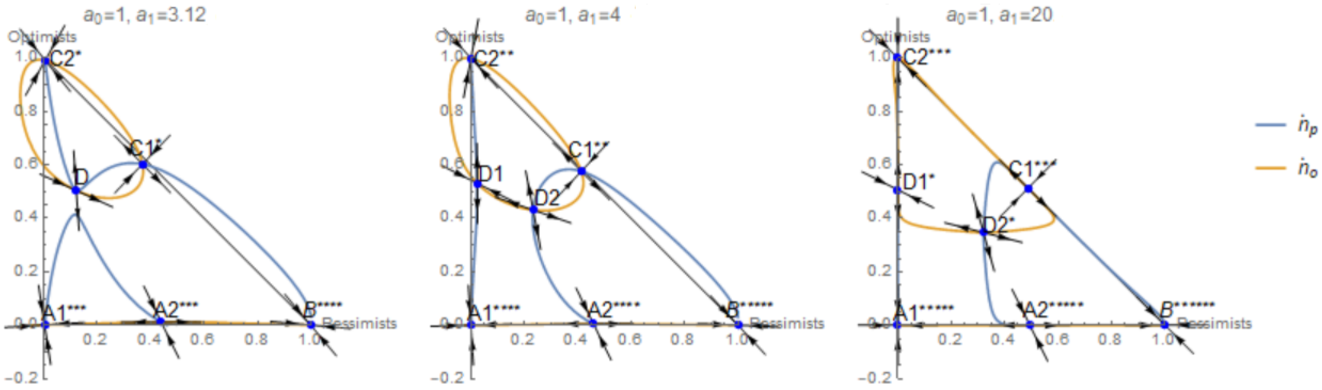


Figure 3.7: Dynamics of the two-dimensional system for the parameters shown in table 3.1, for different levels of social influence and $a_0 = 1$. Inward and outward arrows indicate stable and unstable manifolds, respectively.

of attraction; the higher a_1, the more these basins of attraction become equal to each other[52].

Hence, even in the three types economy, social influence plays a major (non monotone) role on the sentiment dynamics, by allowing islands to place less importance on the potential losses implied in a production expansion and instead weigh more the imitation of others' attitude. Whereas low values of the social influence parameter only amplify individual incentives, as the interaction increases in importance the positive effects emerge. These mechanisms stress that social influence might constitute a factor contributing to the switch between positive and negative states that we observe in the economy.

3.5 Social influence as a coordination device and its impact on production and welfare

To sum up, social influence is crucial in driving the dynamics of our system and the efficiency and stability of the economy. In fact, in the absence of social influence, when islands are only sensitive to profits, both with and without optimistic islands, agents deviate from rational expectations and coordinate on a pessimistic steady state. As the importance of social influence grows, that pessimistic steady state gets even more pessimistic; however, as the social influence parameter crosses a certain threshold, a more

[52]In Appendix C we show how the dynamics vary under different parameters. In particular, higher levels of a_0 require higher levels of social influence for the various bifurcations to occur. The idea is that the more attention islands give to the difference of expected profits between the groups, the higher is the tendency to become pessimistic and the stronger social influence must be in order for the new steady states to arise.

neutral fixed point emerges. A further increase, in the two-dimensional dynamics, leads to the emergence of an optimistic steady state. The higher social influence, the more similar in size the basins of attraction to the different stable points become. Hence, social influence appears as a counteracting force that balances individual incentives to lower expectations and output. Importantly, certain levels of social influence make it possible for agents to converge to where the hierarchy of higher-order beliefs collapses to rational expectations, i.e. to the true fundamental.

But what about social outcomes such as production and welfare: how are they affected by social influence?

Production Y_t is the production of the whole economy in t. Expected production is given by the sum of each type's expected output:

$$\mathbb{E}(Y_t) = n_p\,\mathbb{E}(y_n)(1-\delta)^{\theta\alpha} + n_n\,\mathbb{E}(y_n) + n_o\,\mathbb{E}(y_n)(1+\delta)^{\theta\alpha}. \tag{3.28}$$

It is maximized when all islands are optimistic. Also, with a fixed amount of optimists, as neutral islands increase, output grows as well. Hence, the strength of social influence has a positive impact on production as long as it improves the chances for the population to coordinate on less pessimistic sentiments.

Welfare Welfare is measured as the expected utility of the whole economy. The utility of island i trading with island j is illustrated in equation (3.2), in which we substitute the steady state values of equation (3.4)[53]:

$$\begin{aligned}
\mathbb{E}(U) = \mathbb{E}(y_n^{(1-\eta)})\,\mathbb{E}(y_n^{\eta}) \Big[& (n_n)^2\,[1-\theta] \\
& + (n_n n_p)\,\big[(1-\delta)^{\theta\eta\alpha} - \theta\big] \\
& + (n_n n_o)\,\big[(1+\delta)^{\theta\eta\alpha} - \theta\big] \\
& + (n_p n_n)(1-\delta)^{\theta(1-\eta)\alpha}\,[1-(1-\delta)\theta] \\
& + (n_p)^2(1-\delta)^{\theta(1-\eta)\alpha}\,\big[(1-\delta)^{\theta\eta\alpha} - (1-\delta)\theta\big] \\
& + (n_p n_o)(1-\delta)^{\theta(1-\eta)\alpha}\,\big[(1+\delta)^{\theta\eta\alpha} - (1-\delta)\theta\big] \\
& + (n_o n_n)(1+\delta)^{\theta(1-\eta)\alpha}\,[1-(1+\delta)\theta] \\
& + (n_o n_p)(1+\delta)^{\theta(1-\eta)\alpha}\,\big[(1-\delta)^{\theta\eta\alpha} - (1+\delta)\theta\big] \\
& + (n_o)^2(1+\delta)^{\theta(1-\eta)\alpha}\,\big[(1+\delta)^{\theta\eta\alpha} - (1+\delta)\theta\big] \Big].
\end{aligned} \tag{3.29}$$

[53] See section 3.A.6 for its derivation.

Equation (3.29) helps understanding the different composition effects on welfare. First line indicates the utility generated by a neutral island meeting another neutral island, times the product of their shares; second line displays the utility generated by a neutral island trading with a pessimistic island times the product of their shares and so on. In particular, equation (3.29) reveals that the following matches have an unambiguous positive effect on welfare:

- Neutral-Neutral;
- Neutral-Optimistic;
- Pessimistic-Neutral;
- Pessimistic-Pessimistic;
- Pessimistic-Optimistic.

However, for the following matches the effect is ambiguous:

- Neutral-Pessimistic;
- Optimistic-Neutral;
- Optimistic-Pessimistic;
- Optimistic-Optimistic.

The ambiguity, in all cases, depends mostly on the degree of optimism or pessimism, δ, and the amount of labor employed in the production, θ. For instance, concerning the Neutral-Pessimistic match of second line of equation (3.29): the expression in the square brackets is positive if $\delta < 1 - \theta^{\frac{1}{\theta\eta\alpha}}$, and negative if the opposite is true. The higher θ and η, the smaller the room for δ to satisfy that inequality. We recall that $\theta \equiv \frac{\Theta}{\epsilon}$, where Θ is the labor share of income and ϵ is the Frisch elasticity of labor supply: they are, respectively, positively and negatively related with the optimal amount of labor employed in the production. Thus, when neutral islands trading with pessimists obtain a negative expected utility, the reason is that they are working too much with respect to the expected production of the pessimists, which negatively depends on δ. A similar reasoning explains the ambiguity of the other matches.

The considerations above explain why welfare is not necessarily monotone, depending on the above mentioned parameters, in the population shares, as illustrated in figure 3.8.

We find that the rational expectations scenario, is always the most efficient[54]:

Result *Welfare is highest under rational expectations, that is, when all islands have neutral beliefs.*

This suggests that an economy characterized by a majority of optimists or pessimists implies inefficiencies, brought about by coordination issues that cause islands to either

[54] See section 3.B.5 for its derivation.

produce too little or too much. These deviations from the optimal production level generate losses in welfare. Hence, the rational expectations steady state, by implying that beliefs collapse to the true fundamental, guarantees the best outcome from a welfare perspective. Moreover, as social influence increases the likelihood of the neutral steady state, it brings about a reduction of higher-order uncertainty embedded in the economic system, by letting agents know and imitate the majority belief of the population.

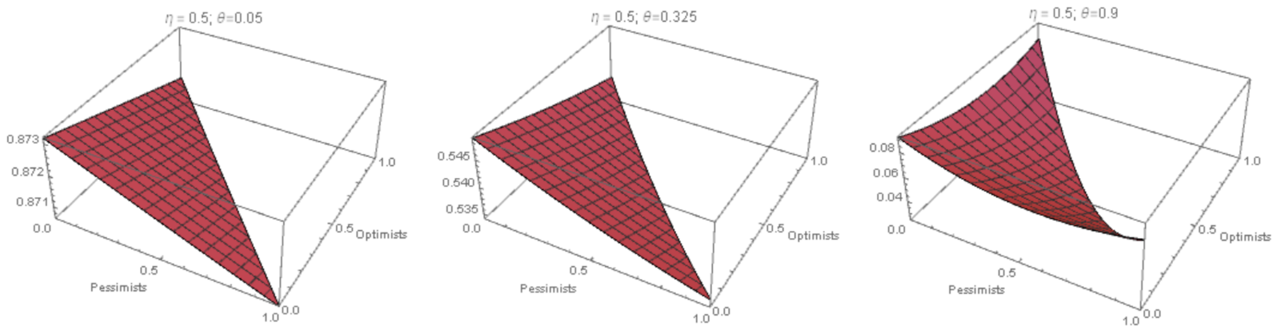


Figure 3.8: Welfare for an economy populated by pessimistic, neutral and optimistic islands.

To sum up, as regards what impact the importance of social influence has on production and welfare, it depends on how social influence affects the population shares. Table 3.5 shows the amount of production and welfare at each steady state for the one-dimensional economy represented in figure 3.3. Columns Output and Welfare present the expected values of such figures for the entire population, that we compute by multiplying values in Eq. Output and Eq. Welfare by the probabilities for the economy to reach such stable steady states, assuming that any initial state is equally likely[55]. In particular, we notice that as the importance of social influence grows from 0 to 1.9, expected output declines from 0.7492 to 0.7481; as a_1 exceeds 1.9, its effect on output is positive, raising production to 0.7549 and 0.7608. In terms of welfare, the impact is strongly positive as the parameter a_1 is raised.

Table 3.6 illustrates the impact of social influence on the economy populated by optimistic islands as well, whose dynamics is shown in 3.5 and 3.18. We do not measure the areas converging to the different steady states and, therefore, expected output and welfare. Nevertheless, the figures there point out to a negative effect of social influence on output at the pessimistic steady state, which declines from 0.7328 to 0.7085. However, it is counterbalanced and probably reversed as in the one dimensional

[55]See Appendix A for details.

case by the output growth at the neutral- (from 0.7959 to 0.8136) and optimistic-dominated (from 0.8349 to 0.8561) steady states. In terms of welfare, social influence leads to a worsening of the utility level characterizing the pessimistic fixed point, which declines by about 0.19%. At the same time, a stronger social influence drives agents to coordinate on more efficient scenarios taking place at the optimistic steady states, characterized at every point by larger welfare levels than at the pessimistic fixed point. Also, it generates the more neutral steady state, at which welfare is highest. As social influence grows, the basins of attraction of the three different steady states get more and more similar in size. Thus, for $a_1 = 20$, about one third of initial states lead to each steady states, so that expected welfare is around 0.5411, 0.9% higher than the economy's welfare in the absence of social influence.

Therefore, with the set of parameters indicated in table 3.1 we find that the effect of social influence on expected utility overall is positive, with welfare being highest under rational expectations.

This sheds light, once again, on the ability of social influence not only to affect the sentiment dynamics by generating multiple steady states, including the REE where welfare is highest, but also on its potential in neutralizing individual incentives in favor of social outcomes.

3.6 Conclusions

In the present paper, we incorporate endogenously emerging beliefs driven by economic outcomes and social influence, in a simple Islands model, characterized by uncertainty and strategic complementarity among agents which generate a hierarchy of beliefs and coordination issues. We aim at studying the impact of social influence on the stability and efficiency of the economy.

We find that social influence is a powerful mechanism which modifies stability and efficiency of such an economy. In its absence, incomplete knowledge and individual incentives drive agents to converge on a pessimistic inefficient steady state and let frictional coordination cause welfare losses. This occurs because individuals, in a context of uncertainty and because of strategic complementarity, are unable to coordinate well their beliefs and actions, and thus are driven to lower their beliefs in order to improve their terms of trade and reduce their costs. However, this negatively affects social outcomes. With social influence, instead, agents, by imitating each other, become able to coordinate on other and eventually more efficient stable steady states. The impact of social influence on such a tendency might be interpreted through two lenses: on the one

Table 3.5: Production and welfare of the one-dimensional system with the parameters shown in table 3.1, with $a_0 = 1$ and different levels of social influence.

	Equilibrium points	Eq. output	Exp. Output	Eq. welfare	Exp. Welfare
$a_1 = 0$	x^* = -0.2259	0.7492	0.7492	0.5278	0.5278
$a_1 = 1$	x^* = -0.7560	0.7213	0.7213	0.5313	0.5313
$a_1 = 1.5357$	x_1^* = -0.9302 x_2^* = 0.5893	0.7121 0.7920	0.7121	0.5341 0.5373	0.5341
$a_1 = 1.9$	x_1^* = -0.9688 x_2^* = 0.2613 x_3^* = 0.9029	0.7101 0.7748 0.8085	0.7481	0.5348 0.5313 0.5457	0.5385
$a_1 = 3$	x_1^* = -0.9968 x_2^* = 0.1149 x_3^* = 0.9918	0.7086 0.7671 0.8132	0.7549	0.5354 0.5295 0.5486	0.5412
$a_1 = 100$	x_1^* = -1 x_2^* = 0.0053 x_3^* = 1	0.7085 0.7613 0.8136	0.7608	0.5355 0.5286 0.5489	0.5422

hand, it abates the role of uncertainty by encouraging agents to interact and imitate each other. In fact, even though individuals are not aware of their exact match, they try to learn the predominant opinion from the majority and act accordingly. Interestingly, as social influence crosses a certain threshold, the neutral steady state emerges where agents are able to coordinate on the rational expectations steady state: here, the economy behaves like under complete knowledge and the hierarchy of beliefs collapses to the true fundamental. On the other hand, social influence smooths the trade off between individual incentives and social outcomes, by nudging individuals to put less weight on their own payoffs in order to conform with the majority. With a closer look, this dual interpretation may remind the double motivation identified by psychologists for the role of social influence mentioned in the Introduction: one based on the goal to form a correct interpretation of reality and the other grounded on the desire of social approval. Another way to look at the impact of social influence on the economic system is that, if its strength lies within a certain range, it reduces the higher-order uncertainty characterizing the economy, thus lowering the inefficiencies that uncertainty creates. We conclude by pointing out the role of social influence as a coordination device in a macroeconomic context.

Table 3.6: Production and welfare for different levels of social influence.

	Equilibrium points	Production	Welfare
$a_1 = 1$	$(n_p^*, n_o^*) = (0.7966, 0.070)$	0.7328	0.5365
$a_1 = 1.6$	$A = (0.1873, 0.0455)$	0.7959	0.5453
	$B = (0.9503, 0.0180)$	0.7144	0.5357
$a_1 = 2.02$	$A1 = (0.0376, 0.0129)$	0.8102	0.5482
	$B^* = (0.9804, 0.0072)$	0.7108	0.5356
$a_1 = 2.05$	$A1^* = (0.0348, 0.0120)$	0.8105	0.5482
	$B^{**} = (0.9817, 0.0068)$	0.7107	0.5356
	$C = (0.1256, 0.8118)$	0.8349	0.5378
$a_1 = 2.5$	$A1^{**} = (0.0120, 0.0044)$	0.8125	0.5487
	$B^{***} = (0.9929, 0.0026)$	0.7093	0.5355
	$C1 = (0.0228, 0.9633)$	0.8522	0.5386
$a_1 = 3.12$	$A1^{***} = (0.0032, 0.0012)$	0.8133	0.5489
	$B^{****} = (0.9981, 0.0007)$	0.7087	0.5355
	$C2^* = (0.0055, 0.9910)$	0.8552	0.5389
$a_1 = 4$	$A1^{****} = (0.0005, 0.0002)$	0.8136	0.5490
	$B^{*****} = (0.9997, 0.0001)$	0.7085	0.5355
	$C2^{**} = (0.0009, 0.9985)$	0.8559	0.5389
$a_1 = 20$	$A1^{*****} = (0., 0.)$	0.8136	0.5490
	$B^{******} = (1., 0.)$	0.7085	0.5355
	$C2^{***} = (0., 1.)$	0.8561	0.5389

The analysis carried out in this paper could be further extended by modifying a number of assumptions that were made for reason of simplicity. For example, with regard to the parameter δ, it would be interesting to make it endogenous and dependent on, e.g. the number of encounters made or the degree of optimism or pessimism of islands met previously. Moreover, in the present model, islands are matched in every period in random pairs, thus implying a random network. In reality, trade is likely to occur within other network structures and this would potentially have important implications for our analysis.

Appendix 3.A Derivation of formulas

3.A.1 Neutral belief benchmark

When forming their beliefs on y_{jt}^{η}, islands know that their trading partner j's output, like theirs, is given by $K_1^{\alpha} A_j^{\alpha}[\mathbb{E}_{jt}(y_{it}^{\eta})]^{\theta\alpha}$. Therefore, they take that into consideration and form their first-order belief:

$$\mathbb{E}_{it}(y_{jt}^{\eta}) = \mathbb{E}_{it}\left(K_1^{\alpha\eta} A_j^{\alpha\eta}[\mathbb{E}_{jt}(y_{it}^{\eta})]^{\theta\alpha\eta}\right). \tag{3.30}$$

We assume that K_1^{α} and $\mathbb{E}_{it}(A_j^{\alpha\eta})$ are common knowledge[56]; thus, the subjective part of the expectation is $\mathbb{E}_{it}[\mathbb{E}_{jt}(y_{it}^{\eta})]^{\theta\alpha\eta}$. However, islands know y_{it}, so they can do a step forward in their reasoning and substitute it in equation (3.30):

$$\mathbb{E}_{it}(y_{jt}^{\eta}) = K_1^{\alpha\eta(1+\theta\alpha\eta)}\,\mathbb{E}(A_j^{\alpha\eta})^{(1+\theta\alpha\eta)}\underline{\underline{\mathbb{E}_{it}\left(\mathbb{E}_{jt}([\mathbb{E}_{it}(y_{jt}^{\eta})]^{\theta\alpha\eta})^{\theta\alpha\eta}\right)}}. \tag{3.31}$$

The underlined term in equation (3.31) describes the hierarchy of beliefs of island i up to the third-order belief, that is, what island i believes that island j thinks of the first-order belief of i on j. By assuming that $\mathbb{E}_{it}\left(\mathbb{E}_{jt}[\mathbb{E}_{it}[y_{jt}^{\eta}]]\right) = \mathbb{E}_{it}(y_{jt}^{\eta})$,[57] that is, a neutral island i believes that the trading partner j knows her own (i's) belief, we can insert the assumed third-order belief on the right hand side of equation (3.31) and solve for the belief:

$$\mathbb{E}_{it}(y_{jt}^{\eta}) = K_1^{\frac{\alpha\eta}{1-\theta\alpha\eta}}\,\mathbb{E}(A_j^{\alpha\eta})^{\frac{1}{1-\theta\alpha\eta}}. \tag{3.32}$$

This result can be generalized for order n; in fact, writing $x = \mathbb{E}_{it}(y_{jt}^{\eta})$ and $K = K_1^{\alpha\eta}\,\mathbb{E}_{it}(A_j^{\alpha\eta})$, $ka = \theta\alpha\eta$, equation (3.32), for the general order n has the following structure:

$$x = K^{\sum_{j=0}^{n} ka^j} x^{ka^n}, \tag{3.33}$$

which is equivalent to

$$x^{(1-ka^n)} = K^{\frac{1-ka^n}{(1-ka)}} \tag{3.34}$$

such that $x = K^{\frac{1}{(1-ka)}}$ is sufficient and necessary for the neutral belief benchmark in equation (3.8) to hold for any order n.

[56] Therefore: $\mathbb{E}_{it}(A_j^{\alpha\eta}) = \mathbb{E}(A_j^{\alpha\eta}) = e^{\frac{(\sigma\alpha\eta)^2}{2}}$. See section 3.A.2 for its derivation.

[57] Since we are dealing with point beliefs and not beliefs' distribution, this assumption translates directly into $\mathbb{E}_{it}\left(\mathbb{E}_{jt}([\mathbb{E}_{it}(y_{jt}^{\eta})]^{\theta\alpha\eta})^{\theta\alpha\eta}\right) = \mathbb{E}_{it}(y_{jt}^{\eta})^{(\theta\alpha\eta)^2}$.

3.A.2 Expected productivity

Islands' productivity is lognormally distributed: $A_i \sim \log N(0, \sigma_A)$, where $\sigma_A > 0$.

$$\mathbb{E}(A_i^{\eta\alpha}) = \int_0^{+\infty} A_i^{\eta\alpha} dF(A_i), \tag{3.35}$$

which, given that $dF(A_i) = f(A_i)dA_i$, becomes:

$$\mathbb{E}(A_i^{\eta\alpha}) = \int_0^{+\infty} A_i^{\eta\alpha} f(A_i) dA_i. \tag{3.36}$$

$f(A_i)$ is lognormal, i.e. $f(A_i) = \frac{1}{A_i\sqrt{2\pi\sigma^2}} e^{-\frac{\log A_i}{2\sigma^2}}$. Changing the variable $\tilde{A}_i = \log A_i$, we obtain:

$$\mathbb{E}(A_i^{\eta\alpha}) = \int_{-\infty}^{+\infty} e^{\eta\alpha\tilde{A}_i} \phi(\tilde{A}_i) d\tilde{A}_i, \tag{3.37}$$

where $\phi(\tilde{A}_i)$ is the Normal distribution of $\tilde{A}_i$. It follows that:

$$\mathbb{E}(A_i^{\eta\alpha}) = \frac{1}{\sqrt{2\pi\sigma^2}} \int_{-\infty}^{+\infty} e^{\eta\alpha\tilde{A}_i - \frac{\tilde{A}_i}{2\sigma^2}} d\tilde{A}_i. \tag{3.38}$$

$e^{\eta\alpha\tilde{A}_i - \frac{\tilde{A}_i}{2\sigma^2}}$ can be transformed in a squared binomial by adding $e^{\frac{\sigma^2\eta^2\alpha^2}{2}}$:

$$\mathbb{E}(A_i^{\eta\alpha}) = e^{\frac{\sigma^2\eta^2\alpha^2}{2}} \int_{-\infty}^{+\infty} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(\frac{\tilde{A}_i}{\sqrt{2\sigma^2}} - \frac{\sigma\eta\alpha}{\sqrt{2}})^2} d\tilde{A}_i. \tag{3.39}$$

Changing again a variable, i.e. $\frac{\tilde{A}_i}{\sqrt{2\sigma^2}} - \frac{\sigma\eta\alpha}{\sqrt{2}} = \frac{z}{\sqrt{2}}$, it follows that

$$\mathbb{E}(A_i^{\eta\alpha}) = e^{\frac{\sigma^2\eta^2\alpha^2}{2}} \int_{-\infty}^{+\infty} \frac{1}{\sqrt{2\pi}} \Phi(+\infty) = e^{\frac{\sigma^2\eta^2\alpha^2}{2}}. \tag{3.40}$$

3.A.3 Profits

Profits are given by the difference of revenues and costs: $\pi_i = p_i y_i - w_i l_i - r_i k_i$. Costs are obtained by considering the optimal quantities and prices of labor and land. As for labor, we have that wage must be equal to the marginal disutility of working and to the expected marginal revenues of labor:
$\frac{\delta y_{it}}{\delta l_{it}} = \frac{\delta(A_i(l_{it})^{\Theta}(k_{it})^{1-\Theta})}{\delta l_{it}} = \mathbb{E}_{it}[p_{it}]\Theta\frac{y_{it}}{l_{it}}$, therefore we have that $l^{\epsilon-1} = \mathbb{E}_{it}[p_{it}]\Theta\frac{y_{it}}{l_{it}}$. From the latter we can find the optimal level of labor $l_{it} = (\mathbb{E}_{it}[p_{it}]\Theta y_{it})^{\frac{1}{\epsilon}}$. Since $w_{it} = l^{\epsilon} - 1$, therefore the optimal $w_{it}l_{it} = l^{\epsilon} = \mathbb{E}_{it}[p_{it}]\Theta y_{it}$.

As for land, the optimal r_{it} must be equal to the marginal utility of k_{it} which is given by $\frac{\delta y_{it}}{\delta k_{it}} = \frac{\delta(A_i(l_{it})^{\Theta}(k_{it})^{1-\Theta})}{\delta k_{it}} = \mathbb{E}_{it}[p_{it}](1-\Theta)\frac{y_{it}}{k_{it}}$, k_{it} in steady state is equal to K which is the fixed endowment of land and it is normalized to one, therefore the optimal $r_{it}k_{it} = \mathbb{E}_{it}[p_{it}](1-\Theta)y_{it}$.

We already know that $p_{it} = y_{it}^{-\eta}y_{jt}^{\eta}$, therefore $\mathbb{E}_{it}[p_{it}] = y_{it}^{-\eta}\,\mathbb{E}_{it}[y_{jt}^{\eta}]$. Therefore, profits are given by $p_{it}y_{it} - w_{it}l_{it} - k_{it}r_{it} = y_{it}^{1-\eta}y_{jt}^{\eta} - \mathbb{E}_{it}[p_{it}]\Theta y_{it} - \mathbb{E}_{it}[p_{it}](1-\Theta)y_{it} = y_{it}^{1-\eta}y_{jt}^{\eta} - \mathbb{E}_{it}[y_{jt}^{\eta}]\Theta y_{it}^{1-\eta} - \mathbb{E}_{it}[y_{jt}^{\eta}](1-\Theta)y_{it}^{1-\eta} = y_{it}^{1-\eta}y_{jt}^{\eta} - y_{it}^{1-\eta}\,\mathbb{E}_{it}[y_{jt}^{\eta}]$, or:

$$y_{it}^{1-\eta}(y_{jt}^{\eta} - \mathbb{E}_{it}(y_{jt}^{\eta})). \tag{3.41}$$

3.A.4 Expected profits of pessimistic and optimistic islands

For pessimists:

$$\begin{aligned}\mathbb{E}(\pi_{p,t}) &= n_p\,\mathbb{E}\left(y_n^{(1-\eta)}\right)(1-\delta)^{\theta(1-\eta)\alpha}\left[\mathbb{E}(y_n^{\eta})(1-\delta)^{\theta\eta\alpha} - \mathbb{E}(y_n^{\eta})(1-\delta)\right]\\ &+ n_n\,\mathbb{E}\left(y_n^{(1-\eta)}\right)(1-\delta)^{\theta(1-\eta)\alpha}\left[\mathbb{E}(y_n^{\eta}) - \mathbb{E}(y_n^{\eta})(1-\delta)\right]\\ &+ n_o\,\mathbb{E}\left(y_n^{(1-\eta)}\right)(1-\delta)^{\theta(1-\eta)\alpha}\left[\mathbb{E}(y_n^{\eta})(1+\delta)^{\theta\eta\alpha} - \mathbb{E}(y_n^{\eta})(1-\delta)\right].\end{aligned} \tag{3.42}$$

For optimists:

$$\begin{aligned}\mathbb{E}(\pi_{o,t}) &= n_p\,\mathbb{E}\left(y_n^{(1-\eta)}\right)(1+\delta)^{\theta(1-\eta)\alpha}\left[\mathbb{E}(y_n^{\eta})(1-\delta)^{\theta\eta\alpha} - \mathbb{E}(y_n^{\eta})(1+\delta)\right]\\ &+ n_n\,\mathbb{E}\left(y_n^{(1-\eta)}\right)(1+\delta)^{\theta(1-\eta)\alpha}\left[\mathbb{E}(y_n^{\eta}) - \mathbb{E}(y_n^{\eta})(1+\delta)\right]\\ &+ n_o\,\mathbb{E}\left(y_n^{(1-\eta)}\right)(1+\delta)^{\theta(1-\eta)\alpha}\left[\mathbb{E}(y_n^{\eta})(1+\delta)^{\theta\eta\alpha} - \mathbb{E}(y_n^{\eta})(1+\delta)\right].\end{aligned} \tag{3.43}$$

3.A.5 The one-dimensional dynamics from discrete to continuous time

Our basic model, as specified by Angeletos and La'O (2013), unfolds in discrete time and it is characterized by a specific succession of events, such as the production, the employment decisions and the actual trading. However, in order to study the dynamics of the economy, we will treat time as continuous and build a dynamic model similar to that developed by Lux (1995). In what follows we briefly show how we derive a continuous dynamics from a model originally expressed in discrete time, in the case without social influence. In the latter, the opinion index x in time $t+\epsilon$ is given by:

$$x(t+\epsilon) = \frac{n_n(t+\epsilon) - n_p(t+\epsilon)}{n}, \tag{3.44}$$

where

$$\begin{aligned} n_n(t+\epsilon) &= n_n(t) - n_n(t)p_{np}(\epsilon, \bar{\pi}_{n-p,t}(x)) + n_p(t)p_{pn}(\epsilon, \bar{\pi}_{n-p,t}(x)) \\ n_p(t+\epsilon) &= n_p(t) - n_p(t)p_{pn}(\epsilon, \bar{\pi}_{n-p,t}(x)) + n_n(t)p_{np}(\epsilon, \bar{\pi}_{n-p,t}(x)). \end{aligned} \tag{3.45}$$

In words, $n_n(t+\epsilon)$ is given by the number of islands that were neutral in time t, minus those of them which became pessimistic $(n_n(t)p_{np}(\epsilon, \bar{\pi}_{n-p,t}(x)))$, plus those which were pessimistic in time t and became neutral $(n_p(t)p_{pn}(\epsilon, \bar{\pi}_{n-p,t}(x)))$. p_{np} and p_{pn} are the probability of switching from neutral belief to pessimism and *vice versa*, respectively. They depend on the time interval ϵ and on $\bar{\pi}_{n-p,t}(x)$, which is the difference between the expected profits of neutral and pessimistic islands in t. Substituting (3.45) into (3.44), we can then compute the change over time and, for $\epsilon \to 0$, we get $\dot{x}$, i.e. the change of x in continuous time:

$$\dot{x} = \lim_{\epsilon \to 0} \frac{x(t+\epsilon) - x(t)}{\epsilon} = \frac{2n_p(t)q_{pn}}{n} - \frac{2n_n(t)q_{np}}{n} \tag{3.46}$$

where $q_{np} = \lim\limits_{\epsilon \to 0} \frac{p_{np}}{\epsilon}$ and $q_{pn} = \lim\limits_{\epsilon \to 0} \frac{p_{pn}}{\epsilon}$ are the transition rates from neutral to pessimism and *vice versa* of the system in continuous time.

From equation (3.19) it follows that an example of switching probabilities satisfying $q_{np} = \lim\limits_{\epsilon \to 0} \frac{p_{np}}{\epsilon}$ and $q_{pn} = \lim\limits_{\epsilon \to 0} \frac{p_{pn}}{\epsilon}$ may be

$$p_{np} = e^{-(a_0 \pi(x))}\epsilon \qquad \text{and} \qquad p_{pn} = e^{(a_0 \pi(x))}\epsilon. \tag{3.47}$$

In fact, $\bar{\pi}_{n-p,t}(x)$ is bounded from above and, thus, also q_{np} and q_{pn}; therefore it is possible to choose an ϵ small enough such that p_{pn} and p_{np} are smaller or equal than one.

3.A.6 Welfare

Utility is given by

$$U_i = \Sigma_{t=0}^{\infty} \beta^t \left[\left(\frac{c_{it}}{1-\eta} \right)^{1-\eta} \left(\frac{c_{it}^*}{\eta} \right)^{\eta} - \frac{l_{it}^{\epsilon}}{\epsilon} \right]. \tag{3.48}$$

In equilibrium, $c_{it} = (1-\eta)y_{it}$ and $c_{it}^* = \eta y_{jt}$. Moreover, $l_{it} = (\mathbb{E}_{it}[p_{it}]\Theta y_{it})^{\frac{1}{\epsilon}} = (\mathbb{E}_{it}[y_{jt}^{\eta}]\Theta y_{it}^{1-\eta})^{\frac{1}{\epsilon}}$, so we can rewrite utility as

$$U_i = \Sigma_{t=0}^{\infty} \beta^t \left[(y_{it})^{1-\eta} \left((y_{jt})^{\eta} - \mathbb{E}_{it}[y_{jt}^{\eta}] \frac{\Theta}{\epsilon} \right) \right], \tag{3.49}$$

where we already defined $\frac{\Theta}{\epsilon} \equiv \theta$. By substituting expected output of the different types, we obtain equation (3.29).

3.A.7 Expected output and welfare

In the one-dimensional system, we compute the probability of the economy to converge to a certain stable steady state, $p_{x_k^*}$, as follows:

$$p_{x_k^*} = \frac{(x_u^* + 1)}{2}, \tag{3.50}$$

where $k \in \{1, 2, 3\}$ indicates the stable steady states and $u \in \{1, 2, 3\}$, with $k \neq u$, indicates the unstable steady state.

We compute expected production, or welfare, considering all steady states, as follows:

$$Y = \sum_{m=1}^{N} p_{x_k^*} \, \mathbb{E}(y_k), \tag{3.51}$$

$N \in \{1, 2\}$ is the total number of stable equilibiurm points. $\mathbb{E}(y_k)$ represents expected output or welfare at steady state k.

Appendix 3.B Proofs

3.B.1 Proof of proposition 1

The average output of neutral islands is given by:

$$\int_0^{+\infty} K_1^{\eta\gamma} A_i^{\eta\alpha} \, \mathbb{E}(A_i^{\eta\alpha})^{\eta\gamma\theta} dF(A_i), \tag{3.52}$$

which can be rewritten as $K_1^{\eta\gamma} \, \mathbb{E}(A_i^{\eta\alpha})^{\eta\gamma\theta+1}$. Given that $\gamma \equiv \frac{1}{1-\theta}$ and $\alpha \equiv \frac{1}{1-\theta+\eta\theta}$, we have that $\eta\gamma\theta + 1 = \frac{\gamma}{\alpha}$ and therefore the average output of neutral islands equals the neutral belief $K_1^{\eta\gamma} \, \mathbb{E}(A_i^{\eta\alpha})^{\frac{\gamma}{\alpha}}$.

3.B.2 Proof of Proposition 2

In an economy populated by two expectation types, neutral islands' expected profits are given by the sum of the profits earned by trading with both expectation types multiplied by their shares:

$$\begin{aligned}\bar{\pi}_{n,t}(x) = \mathbb{E}\left(y_n^{(1-\eta)}\right)\mathbb{E}(y_n^{\eta})\frac{1-x}{2}\left[(1-\delta)^{\theta\eta\alpha}-1\right] \\ +\frac{x+1}{2}\left[1-1\right].\end{aligned} \tag{3.53}$$

For $x = 1$, equation (3.53) equals zero; for $-1 \leq x < 1$, given that $(1-\delta)^{\theta\eta\alpha} < 0$, it takes negative values. Analogously, pessimistic islands' expected profits are given by

$$\begin{aligned}\bar{\pi}_{p,t}(x) =& \frac{1-x}{2}(1-\delta)^{\theta(1-\eta)\alpha}\left[(1-\delta)^{\theta\eta\alpha}-(1-\delta)\right] \\ &+\frac{x+1}{2}(1-\delta)^{\theta(1-\eta)\alpha}\left[1-(1-\delta)\right]\Big].\end{aligned} \tag{3.54}$$

For $x = 1$, equation (3.54) is positive; for $-1 \leq x < 1$, it takes positive values as well, for that $0 < \delta < 1$ and $0 < \theta\eta\alpha < 1 \Rightarrow (1-\delta)^{\theta\eta\alpha} > (1-\delta)$.

3.B.3 Proof of Proposition 3

The fixed point of equation (3.20) is given by

$$\tanh(a_0\bar{\pi}_{n-p}(x)) = x. \tag{3.55}$$

$x = 1$ represent an economy where all agents have rational expectations; however, in order for $\tanh(a_0\bar{\pi}_{n-p}(x)) = 1$, $a_0\bar{\pi}_{n-p}(x) \to \infty$, which is impossible considering that $a_0 \geq 0$ and $\bar{\pi}_{n-p}(x) < 0$.

Instead, for $a_0 \to \infty$, it is possible for $x = -1$ to be a fixed point of equation (3.20).

3.B.4 Proof of Proposition 4

In an economy populated by three expectation types, neutral islands' expected profits are given by the sum of the profits earned by trading with all expectation types multiplied by their shares:

$$\begin{aligned}\mathbb{E}(\pi_{n,t}) = &\left[\mathbb{E}\left(y_n^{(1-\eta)}\right)\mathbb{E}(y_n^{\eta})\right] n_p\left[(1-\delta)^{\theta\eta\alpha}-1\right] \\ &+ n_n\left[1-1\right] \\ &+ n_o\left[(1+\delta)^{\theta\eta\alpha}-1\right],\end{aligned} \tag{3.56}$$

from which we notice that neutral islands earn negative, zero, and positive expected profits when trading with pessimistic, neutral, and optimistic islands, respectively.

Analogously, optimistic islands' expected profits are given by

$$\begin{aligned}\mathbb{E}(\pi_{o,t}) = &\left[\mathbb{E}\left(y_n^{(1-\eta)}\right)\mathbb{E}(y_n^{\eta})\right] n_p(1+\delta)^{\theta(1-\eta)\alpha}\left[(1-\delta)^{\theta\eta\alpha}-(1+\delta)\right] \\ &+ n_n(1+\delta)^{\theta(1-\eta)\alpha}\left[1-(1+\delta)\right] \\ &+ n_o(1+\delta)^{\theta(1-\eta)\alpha}\left[(1+\delta)^{\theta\eta\alpha}-(1+\delta)\right],\end{aligned} \tag{3.57}$$

from which it emerges that optimistic islands earn negative expected profits from all matches. In particular, by comparing the negative factor in equation (3.56), $(1-\delta)^{\theta\eta\alpha}-1$, with one of the negative factors in (3.57), $(1+\delta)^{\theta\eta\alpha}-(1+\delta)$, we observe that the former is less negative than the latter, given that $\delta > 0$.

3.B.5 Result on welfare

For $\delta = 0$, the economy's welfare is given by the first line of equation (3.29) repeated nine times. For $\delta > 0$ we are back in the economy made of neutral, pessimistic and optimistic islands; given that the derivative of equation (3.29) with respect to δ is negative[58], it results that welfare is highest under rational expectations.

Appendix 3.C Robustness

3.C.1 Difference in expected profits of neutral and pessimistic islands, for different parameters

From equation (3.21) and figure 3.9, we observe that all the parameters have the same effect on the difference, except θ. A rise of η expands the difference of expected profits between the two groups. In fact, on the one hand, it reduces what a neutral island earns by meeting a pessimistic island, because it increases the strategic complementarity, which, in turn, diminishes pessimists' output. On the other hand, it increases both the revenues of pessimistic islands and their costs when they meet both types, but the positive effect on the former is stronger than the negative on the latter. The idea is that the higher η, the stronger is the effect of the trading partner's output on an island's price and, thus, on her terms of trade. Likewise, δ decreases pessimistic islands' output and an increment in σ increases the expected productivity of islands amplifying the difference. θ, overall, diminishes $\bar{\pi}_{n-p,t}(x)$: in fact, it reduces the profits of neutral

[58] This result is proven numerically for our parameters.

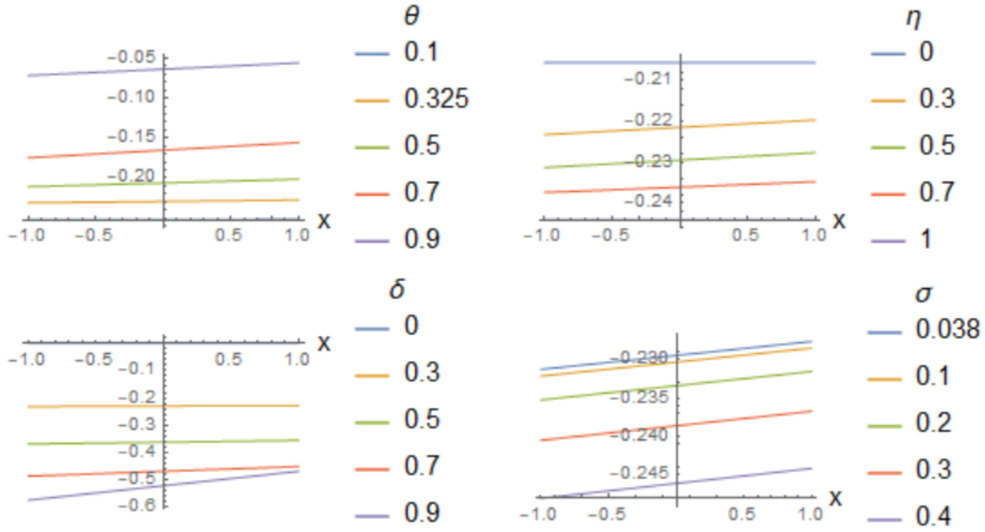


Figure 3.9: Difference in expected profits of neutral and pessimistic islands, for different parameters.

islands meeting pessimists, but it also reduces the revenues of pessimistic islands more than it decreases their cost, regardless of the type of the trading partner.

3.C.2 Sentiment dynamics without social influence

Figure 3.10: Dynamics of $\dot{x}$, without social influence, under different parameters.

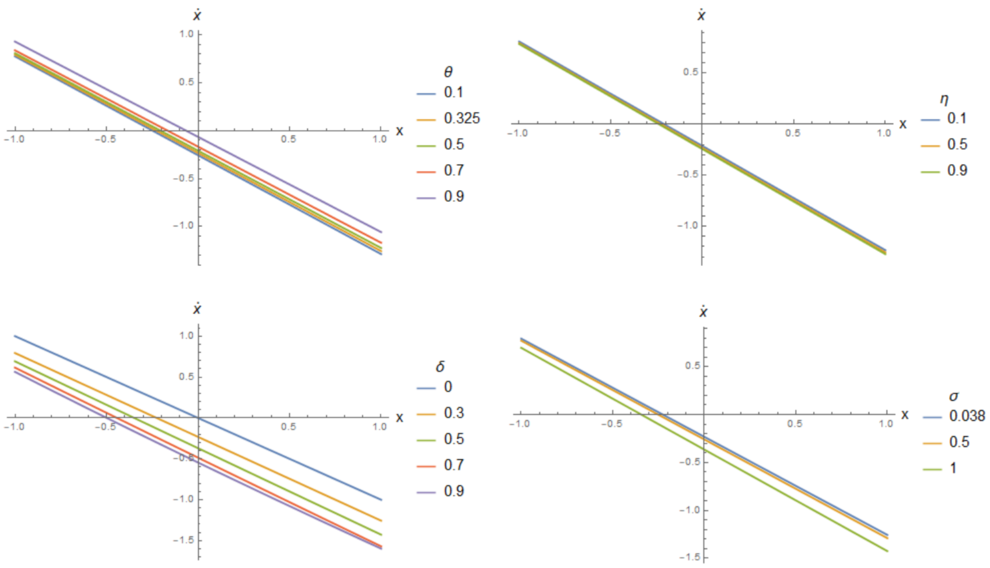


Table 3.7: Equilibrium points of the dynamics shown in figure 3.10.

	Equilibrium points	Derivative at the steady state
$\delta = 0$	$x^* = 0$	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1
$\delta = 0.3$	x^* = -0.2259	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0248
$\delta = 0.5$	x^* = -0.3488	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0610
$\delta = 0.7$	x^* = -0.4431	$\frac{d(\dot{x})}{dx}\|_{x^*}$ =-1.0997
$\delta = 0.9$	x^* = -0.4985	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.1078
$\theta = 0.1$	x^* = -0.2471	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0319
$\theta = 0.325$	x^* = -0.2259	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0248
$\theta = 0.5$	x^* = -0.2043	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0169
$\theta = 0.7$	x^* = -0.1652,	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0045
$\theta = 0.9$	x^* = -0.0640	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -0.9941
$\eta = 0.1$	x^* = -0.2086	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0216
$\eta = 0.5$	x^* = -0.2259	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0248
$\eta = 0.9$	x^* = -0.2371	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0289
$\sigma = 0.038$	x^* = -0.2259	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0248
$\sigma = 0.5$	x^* = -0.2511	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0312
$\sigma = 1$	x^* = -0.3433	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -1.0621

Figure 3.11: Isoclines of the two-dimensional system without social influence and $a_0 = 0$.

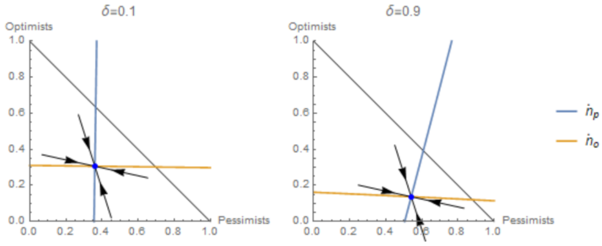


Figure 3.12: Isoclines of the two-dimensional system without social influence and $a_0 = 1.5$.

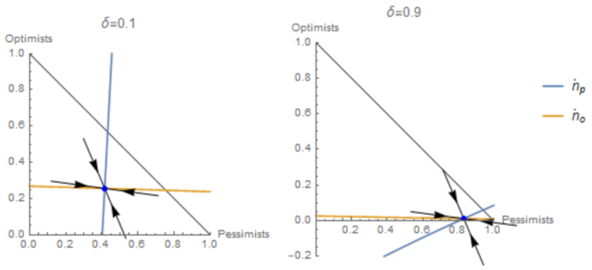


Figure 3.13: Isoclines of the two-dimensional system without social influence and $a_0 = 2$.

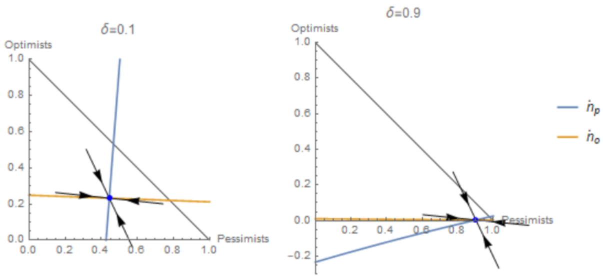


Figure 3.14: Isoclines of the two-dimensional system without social influence and $a_0 = 1$.

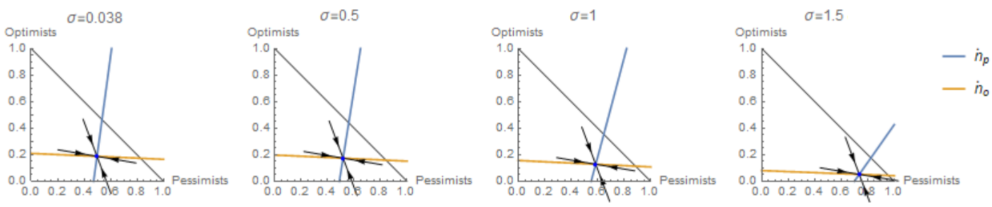


Table 3.8: Equilibrium points of the dynamics shown in figure 3.11, 3.12, 4.4 and 3.14.

	Equilibrium points	Eigenvalues	Eigenvectors
$a_0 = 1, \delta = 0.1$	$(n_p^*, n_o^*) = (0.3883,\ 0.2805)$	λ_1 =-1.8124 λ_2 =-1.3612	v_1 = (-0.3523, 0.9359) v_2 = (0.9858, -0.1678)
$a_0 = 1, \delta = 0.9$	$(n_p^*, n_o^*) = (0.7146,\ 0.0436)$	λ_1 =-1.8166 λ_2 =-1.3607	v_1 = (-0.3525, 0.9358) v_2 = (0.9863, -0.1649)
$a_0 = 1.5, \delta = 0.1$	$(n_p^*, n_o^*) = (0.4165,\ 0.2557)$	λ_1 =-2.0637 λ_2 =-1.339	v_1 = (-0.3918, 0.9200) v_2 = (0.9911, -0.1333)
$a_0 = 1.5, \delta = 0.9$	$(n_p^*, n_o^*) = (0.8311,\ 0.0119)$	λ_1 =-2.0735 λ_2 =-1.3394	v_1 = (-0.3929, 0.9196) v_2 = (0.9916, -0.1294)
$a_0 = 1, \sigma = 0.038$	$(n_p^*, n_o^*) = (0.4974,\ 0.1879)$	λ_1 =-1.8139 λ_2 =-1.3610	v_1 = (-0.3524, 0.9359) v_2 = (0.9860, -0.1666)
$a_0 = 1, \sigma = 0.5$	$(n_p^*, n_o^*) = (0.5163,\ 0.1741)$	λ_1 =-1.8142 λ_2 =-1.361	v_1 = (-0.3524, 0.9359) v_2 = (0.9860, -0.1665)
$a_0 = 1, \sigma = 1$	$(n_p^*, n_o^*) = (0.5850,\ 0.1284)$	λ_1 =-1.8150 λ_2 =-1.3609	v_1 = (-0.3524, 0.9358) v_2 = (0.9861, -0.1659)

3.C.3 Sentiment dynamics with social influence

Figure 3.15: Dynamics of $\dot{x}$ with $a_0 = 1$, $a_1 = 1.54$ and varying parameters.

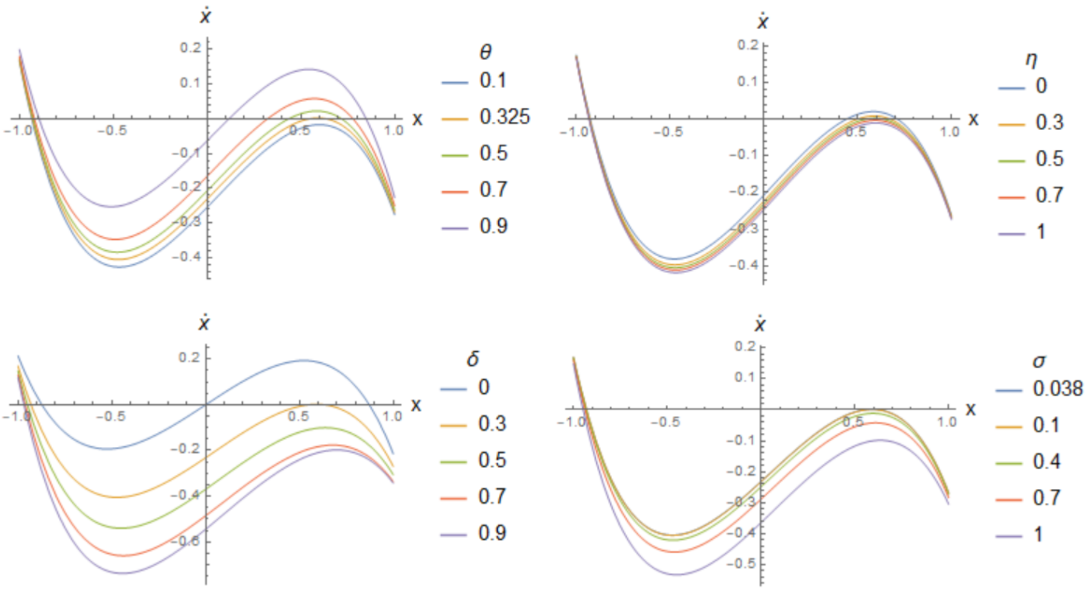


Table 3.9: Equilibrium points of the dynamics shown in figure 3.15.

	Equilibrium points	Derivative at the steady state
$a_1 = 1.5357, \theta = 0.1$	$x^* =$ -0.9343	$\frac{d(\dot{x})}{dx}\|_{x^*} =$ -2.2562
$a_1 = 1.5357, \theta = 0.5$	$x_1^* =$ -0.9273 $x_2^* =$ 0.4423 $x_3^* =$ 0.7106	$\frac{d(\dot{x})}{dx}\|_{x_1^*} =$ -2.0931 $\frac{d(\dot{x})}{dx}\|_{x_2^*} =$ 0.2666 $\frac{d(\dot{x})}{dx}\|_{x_3^*} =$ -0.3373
$a_1 = 1.5357, \theta = 0.7$	$x_1^* =$ -0.9196 $x_2^* =$ 0.3253 $x_3^* =$ 0.7747	$\frac{d(\dot{x})}{dx}\|_{x_1^*} =$ -1.9374 $\frac{d(\dot{x})}{dx}|_{x_2^*} =$0.4037 $\frac{d(\dot{x})}{dx}\|_{x_3^*} =$-0.6045
$a_1 = 1.5357, \theta = 0.9$	$x_1^* =$-0.8946 $x_2^* =$ 0.1179 $x_3^* =$ 0.8462	$\frac{d(\dot{x})}{dx}\|_{x_1^*} =$ -1.5480 $\frac{d(\dot{x})}{dx}\|_{x_2^*} =$ 0.5258 $\frac{d(\dot{x})}{dx}\|_{x_3^*} =$ -1.0543

$a_1 = 1.5357, \eta = 0$	$x_1^* =$ -0.9257 $x_2^* =$ 0.4475 $x_3^* =$ 0.7046	$\frac{d(\dot{x})}{dx}\|_{x_1^*}$ =-2.062 $\frac{d(\dot{x})}{dx}\|_{x_2^*}$ = 0.2551 $\frac{d(\dot{x})}{dx}\|_{x_3^*}$ = -0.3196
$a_1 = 1.5357, \eta = 0.3$	$x_1^* =$ -0.9288 $x_2^* =$ 0.51031 $x_3^* =$ 0.6620	$\frac{d(\dot{x})}{dx}\|_{x_1^*}$ = -2.1282 $\frac{d(\dot{x})}{dx}\|_{x_2^*}$ = 0.1594 $\frac{d(\dot{x})}{dx}\|_{x_3^*}$ =-0.1819
$a_1 = 1.5357, \eta = 0.5$	$x^*1 =$ -0.9302 $x_2^* =$ 0.5893	$\frac{d(\dot{x})}{dx}\|_{x_1^*}$ = -2.1593 $\frac{d(\dot{x})}{dx}\|_{x_2^*}$ = 0.000
$a_1 = 1.5357, \eta = 0.7$	$x^* =$ -0.9312	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -2.1832
$a_1 = 1.5357, \eta = 1$	$x^* =$ -0.9324	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -2.2098
$a_1 = 1.5357, \delta = 0$	$x_1^* =$ -0.8711 $x_2^* = 0$ $x_3^* =$ 0.8711	$\frac{d(\dot{x})}{dx}\|_{x_1^*}$ = -1.2825 $\frac{d(\dot{x})}{dx}\|_{x_2^*}$ = 0.5357 $\frac{d(\dot{x})}{dx}\|_{x_3^*}$ = -1.2825
$a_1 = 1.5357, \delta = 0.3$	$x_1^* =$ -0.9302 $x_2^* =$ 0.5893	$\frac{d(\dot{x})}{dx}\|_{x_1^*}$ = -2.1592 $\frac{d(\dot{x})}{dx}\|_{x_2^*}$ = 0.000
$a_1 = 1.5357, \delta = 0.5$	$x^* =$ -0.9494	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -2.7010
$a_1 = 1.5357, \delta = 0.7$	$x^* =$ -0.9612	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -3.1963
$a_1 = 1.5357, \delta = 0.9$	$x^* =$ -1	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -90789.9
$a_1 = 1.5357, \sigma = 0.1$	$x_1^* =$ -0.9303 $x_2^* =$ 0.5916	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -2.1626 $\frac{d(\dot{x})}{dx}\|_{x^*}$ = 0.0000
$a_1 = 1.5357, \sigma = 0.4$	$x^* =$ -0.9330	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -2.2242
$a_1 = 1.5357, \sigma = 0.7$	$x^* =$ -0.9389	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -2.3765
$a_1 = 1.5357, \sigma = 1$	$x^* =$ -0.9484	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -2.6675

Figure 3.16: Dynamics of $\dot{x}$ with $a_0 = 1$, $a_1 = 1.75$ and varying v and δ.

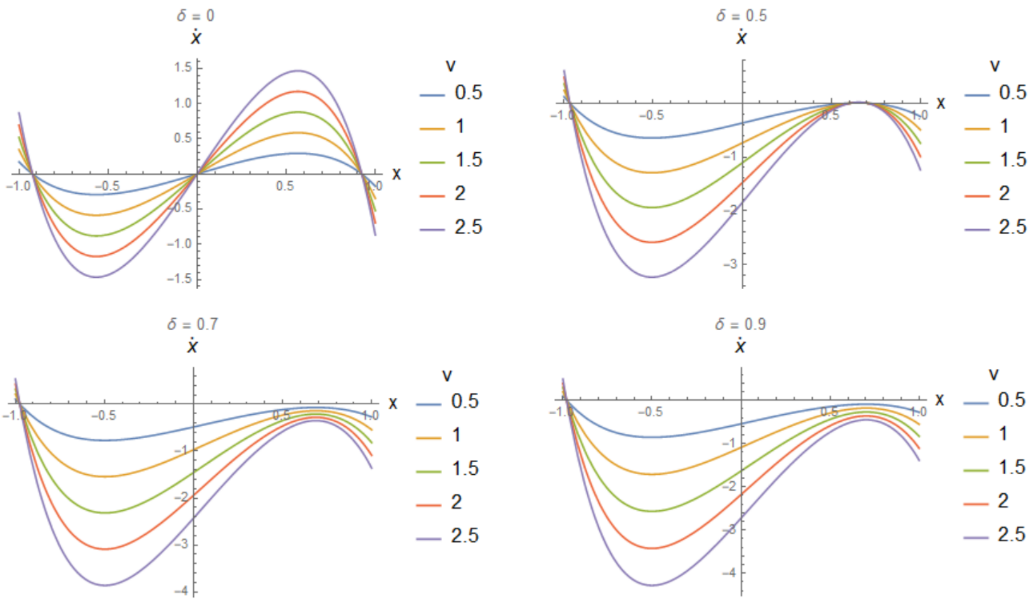


Table 3.10: Equilibrium points of the dynamics shown in figure 3.16.

	Equilibrium points	Derivative at the steady state
$a_1 = 1.74299, \delta = 0, v = 1$	$x_1^* =$ -0.9230 $x_2^* = 0$ $x_3^* = 0.9230$	$\frac{d(\dot{x})}{dx}\vert_{x_1^*} =$ -3.8550 $\frac{d(\dot{x})}{dx}\vert_{x_2^*} = 1.4860$ $\frac{d(\dot{x})}{dx}\vert_{x_3^*} =$ -3.8550
$a_1 = 1.74299, \delta = 0, v = 1.5$	" " "	$\frac{d(\dot{x})}{dx}\vert_{x_1^*} =$ -5.7825 $\frac{d(\dot{x})}{dx}\vert_{x_2^*} =2.2290$ $\frac{d(\dot{x})}{dx}\vert_{x_3^*} =$ -5.7825
$a_1 = 1.74299, \delta = 0, v = 2$	" " "	$\frac{d(\dot{x})}{dx}\vert_{x_1^*} =$ -7.7100 $\frac{d(\dot{x})}{dx}\vert_{x_2^*} = 2.9720$ $\frac{d(\dot{x})}{dx}\vert_{x_3^*} =$ -7.7100
$a_1 = 1.74299, \delta = 0, v = 2.5$	" " "	$\frac{d(\dot{x})}{dx}\vert_{x_1^*} =$ -9.6375 $\frac{d(\dot{x})}{dx}\vert_{x_2^*} = 3.7150$ $\frac{d(\dot{x})}{dx}\vert_{x_3^*} =$ -9.6375

$a_1 = 1.74299, \delta = 0.5, v = 1$	$x_1^* =$ -0.9677 $x_2^* =$ 0.6545	$\frac{d(\dot{x})}{dx}\|_{x_1^*}$ =-7.0514 $\frac{d(\dot{x})}{dx}\|_{x_2^*}$ =0.0000
$a_1 = 1.74299, \delta = 0.5, v = 1.5$	" "	$\frac{d(\dot{x})}{dx}\|_{x_1^*}$ = -10.577 $\frac{d(\dot{x})}{dx}\|_{x_2^*}$ = 0.0000
$a_1 = 1.74299, \delta = 0.5, v = 2$	" "	$\frac{d(\dot{x})}{dx}\|_{x_1^*}$ =-14.1027 $\frac{d(\dot{x})}{dx}\|_{x_2^*}$ = 0.0000
$a_1 = 1.74299, \delta = 0.5, v = 2.5$	" "	$\frac{d(\dot{x})}{dx}\|_{x_1^*}$ =-17.6284 $\frac{d(\dot{x})}{dx}\|_{x_2^*}$ = 0.0000
$a_1 = 1.74299, \delta = 0.7, v = 1$	$x^* =$ -0.9750	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -8.2204
$a_1 = 1.74299, \delta = 0.7, v = 1.5$	"	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -12.3305
$a_1 = 1.74299, \delta = 0.7, v = 2$	"	$\frac{d(\dot{x})}{dx}\|_{x^*}$ =-16.4407
$a_1 = 1.74299, \delta = 0.7, v = 2.5$	"	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -20.5509
$a_1 = 1.74299, \delta = 0.9, v = 1$	$x^* =$ -0.9793	$\frac{d(\dot{x})}{dx}\|_{x_1^*}$ = -9.1469
$a_1 = 1.74299, \delta = 0.9, v = 1.5$	"	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -13.8159
$a_1 = 1.74299, \delta = 0.9, v = 2$	"	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -18.4212
$a_1 = 2, \delta = 0.9, v = 2.5$	"	$\frac{d(\dot{x})}{dx}\|_{x^*}$ = -23.0266

Figure 3.17: Bifurcation diagram for the parameters shown in table 3.1, for varying a_0

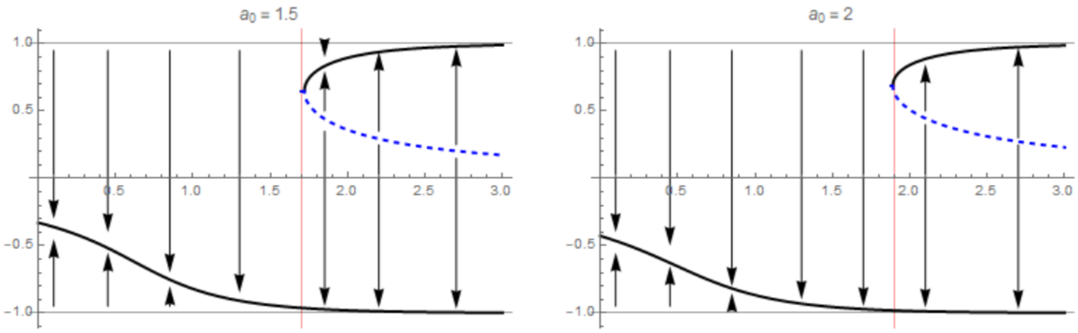


Figure 3.18: Bifurcation diagram for the parameters shown in table 3.1, $a_0 = 1$ and for varying δ

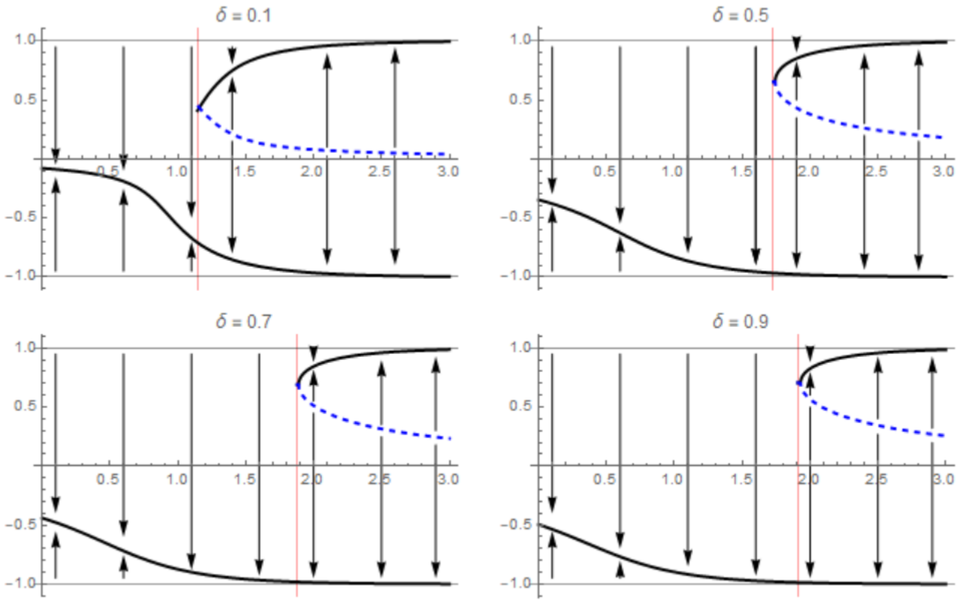


Figure 3.19: Bifurcation diagram for the parameters shown in table 3.1, $a_0 = 1$ and for varying η

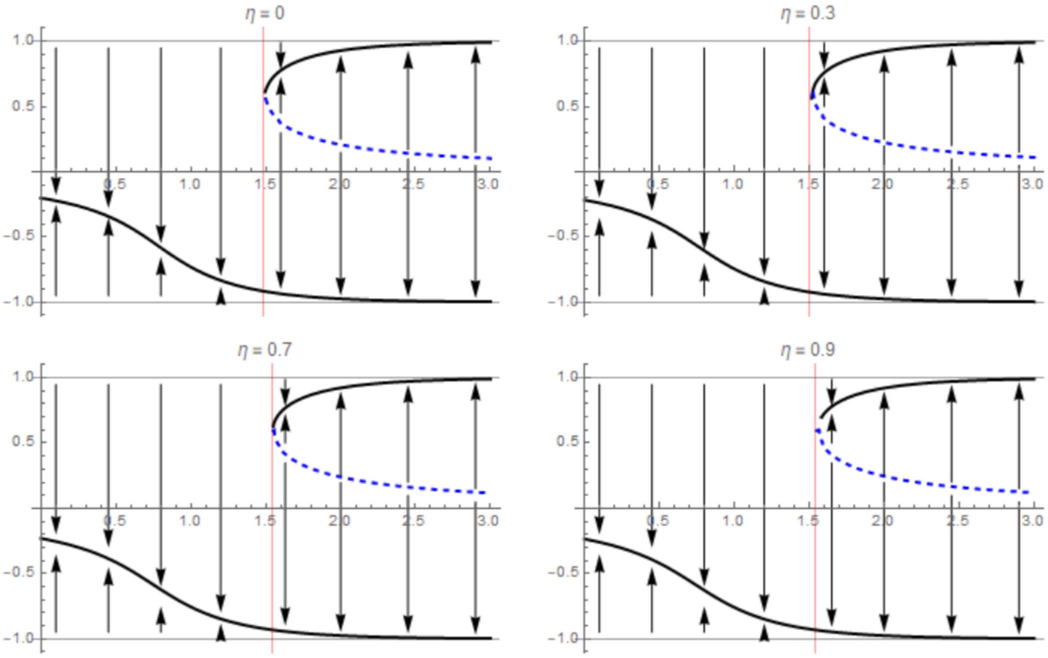


Figure 3.20: Bifurcation diagram for the parameters shown in table 3.1, $a_0 = 1$ and for varying θ

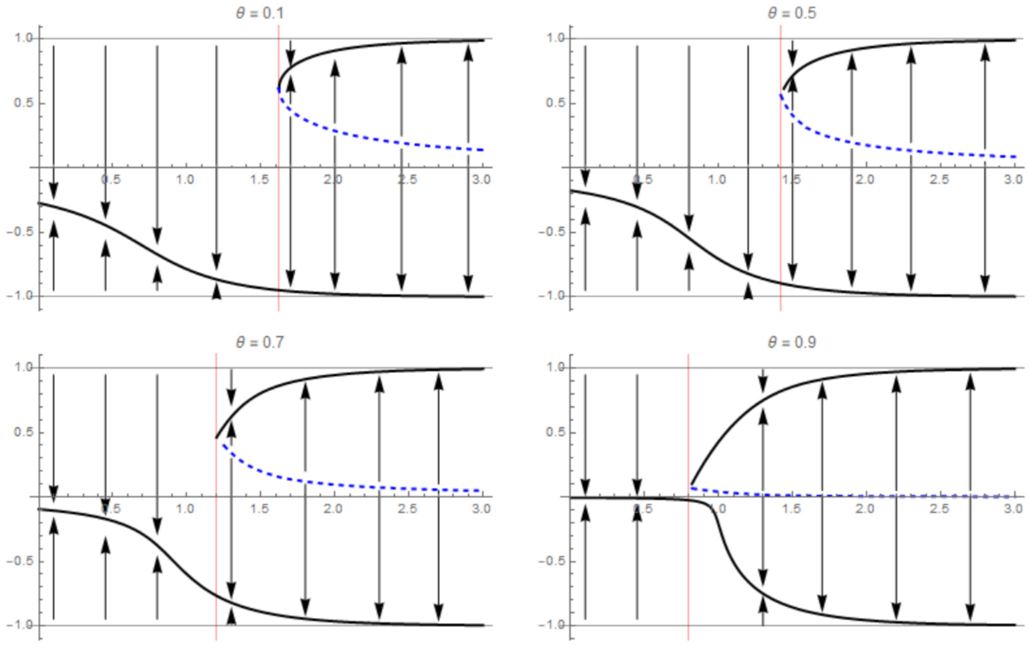


Figure 3.21: First bifurcation point with different a_0.

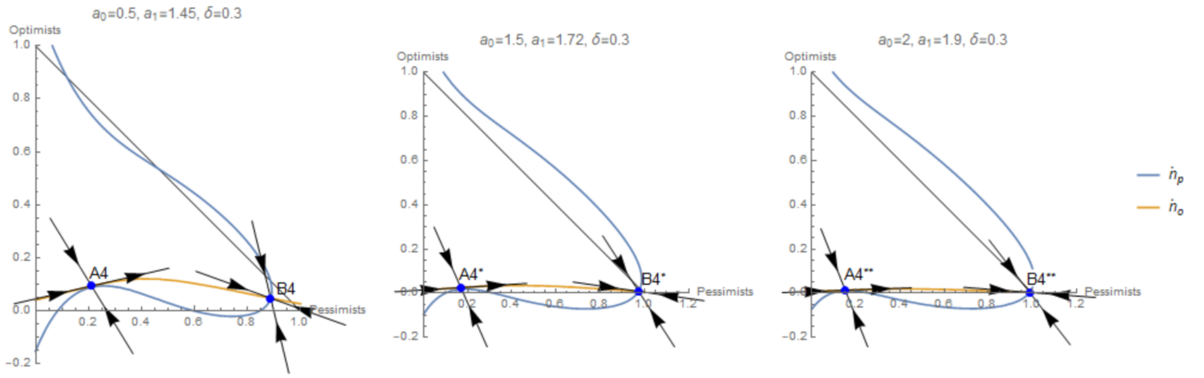


Table 3.11: Equilibrium points shown in figure 3.21.

	Equilibrium points	Eigenvalues	Eigenvectors
$a_0 = 0.5, a_1 = 1.45$	$A4 = (0.2115, 0.0937)$	$\lambda_1 = -1.5454$	$v_1 =$ (-0.5219, 0.8530)
		$\lambda_2 = -8.3188 * 10^{-10}$	$v_2 =$ (0.9980, 0.0636)
	$B4 = (0.8876, 0.0476)$	$\lambda_1 = -2.5828$	$v_1 =$ (-0.5436, 0.8394)
		$\lambda_2 = -1.2349$	$v_2 =$ (0.9900, -0.1409)
$a_0 = 1.5, a_1 = 1.72$	$A4^* = (0.1687, 0.0251)$	$\lambda_1 = -3.7317$	$v_1 =$ (-0.4057, 0.9140)
		$\lambda_2 = -6.9333 * 10^{-8}$	$v_2 =$ (0.9745, 0.2243)
	$B4^* = (0.9738, 0.0081)$	$\lambda_1 = -6.1116$	$v_1 =$ (-0.2357, 0.9718)
		$\lambda_2 = -3.4330$	$v_2 =$ (0.9410, -0.3383)
$a_0 = 2, a_1 = 1.9$	$A4^{**} = (0.1687, 0.0251)$	$\lambda_1 = -5.3593$	$v_1 =$ (-0.3684, 0.9297)
		$\lambda_2 = 5.9396 * 10^{-9}$	$v_2 =$ (0.9993, 0.0370)
	$B4^{**} = (0.9738, 0.0081)$	$\lambda_1 = -9.3830$	$v_1 =$ (-0.6124, 0.7905)
		$\lambda_2 = -4.9689$	$v_2 =$ (0.9970, -0.0772)

Figure 3.22: First bifurcation point with $a_0 = 1$ and different δ.

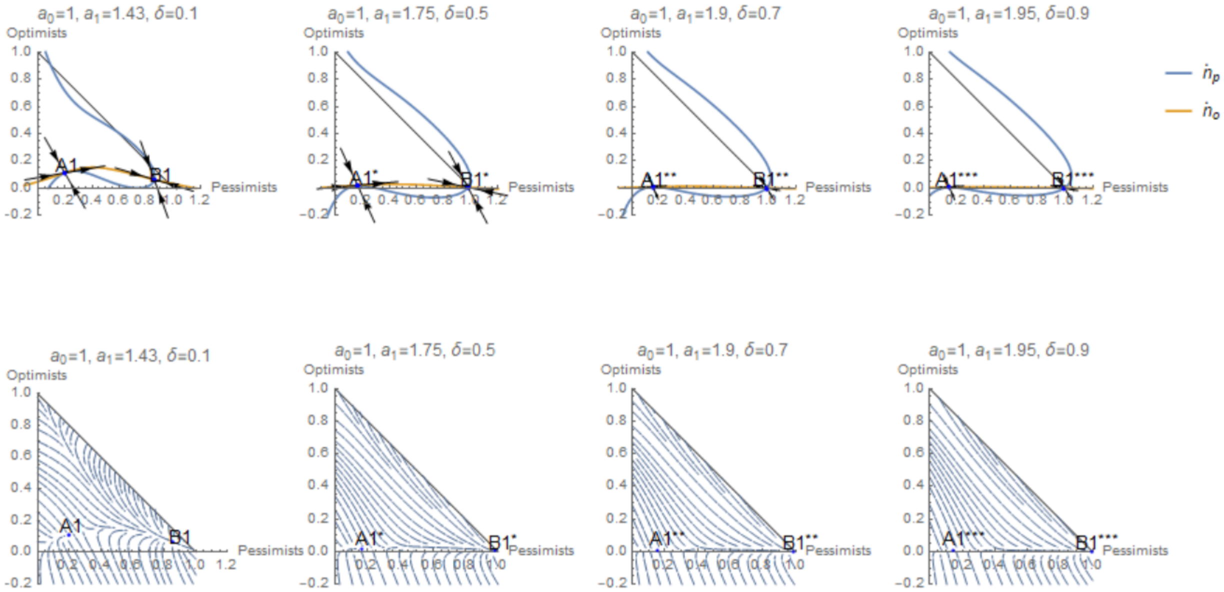


Table 3.12: Equilibrium points shown in figure 3.22.

	Equilibrium points	Eigenvalues	Eigenvectors
$a_1 = 1.425, \delta = 0.1$	$A1 =$ (0.2159, 0.1185)	$\lambda_1 = -1.2659$	$v_1 =$ (-0.5587, 0.8294)
		$\lambda_2 = 6.4310 * 10^{-}9$	$v_2 =$ (0.9532, 0.3024)
	$B1 =$ (0.8550, 0.0649)	$\lambda_1 = -2.1906$	$v_1 =$ (-0.1590, 0.9873)
		$\lambda_2 = -0.9313$	$v_2 =$ (0.9586, -0.2848)
$a_1 = 1.75, \delta = 0.5$	$A1^{*} =$ (0.1663, 0.0209)	$\lambda_1 = -4.1531$	$v_1 =$ (-0.3937, 0.9192)
		$\lambda_2 = 1.07604 * 10^{-}8$	$v_2 =$ (0.9986, 0.0532)
	$B1^{*} =$ (0.9774, 0.0064)	$\lambda_1 = -6.8464$	$v_1 =$ (-0.5692, 0.8222)
		$\lambda_2 = -3.6812$	$v_2 =$ (0.9934, -0.1143)
$a_1 = 1.9, \delta = 0.7$	$A1^{**} =$ (0.1519, 0.0101)	$\lambda_1 = -6.1810$	$v_1 =$ (-0.3556, 0.9346)
		$\lambda_2 = -4.03597 * 10^{-}9$	$v_2 =$ (0.9996, 0.0278)
	$B1^{**} =$(0.9885, 0.0024)	$\lambda_1 = -5.9684$	$v_1 =$ (-0.5045, 0.8634)
		$\lambda_2 = -3.9312$	$v_2 =$ (0.9823, -0.1874)
$a_1 = 1.9367, \delta = 0.9$	$A1^{***} =$ (0.1461, 0.0062)	$\lambda_1 = -8.0787$	$v_1 =$ (-0.3344, 0.9424)
		$\lambda_2 = 2.04594 * 10^{-}9$	$v_2 =$ (0.9999, 0.0167)
	$B1^{***} =$ (0.9918, 0.0012)	$\lambda_1 = -15.4894$	$v_1 =$ (-0.6527, 0.7576)
		$\lambda_2 = -5.8505$	$v_2 =$ (0.9997, -0.0260)

Figure 3.23: Second bifurcation point with $a_0 = 1$ and different δ.

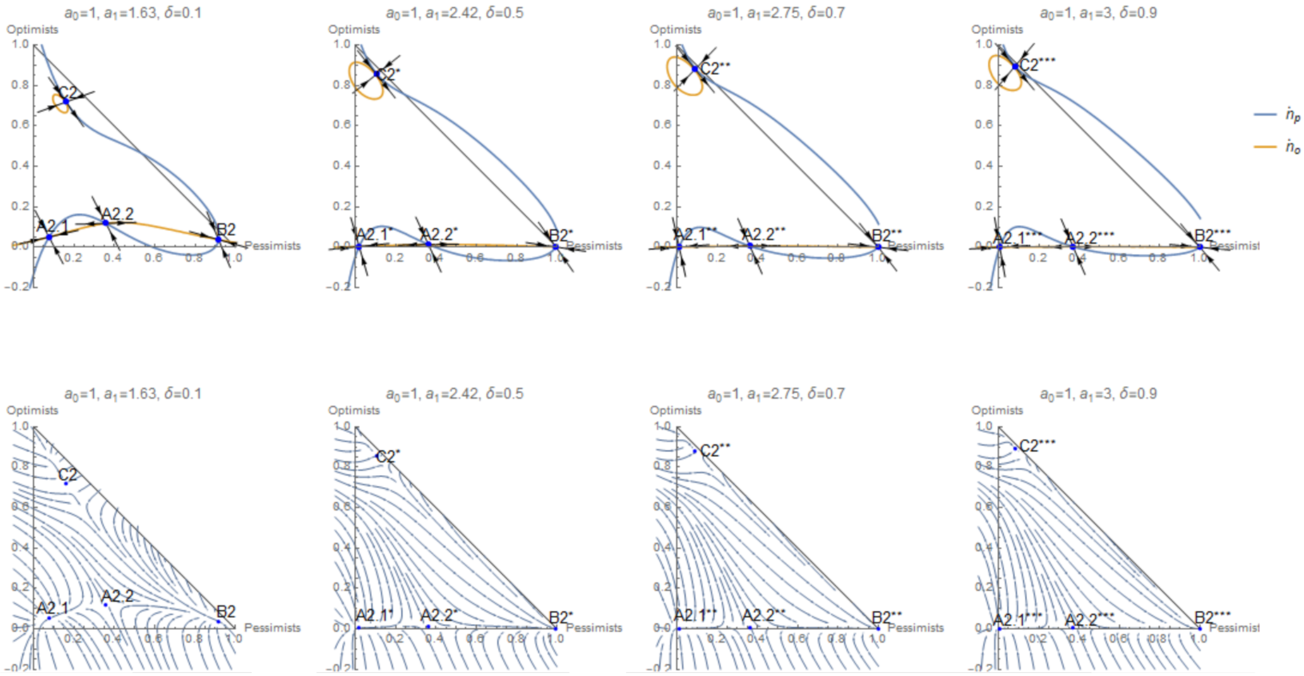


Table 3.15: Equilibrium points shown in figure 3.23

	Equilibrium points	Eigenvalues	Eigenvectors
$a_1 = 1.63, \delta = 0.1$	$A2.1 = (0.0762, 0.0507)$	$\lambda_1 = -2.4010$	$v_1 =$ (-0.5822, 0.8130)
		$\lambda_2 = -0.9268$	$v_2 =$ (0.9006, 0.4346)
	$A2.2 = (0.3581, 0.1184)$	$\lambda_1 = -1.0764$	$v_1 =$ (-0.4779, 0.8784)
		$\lambda_2 = 0.5069$	$v_2 =$ (0.9969, 0.0786)
	$B2 = (0.9167, 0.0377)$	$\lambda_1 = -2.9281$	$v_1 =$ (-0.1747, 0.9846)
		$\lambda_2 = -1.5874$	$v_2 =$ (0.9262, -0.3770)
	$C2 = (0.1604, 0.7195)$	$\lambda_1 = -1.2131$	$v_1 =$ (-0.9754, -0.2206)
		$\lambda_2 = 8.2542 * 10^-10$	$v_2 =$ (0.5333, -0.8459)
$a_1 = 2.42, \delta = 0.5$	$A2.1^* = (0.0193, 0.0036)$	$\lambda_1 = -9.1308$	$v_1 =$ (-0.2269, 0.9739)
		$\lambda_2 = -3.0854$	$v_2 =$ (0.9987, 0.052)
	$A2.2^* = (0.3630, 0.0134)$	$\lambda_1 = -5.5033$	$v_1 =$ (-0.4229, 0.9062)
		$\lambda_2 = 1.3804$	$v_2 =$ (0.9999, 0.0107)
	$B2^* = (0.9945, 0.0016)$	$\lambda_1 = -13.1787$	$v_1 =$ (-0.6370, 0.7709)
		$\lambda_2 = -7.9136$	$v_2 =$ (0.9976, -0.0694)
	$C2^* = (0.1051, 0.8564)$	$\lambda_1 = -2.5105$	$v_1 =$ (-0.7720, -0.6356)
		$\lambda_2 = -1.10261 * 10^-8$	$v_2 =$ (0.6360, -0.7717)

Table 3.16: Equilibrium points of the dynamics shown in figure 3.24.

	Equilibrium points	Eigenvalues	Eigenvectors
$a_1 = 2.75, \delta = 0.7$	$A2.1^{**} = (0.0113, 0.0012)$	$\lambda_1 = -15.523$	v_1 = (-0.1532, 0.9882)
		$\lambda_2 = -4.2509$	v_2 = (0.9998, 0.0206)
	$A2.2^{**} = (0.3624, 0.0056)$	$\lambda_1 = -8.9222$	v_1 = (-0.4136, 0.9105)
		$\lambda_2 = 1.6978$	v_2 = (0.9999, 0.0049)
	$B2^{**} = (0.9980, 0.0004)$	$\lambda_1 = -25.0545$	v_1 = (-0.6752, 0.7376)
		$\lambda_2 = -12.6226$	v_2 = (0.9997, -0.0240)
	$C2^{**} = (0.0909, 0.8818)$	$\lambda_1 = -3.0653$	v_1 = (-0.7045, -0.7097)
		$\lambda_2 = -6.6986 * 10^-9$	v_2 = (0.6506, -0.7594)
$a_1 = 3, \delta = 0.9$	$A2.1^{***} = (0.0068, 0.0005)$	$\lambda_1 = -24.2385$	v_1 = (-0.1105, 0.9939)
		$\lambda_2 = -5.6683$	v_2 = (0.9999, 0.0098)
	$A2.2^{***} = (0.3702, 0.0027)$	$\lambda_1 = -13.0734$	v_1 = (-0.4098, 0.9122)
		$\lambda_2 = 1.9785$	v_2 = (0.9999, 0.0022)
	$B2^{***} = (0.9991, 0.0001)$	$\lambda_1 = -43.4478$	v_1 = (-0.6890, 0.7248)
		$\lambda_2 = -17.7698$	v_2 = (0.9999, -0.0093)
	$C2^{***} = (0.0811, 0.8948)$	$\lambda_1 = -3.2358$	v_1 = (-0.6899, -0.7239)
		$\lambda_2 = 0.0000$	v_2 = (0.6509, -0.7591)

Figure 3.24: Third bifurcation point with $a_0 = 1$ and different δ.

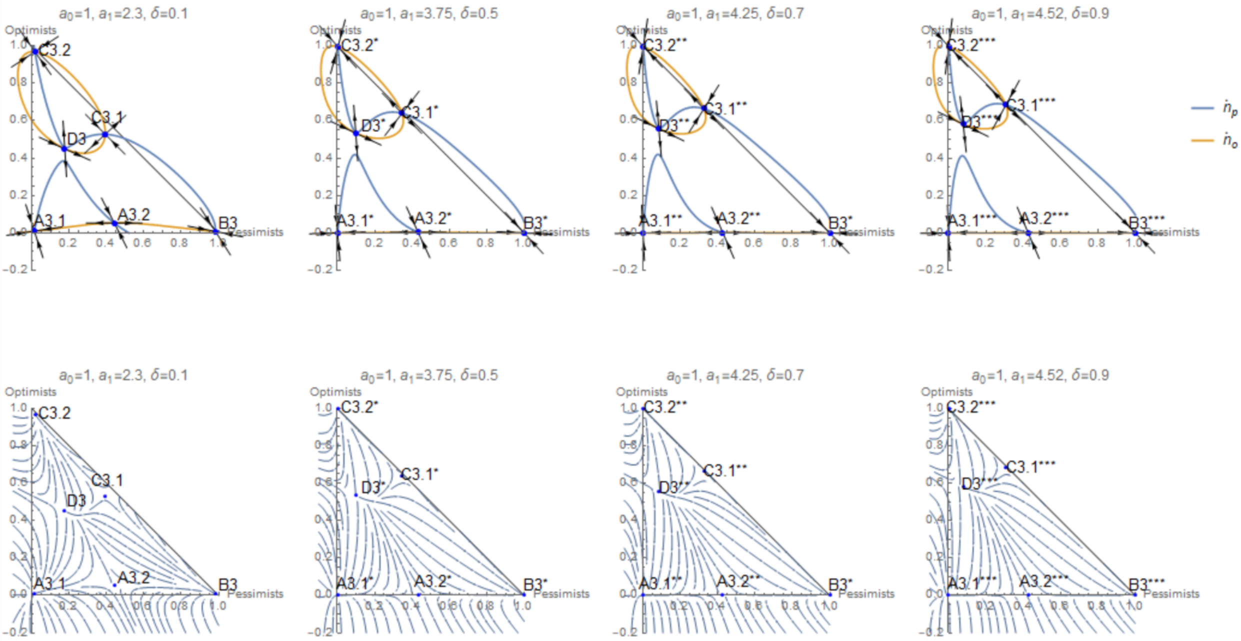


Table 3.17: Equilibrium points of the dynamics shown in figure 3.24.

	Equilibrium points	Eigenvalues	Eigenvectors
$a_1 = 2.3, \delta = 0.1$	$A3.1 = (0.0136,\ 0.0097)$	$\lambda_1 = -5.5142$	$v_1 =$ (-0.4939, 0.8695)
		$\lambda_2 = -3.8294$	$v_2 =$ (0.9228, 0.3853)
	$A3.2 = (0.4411,\ 0.0536)$	$\lambda_1 = -2.0404$	$v_1 =$ (-0.4482, 0.8939)
		$\lambda_2 = 1.3671$	$v_2 =$ (0.9999, 0.0107)
	$B3 = (0.9825,\ 0.0080)$	$\lambda_1 = -6.116$	$v_1 =$ (-0.2870, 0.9579)
		$\lambda_2 = -4.7003$	$v_2 =$ (0.9364, -0.3508)
	$C3.2 = (0.0168,\ 0.9691)$	$\lambda_1 = -4.6590$	$v_1 =$ (-0.9587, -0.2843)
		$\lambda_2 = -3.2160$	$v_2 =$ (0.5155, -0.8569)
	$C3.1 = (0.3931,\ 0.5278)$	$\lambda_1 = 1.3155$	$v_1 =$ (0.6942, -0.7198)
		$\lambda_2 = -1.3045$	$v_2 =$ (-0.7291, -0.6844)
	$D3 = (0.1764,\ 0.4500)$	$\lambda_1 = 1.1772$	$v_1 =$ (0.0724, -0.9974)
		$\lambda_2 = 1.94067 * 10^-8$	$v_2 =$ (-0.9118, 0.4106)
$a_1 = 3.75, \delta = 0.5$	$A3.1^* = (0.0011,\ 0.0002)$	$\lambda_1 = -33.8293$	$v_1 =$ (-0.0638, 0.9980)
		$\lambda_2 = -14.7287$	$v_2 =$ (0.9999, 0.0143)
	$A3.2^* = (0.4324,\ 0.0035)$	$\lambda_1 = -11.5348$	$v_1 =$ (-0.4310, 0.9024)
		$\lambda_2 = 2.8149$	$v_2 =$ (0.9999, 0.0017)
	$B3^* = (0.9996,\ 0.0001)$	$\lambda_1 = -48.7451$	$v_1 =$ (-0.6899, 0.7238)
		$\lambda_2 = -30.8416$	$v_2 =$ (0.9998, -0.0193)
	$C3.2^* = (0.0028,\ 0.9959)$	$\lambda_1 = -14.0214$	$v_1 =$ (0.2308, 0.9730)
		$\lambda_2 = -9.3672$	$v_2 =$ (0.672, -0.7405)
	$C3.1^* = (0.3462,\ 0.6397)$	$\lambda_1 = -4.9976$	$v_1 =$ (0.6670, 0.7451)
		$\lambda_2 = 2.7180$	$v_2 =$ (0.7016, -0.7126)
	$D3^* = (0.0986,\ 0.5340)$	$\lambda_1 = 2.9339$	$v_1 =$ (0.0661, -0.9978)
		$\lambda_2 = -0.4406$	$v_2 =$ (-0.9095, 0.4157)
$a_1 = 4.25, \delta = 0.7$	$A3.1^{**} = (0.0005,\ 0.0001)$	$\lambda_1 = -67.129$	$v_1 =$ (-0.0347, 0.9994)
		$\lambda_2 = -22.2154$	$v_2 =$ (0.9999, 0.0044)
	$A3.2^{**} = (0.4275,\ 0.0013)$	$\lambda_1 = -19.6166$	$v_1 =$ (-0.4265, 0.9045)
		$\lambda_2 = 3.2881$	$v_2 =$ (1., 0.0008)
	$B3^{**} = (0.9999,\ 0.0000)$	$\lambda_1 = -109.956$	$v_1 =$ (-0.7004, 0.7138)
		$\lambda_2 = -57.1282$	$v_2 =$ (0.9999, -0.0052)

	$C3.2{**} = (0.0017, 0.9975)$	$\lambda_1 = -19.1844$	$v_1 = (0.1460, 0.9893)$
		$\lambda_2 = -11.9323$	$v_2 = (0.6868, -0.7268)$
	$C3.1^{**} = (0.3266, 0.6644)$	$\lambda_1 = -6.5715$	$v_1 = (0.6482, 0.7615)$
		$\lambda_2 = 3.1399$	$v_2 = (0.7027, -0.7115)$
	$D3^{**} = (0.0853, 0.5573)$	$\lambda_1 = 3.3990$	$v_1 = (0.0690, -0.9976)$
		$\lambda_2 = 5.17766 * 10^-8$	$v_2 = (-0.9099, 0.4148)$
$a_1 = 4.52, \delta = 0.9$	$A3.1^{***} = (0.0003, 0.0000)$	$\lambda_1 = -106.823$	$v_1 = (-0.0243, 0.9997)$
		$\lambda_2 = -28.6499$	$v_2 = (0.9999, 0.0020)$
	$A3.2^{***} = (0.4266, 0.0006)$	$\lambda_1 = -28.5918$	$v_1 = (-0.4241, 0.9056)$
		$\lambda_2 = 3.5711$	$v_2 = (1., 0.0003)$
	$B3^{***} = (0.9999, 6.6381 * 10^-6)$	$\lambda_1 = -195.232$	$v_1 = (-0.7033, 0.7109)$
		$\lambda_2 = -81.6238$	$v_2 = (0.9999, -0.0019)$
	$C3.2^{***} = (0.0015, 0.9979)$	$\lambda_1 = -20.6881$	$v_1 = (0.1353, 0.9908)$
		$\lambda_2 = -12.9541$	$v_2 = (0.6880, -0.7257)$
	$C3.1^{***} = (0.3074, 0.6847)$	$\lambda_1 = -6.9728$	$v_1 = (0.6368, 0.7710)$
		$\lambda_2 = 3.3669$	$v_2 = (0.7025, -0.7117)$
	$D3^{***} = (0.0787, 0.5815)$	$\lambda_1 = 3.6467$	$v_1 = (0.0797, -0.9968)$
		$\lambda_2 = -3.19979 * 10^-8$	$v_2 = (-0.9127, 0.4086)$

Table 3.13: Equilibrium points of the dynamics shown in figure 3.5 and 3.6.

	Equilibrium points	Eigenvalues	Eigenvectors
$a_1 = 1$	$(n_p^*, n_o^*) = (0.7966, 0.070)$	$\lambda_1 =$-2.1763	$v_1 =$ (-0.3470, 0.9379)
		$\lambda_2 =$-0.8154	$v_2 =$ (0.9728, -0.2316)
$a_1 = 1.6$	$A = (0.1873, 0.0455)$	$\lambda_1 =$ -2.5841	$v_1 =$ (-0.4486, 0.8937)
		$\lambda_2 = 3.8638 * 10^-9$	$v_2 =$ (0.9938, 0.1110)
	$B = (0.9503{,}0.0180)$	$\lambda_1 =$ -4.1543	$v_1 =$ (-0.4277, 0.9039)
		$\lambda_2 = -2.36097$	$v_2 =$ (0.9728, -0.2314)
$a_1 = 2.02$	$A1 = (0.0376, 0.0129)$	$\lambda_1 =$ -4.8682	$v_1 =$ (-0.3659, 0.9306)
		$\lambda_2 =$ -1.9329	$v_2 =$ (0.9891, 0.1475)
	$A2 = (0.3624, 0.0367)$	$\lambda_1 =$ -2.9309	$v_1 =$ (-0.4396, 0.8982)
		$\lambda_2 =$ 0.9791	$v_2 =$ (0.9997, 0.0263)
	$B^* = (0.9804, 0.0072)$	$\lambda_1 =$ -6.3727	$v_1 =$ (-0.5066, 0.8622)
		$\lambda_2 =$ -4.2244	$v_2 =$ (0.9804, -0.1972)
$a_1 = 2.05$	$A1^* = (0.0348, 0.0120)$	$\lambda_1 =$ -5.0352	$v_1 =$ (-0.3594, 0.9332)
		$\lambda_2 =$ -2.0562	$v_2 =$ (0.9893, 0.1456)
	$A2^* = (0.3669, 0.0357)$	$\lambda_1 =$ -2.9865	$v_1 =$ (-0.4394, 0.8983)
		$\lambda_2 =$ 1.0183	$v_2 =$ (0.9997, 0.0246)
	$B^{**} = (0.9817, 0.0068)$	$\lambda_1 =$ -6.5668	$v_1 =$ (-0.5119, 0.8590)
		$\lambda_2 =$ -4.3856	$v_2 =$ (0.9809, -0.1943)
	$C = (0.1256, 0.8118)$	$\lambda_1 =$ -1.8605	$v_1 =$ (-0.8720, -0.4895)
		$\lambda_2 =$ -0.00001	$v_2 =$ (0.6042, -0.7968)
$a_1 = 2.5$	$A1^{**} = (0.0120, 0.0044)$	$\lambda_1 =$ -8.0997	$v_1 =$ (-0.2613, 0.9652)
		$\lambda_2 =$ -4.1996	$v_2 =$ (0.9941, 0.1089)
	$A2^{**} = (0.4109, 0.0222)$	$\lambda_1 =$ -4.0015	$v_1 =$ (-0.4376, 0.8991)
		$\lambda_2 =$ 1.5534	$v_2 =$ (0.9999, 0.0105)
	$B^{***} = (0.9929, 0.0026)$	$\lambda_1 =$ -10.2595	$v_1 =$ (-0.5818, 0.8133)
		$\lambda_2 =$ -7.3972	$v_2 =$ (0.9891, -0.1475)
	$C1 = (0.0228, 0.9633)$	$\lambda_1 =$ -4.5529	$v_1 =$ (-0.7717, -0.6360)
		$\lambda_2 =$ -2.6134	$v_2 =$ (0.5939, -0.8045)
	$C2 = (0.2976, 0.6457)$	$\lambda_1 =$ -1.8165	$v_1 =$ (-0.7334, -0.6798)
		$\lambda_2 =$ 1.3444	$v_2 =$ (0.6816, -0.7317)

Table 3.14: Equilibrium points of the dynamics shown in figure 3.7.

$a_1 = 3.12$	$A1^{***} = (0.0032,\ 0.0012)$	$\lambda_1 =$ -15.0544,	$v_1 =$ (-0.1510, 0.9885)
		$\lambda_2 =$ -8.7216	$v_2 =$ (0.9981, 0.0621)
	$A2^{***} = (0.4398,\ 0.0115)$	$\lambda_1 =$ -5.9279	$v_1 =$ (-0.4378, 0.8991)
		$\lambda_2 =$ 2.2188	$v_2 =$ (0.9999, 0.0041)
	$B^{****} = (0.9981,\ 0.0007)$	$\lambda_1 =$ -18.9035	$v_1 =$ (-0.6429, 0.7660)
		$\lambda_2 =$ -14.2323	$v_2 =$ (0.9959, -0.0894)
	$C1^{*} = (0.3693,\ 0.6029)$	$\lambda_1 =$ -3.1885,	$v_1 =$ (0.6921, 0.7218)
		$\lambda_2 =$ 2.1569	$v_2 =$ (0.6993, -0.7148)
	$C2^{*} = (0.0055,\ 0.9910)$	$\lambda_1 =$ -8.9162	$v_1 =$ (0.4885, 0.8726)
		$\lambda_2 =$ -6.4661	$v_2 =$ (0.6284, -0.7779)
	$D = (0.1220,\ 0.5039)$	$\lambda_1 =$ 2.1603	$v_1 =$ (0.0664, -0.9978)
		$\lambda_2 = -7.7107 * 10^-9$	$v_2 =$ (-0.9102, 0.4142)
$a_1 = 4$	$A1^{****} = (0.0005,\ 0.0002)$	$\lambda_1 =$ -35.8835,	$v_1 =$ (-0.0631, 0.9980)
		$\lambda_2 =$ -21.7414	$v_2 =$ (0.9997, 0.0252)
	$A2^{****} = (0.4594,\ 0.0046)$	$\lambda_1 =$ -9.9205	$v_1 =$ (-0.4387, 0.8986)
		$\lambda_2 =$ 3.1111	$v_2 =$ (0.9999, 0.0014)
	$B^{*****} = (0.9997,\ 0.0001)$	$\lambda_1 =$ -45.1062	$v_1 =$ (-0.6824, 0.7310)
		$\lambda_2 =$ -34.5745	$v_2 =$ (0.9992, -0.0388)
	$C1^{**} = (0.4136,\ 0.5760)$	$\lambda_1 =$ -6.0773	$v_1 =$ (0.6817, 0.7316)
		$\lambda_2 =$ 3.1089	$v_2 =$ (0.7048, -0.7094)
	$C2^{**} = (0.0009,\ 0.9985)$	$\lambda_1 =$ -21.5163	$v_1 =$ (0.1850, 0.9827)
		$\lambda_2 =$ -16.8421	$v_2 =$ (0.6713, -0.7412)
	$D1 = (0.0241,\ 0.5309)$	$\lambda_1 =$ -3.2997	$v_1 =$ (-0.8932, 0.4496)
		$\lambda_2 =$ 3.2076	$v_2 =$ (0.0075, -0.9999)
	$D2 = (0.2334,\ 0.4310)$	$\lambda_1 =$ 2.8690	$v_1 =$ (0.1869, -0.9824)
		$\lambda_2 =$ 1.8837	$v_2 =$ (-0.9457, 0.3251)
$a_1 = 20$	$A1^{*****} = (0.,\ 0.)$	$\lambda_1 = -3.1358 * 10^8$	$v_1 = (-6.7415 * 10^-9, 1.)$
		$\lambda_2 = -1.9319 * 10^8$	$v_2 = (1., 2.5589 * 10^-9)$
	$A2^{*****} = (0.4940,\ 4.889 * 10^-10)$	$\lambda_1 =$ -31979.3	$v_1 =$ (-0.4451, 0.8955)
		$\lambda_2 =$ 19.0006	$v_2 = (1., 1.1937 * 10^-10)$
	$B^{******} = (1.,\ 0.)$	$\lambda_1 = -3.9630 * 10^8$	$v_1 =$ (-0.7071, 0.7071)
		$\lambda_2 = -3.0571 * 10^8$	$v_2 = (1., -4.2576 * 10^-9)$
	$C1^{***} = (0.4872,\ 0.5128)$	$\lambda_1 =$-21711.3	$v_1 =$ (0.6980, 0.7161)
		$\lambda_2 =$ 18.9994	$v_2 =$ (0.7071, -0.7071)
	$C2^{***} = (0.,\ 1.)$	$\lambda_1 = -1.8808 * 10^8$	$v_1 = (1.6533 * 10^-8, 1.)$
		$\lambda_2 = -1.5021 * 10^8$	$v_2 =$ (0.7071, -0.7071)
	$D1^{*} = (2.0918 * 10^-9,\ 0.5067)$	$\lambda_1 =$-15460.2	$v_1 =$ (-0.8932, 0.4496)
		$\lambda_2 =$ 18.9998	$v_2 = (6.0673 * 10^-10, -1.)$
	$D2^{*} = (0.3205,\ 0.3467)$	$\lambda_1 =$ 18.738	$v_1 =$ (0.2702, -0.9628)
		$\lambda_2 =$ 18.2512	$v_2 =$ (-0.9690, 0.2471)

Chapter 4

Concentration, Stagnation and Inequality: an Agent-Based Approach

4.1 Introduction

Over the last three decades, advanced economies, particularly the U.S., have undergone major structural changes which manifest themselves in a number of secular trends, i.e., rising market concentration, widening income inequality and secular stagnation (Syverson, 2019)[59].

Since the early 1990s, more than 75% of U.S. industries have witnessed rising concentration levels, as measured by the Herfindahl-Hirschman (HH) index, which grew on average by 90% (Grullon et al., 2019). Moreover, many studies have documented a widespread increase in income inequality, especially among western countries, both in the functional and personal distribution (Atkinson, 2015; Karabarbounis and Neiman, 2014; Piketty, 2014; Stiglitz, 2012).

In the U.S., excluding the top 1%, the income share going to wages has plummeted from 75% in 1980 to 60% in 2010 (Giovannoni, 2014); real wages have slowed down since the early 1970s, so has productivity but at lower rates, causing the labor share to decline (Autor et al., 2020; Barkai, 2020; Benmelech et al., 2018). More recently, empirical research has made attempts to identify potential links between changes in market structure and income distribution. Barkai (2020), for instance, highlights that firms operating in more concentrated industries have experienced extraordinary high

[59]This chapter is the result of a joint work with Enrico Turco.

profit rates. This evidence opened a debate, mostly empirical, on the causes and consequences of market concentration. Whilst Autor et al. (2017, 2020) emphasize the role of technical change and productivity gains in enabling superstar firms to achieve a larger market share with less labor, Grullon et al. (2019) and De Loecker et al. (2020) suggest that the rise in corporate profits is mainly driven by increasing profit margins due to market power and entry barriers rather than improvements in operational efficiency. De Loecker et al. (2020), in particular, find that in the U.S. economy mark-ups remained roughly constant between 1950-1980 and, from then on, have grown steadily, with the average price going from 21% to 61% above marginal cost. Against this background, some authors have stressed that, despite historically low interest rates, increasing profitability and high funds availability, the investment rate of U.S. non-financial corporations has been constantly slowing down, from 32% in the 1980s to 26% in the 2010s (Gutiérrez and Philippon, 2016; Villani, 2021). According to Gutiérrez and Philippon (2017), such an "investment gap" is stronger in concentrating industries, where, in view of diminishing profitable investment outlets, monopolistic rents are largely distributed to shareholders by means of dividend payments and share buybacks (Gutiérrez and Philippon, 2016, 2017; Turco, 2018). The slowdown of capital accumulation is then reflected in the long-lasting decline in average output growth, which decreased from 3.7% between 1947-1980 to 2.7% between 1980-2017 (Stiglitz, 2019).

Although recent empirical research has lately endeavored to document and emphasize the potential connections among these trends (Syverson, 2019), in our view, a comprehensive theoretical framework is yet to be developed.

The present paper aims to contribute to filling this gap, by proposing a theoretical framework that allows to systematically analyze the endogenous formation and dynamic interdependence between changes in market structure, income distribution and economic growth. In particular, the aim of this paper is threefold: (i) to develop a macroeconomic agent-based model (ABM) in order to examine the causes and consequences of rising market concentration, by focusing on the interplay of technical change and market power; (ii) to explore, by means of computer simulations, the conditions under which the tendency to concentration at the micro level may give rise to a tendency to stagnation at the macro level; (iii) to implement a variety of policy experiments in order to assess the role of different institutional setups, e.g. entry barriers, and identify the best policy mix able to curb the stagnation tendency and to foster a competitive and innovation-led growth process.

4.1.1 Theoretical roots

To explain the endogenous formation and the dynamic interdependence among the secular trends characterizing modern advanced economies, that is, concentration, stagnation and inequality (De Loecker et al., 2020; Stiglitz, 2019; Syverson, 2019), we propose a narrative that combines old and new findings from the micro- and macro-economic literature on oligopoly, technical change, distribution and growth, and, additionally, introduces some novel features.

First of all, we resume and revise Sylos Labini's (1967) theory of oligopoly and technical progress, according to which the tendency to concentration is driven by technical change that generates "technological discontinuities", i.e., systematic differences in productivity across firms, leading to a reallocation of market shares towards more productive firms. This is because heterogeneous firms do not have equal access to capital-embodied innovations, as we assume that this depends on the "knowledge gap", i.e., the difference between the degree of capital vintage's technical advancement and firm's level of technological knowledge. Based on Cohen and Levinthal (1989), we explicitly formalize a process of knowledge accumulation, whose function is to improve firms' ability to identify, assimilate and master the best machines developed by capital good producers. By influencing the firms' access to capital-embodied innovations, the knowledge stock, accumulated over time through R&D, constitutes a form of technical barrier to entry, or rather *to use* (Dosi and Nelson, 2010), which underlies the growing divergence in productivity and competitiveness across firms. It follows that, *in the absence of* consistent knowledge spillovers and *as long as* capital goods remain considerably different from each other, the intertwined dynamics of knowledge accumulation and technical change is the driver of the endogenous formation of firms' heterogeneity and technical entry barriers, paving the way for a shift in the market structure from a competitive to an oligopolistic form.

The theoretical link between the microeconomic analysis of oligopoly and technical progress and the macroeconomic analysis of income distribution and growth passes through the changing pricing behavior by the large newly-emerging firms.

In a competitive economy, because of low entry barriers and limited market power, firms act as *price taker* units, i.e., the price converges to the unitary cost. In such a context, the falling unit labor cost stemming from technical change translates into lower output prices and subsequently higher real incomes, providing the basis for a self-sustained growth process. At this stage, a rise in concentration due to, for instance, an increased market competition may in fact imply a higher productivity growth and better economic performance, as argued by Autor et al. (2020).

However, the shift towards an oligopolistic market form following the emergence of technical entry barriers implies that large firms end up with a considerable degree of market power, thus becoming *price maker*. In the absence of a competitive pressure, the price is not taken as given, but is set endogenously by firms, which apply a mark-up over unit labor cost according to their 'degree of monopoly power', as reflected in the individual market share (Kalecki, 1942). Operating under conditions of oligopoly characterized by technical entry barriers, large firms seek to translate the enhanced market power into higher profit margins. Consequently, as the influence of large firms grows over the economy, the rise in the weighted-average mark-up leads to a shift in the income distribution from wages to profits that eventually undermines consumption and aggregate demand (Keynes, 1936), with detrimental effects on investment and long-run growth. As a result, in the absence of countervailing forces, the tendency to concentration at the micro level may give rise to a tendency to stagnation at the macro level.[60]

4.1.2 The formal model: key features and properties

We formalize this framework and further explore its dynamic properties by means of an agent-based macroeconomic model. From a methodological point of view, we believe that an ABM is the most appropriate tool to address our research question. Indeed, we exploit the granularity of the agent-based approach to study the endogenous evolution of firms' heterogeneity underlying the emergent dynamics of concentration, without resorting to different initial conditions across firms and/or exogenous shocks to the parameters of the model. By contrast, similar studies based on a standard (partial) equilibrium framework, such as Autor et al. (2020), require firms to be initially endowed with different productivity levels, while the rise in concentration occurs through an exogenous change that allocates more market share to more productive firms, e.g. through an increase in the consumers sensitivity to prices. In our framework, such a reallocation mechanism is endogenous to the model dynamics and results from the firms' choice of heterogeneous capital vintages in a decentralized capital goods market. This allows us not only to describe the effects of rising concentration on the economic system but also to explain the forces behind this process.

In line with the macro-evolutionary tradition, our model is characterized by endogenous technical change and heterogeneous capital goods, whose built-in productivity depends on a stochastic innovation process. Yet, differently from other ABMs in this

[60] Baran and Sweezy (1966), Sylos Labini (1967) and Steindl (1976) previously reached similar conclusions, albeit from different perspectives.

literature where the innovation activity is carried out exclusively by capital good firms (K-firms hereafter) to search for new innovations and to imitate that of competitors (Caiani et al., 2018a; Dawid et al., 2019; Dosi et al., 2010), in our model also consumption good firms (C-firms) can invest in R&D in order to accumulate technological knowledge, which allows them to identify and employ the best techniques produced by K-firms. Following the seminal work of Cohen and Levinthal (1989), technological knowledge can either be generated internally by means of firms' own R&D or externally by absorbing knowledge spillovers coming from other firms. The knowledge stock, in turn, affects the firms' choice of capital vintages, which depends on the "knowledge gap", i.e., the difference between the degree of capital good's technical advancement and firm's accumulated technological knowledge. Therefore, throughout the process of capital accumulation, firms with greater technological knowledge are more likely to adopt more efficient machines, thus achieving faster productivity gains.

The remaining part of the model incorporates the following features: the households sector consists of workers and firm owners, who earn labor and capital income, respectively, and consume a homogeneous good produced by C-firms using labor and heterogeneous capital; a single representative bank collects deposits from households and firms, extends credit to borrowing firms and buys Government bonds; the Government levies taxes on wages and dividends and distributes unemployment subsidies to non-working individuals. Despite starting with the same initial conditions, households and firms become heterogeneous over time by virtue of the casual interactions in decentralized labor, consumption and capital good markets.

The model is able to reproduce the intertwined stylized facts of concentration, stagnation and inequality. These dynamics emerges 'from the bottom up', as a result of the adaptive behavior of heterogeneous agents interacting in decentralized markets.

In particular, after a short period of transition, the model endogenously generates a wave of market concentration driven by technical change, which leads to a reallocation of market shares towards more productive and knowledge-intensive firms. Afterwards, large firms tend to exert their enhanced market power to raise mark-ups. The ensuing slowdown in real wages determines a shortage in aggregate demand, on the one hand, and excess capacity, on the other. As a result, firms cope with the lower demand by reducing the utilization rate of the existing plants without investing in new capital formation, net of depreciation, with negative effects on output and productivity growth. Therefore, the economic system spontaneously reaches a state of stagnation as a consequence of changes in market structure and income distribution, triggered by technical progress and market power.

However, by comparing two alternative scenarios corresponding to different patent system regulations, we find that, when K-firms are allowed to imitate their competitors' technologies, market competition is soon re-established. This is because the imitation activity carried out by K-firms brings about a convergence amongst different techniques, which, by reducing technological discontinuities in the consumption sector, allows laggards to catch up. Conversely, in the "no-imitation" scenario, the persistent heterogeneity among capital goods is then reflected in the systematic divergence in productivity across C-firms. In such a scenario, in so far as legal entry barriers reinforce technological discontinuities, large firms are able to consolidate their dominant position and to extract a higher share of rents, with harmful effects on distribution, demand and growth also in the long run.

Therefore, from our simulation analysis it emerges that, whereas the initial wave of concentration is triggered by knowledge-based technical entry barriers, which constrain firms' access to capital-embodied innovations, the evolution of concentration over time crucially depends on the presence (or lack thereof) of legal entry barriers, which affects the process of diffusion of technological innovations and thus firms' ability to consolidate their position and to exploit their market power. Our simulation results are in line with Nelson and Winter's (1978) analysis of the forces generating and limiting concentration under Schumpeterian competition. One of their main findings is that the evolution of industry concentration is significantly affected by the effectiveness of technological imitation efforts. Moreover, by exploring firms' investment decisions in response to changes in perceived market power, they find that large firms operating in concentrated industry have less incentives to invest if they expect a sufficiently high mark-up. In both respects, our analysis can be seen as complementary to the industry-level model developed by Nelson and Winter (1978), as we investigate in a macroeconomic framework not only the role of entry barriers on industry concentration and market power, but also the resulting macroeconomic consequences in terms of high inequality and low growth. More generally, our findings suggest that the pattern of economic growth is driven by the dynamic interrelationship between technological evolution in the capital sector and market power in the consumption sector, with following non-trivial effects on income distribution and aggregate demand.

Furthermore, we perform a battery of policy experiments, such as competition, innovation, fiscal and labor market policies, in order to identify the best policy mix able to halt the stagnation tendency and to foster a competitive and innovation-led growth process.

We find that labor market reforms aimed at weakening labor unions, by boosting profit margins and innovation, can foster a profit-led growth. This comes from the assumption that R&D is a function of realized profits – instead of sales, as in Dosi et al.

(2010) –, which makes the relationship between innovation, growth and distribution less trivial. Yet, the following slowdown in wages and demand needs be compensated by an anti-cyclical fiscal policy, without which the economy would remain stuck in a high unemployment-low growth trap. Moreover, while in the absence of entry barriers a reduction of transaction costs may promote a competition-driven concentration which benefits growth, innovation policies geared to spurring knowledge spillovers across firms risk to be ineffective as long as the technical ability to process them remains unequally distributed in a concentrated industry. Finally, a restrictive fiscal policy that prevents a fully anti-cyclical management of the public budget accentuates the stagnation tendency which eventually results in higher concentration, as the reduced demand is largely satisfied by a lower number of firms.

Finally, drawing on the ongoing debate on the macroeconomic consequences of concentration, we address the question: “can concentration be good for the economy?". We answer this question by means of a sensitivity analysis in order to assess the impact of a higher degree of competition on HH index and GDP. We find that, in the baseline scenario with imitation, a competition-driven concentration may actually benefit growth, while this is no longer true in the presence of legal entry barriers fostering market power. These findings suggest that it is the degree of persistence, more than its level per se, that determines whether or not market concentration benefits the economy. A high and volatile concentration may foster growth as long as competitive forces bring about a continuous reallocation of market shares towards more productive firms, without them having the opportunity to consolidate and exploit a dominant position. Conversely, a persistent market concentration triggered by the presence of legal barriers enables large firms to exert the enhanced market power to extract higher rents, with negative effects on income distribution and GDP.

4.1.3 Existing literature

The present work provides a contribution to four streams of literature.

First of all, this paper belongs to the increasing body of literature on macroeconomic agent-based models, of which Dawid and Delli Gatti (2018) provide an extensive review. In particular, our model builds upon Assenza et al. (2015), who develop a macro ABM with capital and credit in order to investigate how the interaction between firms of different sectors and the evolution of their financial conditions lead to the emergence of recurrent economic crises. Moreover, we incorporate features from macro-evolutionary ABMs, such as Dosi et al. (2010), Caiani et al. (2019) and Dawid et al. (2019), where technical progress is driven by stochastic innovations introduced in the economy by heterogeneous capital good firms. Macroeconomic agent-based models have been employed to study various complex economic phenomena as well as to address a wide range of policy questions (Dosi and Roventini, 2019; Fagiolo and Roventini, 2016). Narrowing the focus on the issues discussed in this paper, while there are numerous studies on inequality (e.g. Caiani et al., 2019; Cardaci, 2018; Dawid et al., 2018; Dosi et al., 2013, 2018; Russo et al., 2016) and, to a lesser extent, on large-scale economic downturn (e.g. Giri et al., 2019), the causes and consequences of rising market concentration, especially in relation with income inequality and economic stagnation, are less investigated in the macro ABM literature. Similar attempts include Hepp (2021), who, building on the EURACE model (Dawid et al., 2019), studies the impact of technical change on industry concentration and firm dynamics, and Dawid et al. (2021), who employs the EURACE model to examine the role of different degrees of centralization of the wage setting process on concentration and inequality. While these papers are close in spirit to ours, the analysis presented here provides an alternative explanation for the process of rising concentration and its implications, based on the role of firms' accumulation of technical knowledge and increased market shares as source of market power.

Secondly, this paper contributes to the ongoing debate on the causes and consequences of market concentration. In the current literature, mostly empirical, it is possible to identify two alternative views that we will label as "efficiency-enhancing" and "rent-extracting" concentration hypotheses. According to the *efficiency-enhancing hypothesis*, market concentration is the outcome of technical change spurred by the adoption of more efficient techniques by large ("superstar") firms (Autor et al., 2020). By exploiting scales economies and low unitary costs, those firms are able to sustain big upfront innovative investment, hence achieving productivity gains, cost reductions and larger market shares. Therefore, rising concentration, by improving the efficient allocation of resources and fostering aggregate productivity, has a positive impact on the economy, although it may come at the cost of a lower wage share following the introduction of labor-saving innovations (Autor et al., 2017).

On the other hand, according to the *rent-extracting hypothesis*, market concentration is associated with the enhanced market power resulting from higher entry barriers, either legal or technological, which undermine competition by preventing potential rivals from entering the market (Barkai, 2020; De Loecker et al., 2020; Grullon et al., 2019). The enhanced market power is then reflected in higher mark-ups, leading to a shift in the income distribution from wages to profits. From a macroeconomic perspective, a falling labor share determines a decline in aggregate consumption because "those at the top have lower propensity to consume than those at the bottom" (Stiglitz, 2019).

Moreover, due to the lack of competitive threats, firms operating in concentrated industries might have less incentives to innovate, while patent protections may restrict laggards' possibility to imitate, with this resulting in lower investment (Decker et al., 2016; Gutiérrez and Philippon, 2019). As a result, the process of market concentration, by exacerbating income inequality and weakening aggregate demand, is detrimental to economic growth.

In their analysis of intangible capital and concentration, Crouzet and Eberly (2019) put forward a third interpretation, based on the idea that the two aforementioned hypotheses, rather than mutually exclusive, can be regarded as two alternative equally-likely scenarios that arise depending on the sources of rising concentration. In this view, concentration might be "good", if triggered by productivity-enhancing technological innovations, or "bad", if due to entry barriers giving rise to market power.[61] Using U.S. firm and industry level data between 1988-2015, the authors find mixed, sector-specific evidence on the impact of rising concentration on business investment and economic performance, claiming that this would provide support to their thesis.

Like Crouzet and Eberly (2019), we are reluctant to consider the two above mentioned hypotheses as mutually exclusive. Rather, by adopting a complex approach, we interpret them as distinct outcomes that may possibly emerge out of the dynamic interaction between technical change and market power, and their relationship with the changing institutional environment. To put it differently, in our framework the effects of concentration are not necessarily pre-determined by its sources, as in Crouzet and Eberly (2019). It is possible that rising concentration, even if triggered by technical change, may eventually have detrimental effects on the economy as long as large firms manage to exploit their enhanced market power resulting from the establishment of (technical or legal) entry barriers. On the other hand, if imitation activity is allowed, a higher product market competition may actually foster a positive concentration – see policy experiments –, because, in the absence of legal entry barriers, large firms would not be able to consolidate their position and extract monopolistic rents.

Thirdly, the present paper is related to the evolutionary economics literature empirically investigating how various sector- and technology-specific characteristics influence the patterns of innovative activities. Within this approach, one fundamental contribution involves the distinction between the Schumpeter- Mark I and Mark II types of competition, corresponding to the alternative views on innovation developed by Schumpeter over the course of his academic life. In particular, the former hypothesis sees innovation as spurred by small new firms competing with large incumbents and

[61] "The source of rising concentration is thus important for understanding the extent to which rising concentration is efficient or not, and possible policy implications" (Crouzet and Eberly, 2019).

eventually pushing them out of the market. Accordingly, in such a competition-based economy, entrants are responsible for the creative destruction at the basis of economic development. On the other hand, the view implied by the Schumpeter-Mark II emphasizes the key role played by large corporations in promoting innovative activities through their R&D laboratories. Building on this framework, subsequent empirical studies (cfr. e.g. Malerba and Orsenigo, 1996 and Fontana et al., 2013) have identified consistent relationships between certain technological classes (and sectors) and the resulting Schumpeterian patterns of innovation. In our paper, we also explore the intertwined dynamics between market structure and innovation; however, we bring into focus the role of firms' power and its effects on the demand side of the economy.

Fourthly, the present paper faces the challenge of incorporating features from the empirical and theoretical literature specialized on innovation and knowledge accumulation into a comprehensive macroeconomic model. As Aistleitner et al. (2021) point out, in fact, despite the literature clearly shows that the process of acquisition and diffusion of new technological capabilities is an important determinant for growth and development on the national and regional level (Acemoglu and Zilibotti, 2001), as well as for the business success on the firm level (Cohen and Levinthal, 1990), in the macroeconomic modelling framework little attention is given to the precise mechanisms according to which such a capability accumulation takes place. More specifically, by the way in which the firm's choice of capital vintages is formalized, this paper creates a bridge between the macro and the micro/industrial evolutionary literature of innovation and technical change. In the macro-evolutionary literature (Caiani et al., 2019; Dosi et al., 2010), in fact, the corporate sector is made of consumption good firms and capital good firms whereby the former buy machine tools from the latter based on their relative price, which is inversely proportional to the respective productivity. This means that, quite oddly, the most efficient machines are also the cheapest ones, thereby everyone can easily access them. Many contributions in the micro-evolutionary literature, instead, stress the role of technological knowledge in the success of innovative activities carried out by (capital good) firms (Cantner and Pyka, 1998; Cohen and Levinthal, 1989; Dawid, 2006). This paper proposes a synthesis of the two approaches by conceiving technological knowledge as a means to improve the C-firms' ability to employ the best machines produced by K-firms. As such, the knowledge stock has a similar function as the average skill level of workers in the EURACE model (Dawid et al., 2019), where the firm's choice of a capital vintage depends upon the current expectation of its effective productivity, which, in turn, may be possibly constrained by the workers' accumulated capabilities. In this regard, the main difference with the EURACE model is that while in Dawid et al. (2019) technological knowledge is embedded in the skill level of workers, we put forward an explicit formalization of the process of knowledge accumulation, which evolves over time by means of firm's own R&D investment as well as knowledge spillovers coming from other firms, in tune with Cohen and Levinthal (1989). This view is empirically supported by Dosi et al. (2019), who, exploring an Italian micro-level data set in the period 2010-2014, find a weak relationship between workers training activities and labor productivity, suggesting that the organizational structure is the locus of knowledge rather than individuals.

4.2 Model setup

The model is characterized by (i) a corporate sector, including N capital good producers (or *innovators*) and F consumption good producers (or *entrepreneurs*); (ii) a household sector, composed of W workers and $K = N + F$ capitalists, i.e., there is one owner per firm; (iii) a banking sector with one representative bank; (iv) a public sector, namely the Government.

The structure of the model builds upon the macro agent-based model with capital and credit (CC-MABM) developed by Assenza et al. (2015). A few major changes are introduced with respect to the parental model: (i) entrepreneurs' quantity and price decisions are taken separately, being the former based on expected sales, while the latter on the degree of market power; (ii) capital goods are heterogeneous with respect to built-in productivity, whose improvements depend upon a stochastic innovation process à la Dosi et al. (2010); (iii) C-firms also perform R&D in order to accumulate technological knowledge, which enhances their ability to identify and employ the best machines produced by innovators.

Coherent with Assenza et al. (2015), workers and firms are heterogeneous agents and interact in decentralized labor, consumption and capital goods markets. In the labor and C-good markets, the interaction occurs via the search-and-matching mechanism (Riccetti et al., 2015), while the choice of the capital vintage is determined by a logit model, similarly to Dawid et al. (2019). Because of transaction costs, markets are incomplete and coordination issues may arise. In the absence of a centralized market-clearing mechanism, the system may self-organize towards a spontaneous order characterized by sub-optimal outcomes and out-of-equilibrium dynamics.

4.2.1 Sequence of events

Over one period of the simulation run, events unfold in the following order:

1. *Production planning and factors demand:* Based on expected sales, C-firms compute desired production, utilization rate and labor demand for both production and research workers.

2. *Capital goods market (1):* C-firms select their potential supplier of machine tools depending on the 'knowledge gap', which measures the distance between capital goods' technical advancement and C-firms' level of technological knowledge.

3. *Credit market:* If planned production costs exceed internal funds, C-firms resort to the bank asking for a loan.

4. *Labor market:* Firms can hire and fire production and research workers according to their labor requirements; employees receive a wage, net of taxes.

5. *Production and price:* C-firms' production is computed as the minimum between desired and potential output, given the available resources; the price is set by charging a mark-up over the unit labor cost depending on the firm's degree of market power.

6. *Capital goods market (2):* Entrepreneurs with a positive investment demand buy the required capital units from the previously selected supplier. Capital goods, produced by innovators according to a Make-to-Order plan, are made available for the production process starting from next period.

7. *R&D activity (1):* Both consumption and capital good firms implement R&D activity based on previously allocated funds: C-firms update their knowledge stock; K-firms perform innovation and imitation activities to develop more efficient vintages of capital goods.

8. *Taxes and subsidies:* Government collects taxes on wages and dividends and distributes unemployment benefits to non-working individuals.

9. *Consumption goods market:* Having defined their consumption budget, households visit a given number of firms and choose the supplier after comparing their selling prices.

10. *Profits and dividends:* Firms collect revenues and distribute part of their profits to capitalists as dividends, on which the Government collects taxes.

11. *R&D activity (2):* Both consumption and capital good firms allocate part of realized profits to the R&D budget that will be invested in the following period.

12. *Entry-exit dynamics:* Retained earnings accumulate to net worth. If the equity turns negative or liquidity is not enough to repay interests and debt installments, firms declare default. Bankrupted firms are re-capitalized by means of the owner's wealth.

13. *Public deficit and bond issuance:* The Government issues bonds, purchased by the bank, to finance the public expenditure in excess of tax revenues; public debt is updated accordingly.

14. *Bank's profits, dividends and equity:* The bank collects interest payments from borrowings, records non-performing loans and distributes dividends to capitalists; after-dividends earnings pile up to the bank's equity. If the latter turns negative, all households participate to the bail-in proportionally to the scale of their deposits.

4.2.2 Corporate sector

Consumption good firms

Quantity choice C-firms produce a homogeneous consumption good using labor and heterogeneous capital goods. Being unable to observe actual demand, the desired output, $\tilde{Y}_{it}$, is set on the basis of expected sales, S^e_{it}, as computed by means of a simple adaptive rule depending on past forecasting errors, according to equation (4.2). Additionally, in defining the planned production, firms take into account: (i) the desired inventory level, given by a fraction κ of expected sales, in order to hedge against short-term demand swings (Caiani et al., 2018b), (ii) the involuntary inventories of unsold goods, inv_{it-1}, inherited from the past period, which depreciate at a rate δ^{inv}. Hence, the desired output is defined as

$$\tilde{Y}_{it} = S^e_{it}(1+\kappa) - inv_{it-1}, \tag{4.1}$$

$$S^e_{it} = S^e_{it-1} + \rho(S_{it-1} - S^e_{it-1}). \tag{4.2}$$

Because frictions in the labor or credit markets may possibly constrain firms' factor demands, the actual scale of economic activity is computed as the minimum between desired and potential output. To produce the consumption good, firms combine labor and heterogeneous capital in fixed proportions, according to a Leontief technology.

Assuming labor is the abundant factor, the production function reads

$$Y_{it} = \sum_{v \in V_{it}} \omega_{it}^{v} k_{it}^{v} \bar{A}_{it}^{v}, \tag{4.3}$$

where V_{it} is the set of capital goods owned by firm i at time t, ω_{it}^{v} is the utilization rate relative to each capital vintage v, k_{it}^{v} and $\bar{A}_{it}^{v}$ are the amount of capital units of type v and its related effective productivity, respectively. As shown in equation (4.12) below, the latter depends on the ability of firm i to exploit the built-in technology of the capital vintage v.

C-firms respond to short run fluctuations in expected sales by adjusting the rate of capacity utilization as well as the required workforce, whereas the capital stock is modified according to long-run production requirements, in tune with Assenza et al. (2015).

Determination of utilization capacity Having defined the desired level of production, the required utilization rate by capital vintage, ω_{it}^{v}, and labor demand, N_{it}, are derived from equation (4.3). Following Caiani et al. (2018b), in each period C-firms rank the available machine tools based on their built-in productivity – $v = 1, 2, 3, ...$ with the first being the most productive – and employ them in the production process starting from those with the highest quality. The desired utilization rate of capital vintage v by firm i is determined according to the following algorithm:

$$\tilde{\omega}_{it}^{v} = \begin{cases} 1 & \text{if} \quad \sum_{s=1}^{v-1} \tilde{\omega}_{it}^{s} k_{it}^{s} \bar{A}_{i}^{s} + k_{it}^{v} \bar{A}_{i}^{v} \leq \tilde{Y}_{it} \\ \frac{\tilde{Y}_{it} - \sum_{s=1}^{v-1} \tilde{\omega}_{it}^{s} k_{it}^{s} \bar{A}_{i}^{s}}{k_{it}^{v} \bar{A}_{i}^{v}} & \text{if} \quad \sum_{s=1}^{v-1} \tilde{\omega}_{it}^{s} k_{it}^{s} \bar{A}_{i}^{s} \leq \tilde{Y}_{it} \text{ and } \sum_{s=1}^{v-1} \tilde{\omega}_{it}^{s} k_{it}^{s} \bar{A}_{i}^{s} + k_{it}^{v} \bar{A}_{i}^{v} > \tilde{Y}_{it} \\ 0 & \text{if} \quad \sum_{s=1}^{v-1} \tilde{\omega}_{it}^{s} k_{it}^{s} \bar{A}_{i}^{s} \geq \tilde{Y}_{it}. \end{cases}$$

Labor demand C-firms need workers to carry out both production and R&D activities. To preserve the stock-flow consistency of the model, in fact, the research budget is used to hire workers who perform R&D activity during the current period. Given the desired capacity utilization, $\tilde{\omega}$, and the constant capital-labor ratio, $\bar{l}_k$, labor demand for production is given by

$$\tilde{N}_{it} = \sum_{v \in V_{it}} \tilde{\omega}_{it}^{v} \frac{k_{it}^{v}}{\bar{l}_k}. \tag{4.4}$$

If labor demand $\tilde{N}_{it}$ is greater than the current workforce N_{it-1}, or if R&D investment is positive[62], firms post vacancies on the job market, hence defined as

$$J_{it} = \begin{cases} \max(\tilde{N}_{it} - N_{it-1}, 0) + \frac{RD_{it}}{w_t} & \text{if } \frac{RD_{it}}{w_t} > 1, \\ \max(\tilde{N}_{it} - N_{it-1}, 0) & \text{otherwise,} \end{cases} \tag{4.5}$$

where w_t is the market wage uniform across firms.

The job market unfolds according to the search and matching process (cfr. Assenza et al., 2015): unemployed workers visit Z_e randomly sampled firms and get hired at the prevailing wage as they encounter one firm with available job vacancies. This means that firms can fill their open positions only if they are visited by a sufficient number of unemployed workers. It follows that, despite the absence of transaction costs on the labor market, i.e., firms can hire or fire employees at no cost, the presence of firms with job vacancies can coexist with unemployed workers looking for a job. In case the current number of employees exceeds labor requirements, i.e., $\tilde{N}_{it} < N_{it-1}$, workers in excess are randomly selected from the firm's workforce and then fired.

R&D and technological knowledge The R&D budget is determined as a constant fraction of past net profits, i.e., $RD_{it} = \sigma^c \pi^{net}_{it-1}$. The purpose of research activity carried out by C-firms is to accumulate a stock of technological knowledge, which, in turn, improves their ability to identify and employ the best machines produced by K-firms. The idea is that technological knowledge is not entirely a public good, but costly to acquire and process; as such, it requires prior R&D investment (Dosi and Nelson, 2010). Following the seminal work by Cohen and Levinthal (1989), R&D spending has a dual role in the process of knowledge accumulation: (i) to generate new technical knowledge; (ii) to increase the firm's 'absorptive capacity', i.e., its ability to assimilate external knowledge spillovers. Thus, the knowledge stock, z_{it}, evolves according to

$$z_{it} = (1 - \delta^z) z_{it-1} + RD_{it} + \gamma_{it}(\psi \sum_{j \neq i} RD_{jt}), \tag{4.6}$$

where

$$\gamma_{it} = 1 - e^{-\eta \overline{RD}_{it}}, \tag{4.7}$$

$$\overline{RD}_{it} = \xi \overline{RD}_{it-1} + (1 - \xi) RD_{it}. \tag{4.8}$$

[62] The number of research workers hired by the firm is equal to the ratio R&D over nominal wage rounded down to the nearest integer.

According to equation (4.6), the knowledge base is generated both internally through firm's own R&D investment and externally by absorbing outside knowledge spillovers coming from other firms' R&D activity, with ψ indicating the degree of knowledge spillovers.

The absorptive capacity, $\gamma_{i,t} \in (0,1)$, is determined endogenously based on firm's own R&D experience, where $\overline{RD}_{it}$ is the weighted average of current and past R&D spending with exponentially decaying weights. The knowledge stock depreciates at a rate δ^z, reflecting a sort of knowledge obsolescence. Note that, the fact that the absorptive capacity is firm-specific emphasizes the role of firms' heterogeneity in the acquisition process of external knowledge spillovers, regardless of ψ.

Choice of capital vintage The process of knowledge accumulation plays a crucial role in the investment dynamics. In fact, following Sylos Labini's (1967) intuition, heterogeneous firms do not have equal access to capital-embodied innovations, as we assume that this ultimately depends on their accumulated technological knowledge.

To capture this idea, we formalize the choice between heterogeneous vintages of capital goods through a logit model, where the probability for firm i of selecting a machine v is a function of the 'knowledge gap', i.e., the difference between the degree of capital vintage's technical advancement, A^v, and the firm's level of technological knowledge, z_i, both computed as relative position in their respective distribution normalized into the range (0,1). Therefore, we have

$$\mathbb{P}[\text{Firm } i \text{ selects vintage } v] = \frac{\exp\left[-\beta(\hat{A}_t^v - \hat{z}_{it})^2\right]}{\sum_{v=1}^{V} \exp\left[-\beta(\hat{A}_t^v - \hat{z}_{it})^2\right]}, \tag{4.9}$$

where

$$\hat{A}_t^v = \frac{A_t^v - A_t^{min}}{A_t^{max} - A_t^{min}}, \tag{4.10}$$

$$\hat{z}_{it} = \frac{z_{it} - z_t^{min}}{z_t^{max} - z_t^{min}}. \tag{4.11}$$

The parameter $\beta \in (0,\infty)$ in equation (4.9) represents the *intensity of choice*, determining how fast firms choose a vintage v coherent with their technological knowledge. In words, Equation (4.9) states that the probability for firm i of selecting a given capital vintage v is inversely proportional to the knowledge gap with respect to that particular technology. For instance, let us consider the case of the machine tool at the technological frontier, i.e., $\hat{A}^v = 1$. In this case, the higher the firm's technological knowledge, z_{it}, the lower the knowledge gap with respect to the best technology $(\hat{A}_t^v - \hat{z}_{it})$, the

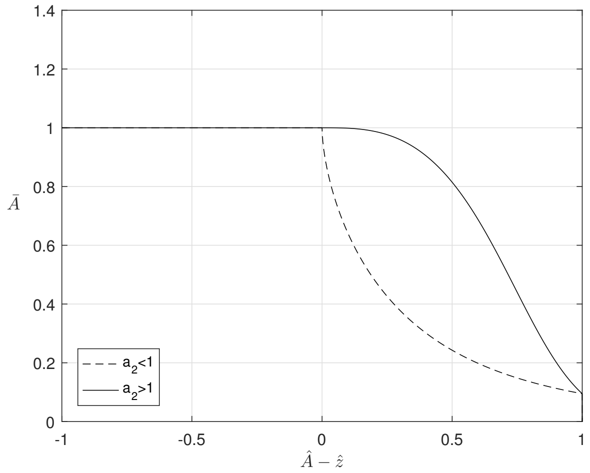


Figure 4.1: Effective productivity of capital vintage, $\bar{A}_{it}^{v}$, as a function of the knowledge gap, $\hat{A}_{it}^{v} - \hat{z}_{it}$. The slope of the function represents the intensity of the knowledge constraints.

higher the probability for firm i of choosing it.

The underlying motivation is that to access and master the most efficient machines produced by innovators, C-firms require to build up an in-house technical capacity. In this sense, the technological knowledge shall be considered as the firm's know-how, that is the set of skills and abilities accumulated over time by means of R&D. As such, it constitutes a form of technological barrier to entry, or rather to *use* (Dosi and Nelson, 2010), which, by influencing firms' access to technological innovations, is the ultimate driver of firms' heterogeneity and productivity differentials.

Because the choice of the capital good is stochastic, a firm may happen to buy a machine with a degree of technical advancement relatively greater than her accumulated knowledge, that is $\hat{A}^{v} > \hat{z}_{it}$. In this case, the knowledge gap acts as a constraint on the effective usage of vintage technology, $\bar{A}_{it}^{v}$. Thus, the effective productivity associated with a capital vintage v owned by firm i is defined as

$$\bar{A}_{it}^{v} = \begin{cases} A_t^v & \text{if } \hat{A}_t^v \leq \hat{z}_{it}, \\ \frac{2A_t^v}{1+e^{a_1(\hat{A}_t^v - \hat{z}_{it})^{a_2}}} & \text{otherwise,} \end{cases} \tag{4.12}$$

with $a_1, a_2 > 1$. The function of the effective capital productivity is displayed in figure 4.1. Here we can observe that firm i can fully exploit the productivity of vintage v as long as her degree of technological knowledge is higher than or equal to the capital's technical advancement. Otherwise, the knowledge constraints become tighter the higher the size of the knowledge gap.

Investment demand Following Assenza et al. (2015), we assume that capital is fixed in the short run: the investment goods acquired in t can be employed in the production process starting from $t+1$. That being the case, the demand for capital by C-firms aims to meet long-run production needs, rather than the short-run market fluctuations.

To determine the investment demand, in particular, C-firms compare the long-run desired output with the current potential output, given the effective productivity of the selected vintage. The demand for capital is thus formalized as

$$I_{it} = \Big(\frac{\bar{Y}_{it-1}}{\bar{\omega}} - \hat{Y}_{it}\Big)\frac{1}{\bar{A}^v_{it}}, \tag{4.13}$$

where

$$\bar{Y}_{it-1} = v\bar{Y}_{it-2} + (1-v)\tilde{Y}_{it-1} \tag{4.14}$$

$$\hat{Y}_{it} = \sum_{v\in V_{it}} (1-\delta)k^v_{it}\bar{A}^v_{it}. \tag{4.15}$$

The long-run desired production is computed after discounting the weighted-average planned output in equation (4.1) for the target utilization rate, $\bar{\omega}$. Potential output in equation (4.15) corresponds to the maximum level of production a firm can achieve by fully employing the entire capital stock inherited from the last period, depreciated at a rate δ, similar to Dawid et al. (2019). In other words, equation (4.13) states that in case firms are not able to produce as much as they desire with the existing capacity, they will buy additional capital units from the previously selected supplier.

The law of motion for capital at the firm level, once taking into account the batch of heterogeneous machines, is given by

$$K_{it+1} = \sum_{v=1}^{V_{it}} (1-\delta)k^v_{it} + I_{it}. \tag{4.16}$$

Price setting Similarly to Dosi et al. (2010), C-firms set the price by charging a mark-up μ_{it} on the unitary labor cost, i.e.

$$p_{it} = (1+\mu_{it})c_{it}. \tag{4.17}$$

with $c_{it} = \frac{w_t N_{it}}{Y_{it}}$. According to surveys on price-setting behavior, mark-up pricing is the dominant strategy adopted by firms, especially in the presence of imperfect market competition which provides firms with some degree of market power (Alvarez et al., 2006; Fabiani et al., 2005).

Similarly to Dosi et al. (2010), the mark-up is determined endogenously and updated every period depending on the firm's degree of market power, as manifested in its individual market share (Kalecki, 1942). In particular, the mark-up is set according to the following rule

$$\mu_{it} = \begin{cases} \mu_{it-1}(1+\mu_t^r) & \text{if} \quad f_{it} > \bar{f}_t \;\; \& \;\; \Delta f_{it} > 0 \\ \mu_{it-1}(1-\mu_t^r) & \text{if} \quad f_{it} < \bar{f}_t \;\; \text{or} \;\; \Delta f_{it} < 0 \\ \mu_{it-1} & \qquad \text{otherwise.} \end{cases} \tag{4.18}$$

Equation (4.18) states that if the firm's market share, f_{it}, is above (below) the average share, $\bar{f}_t$, *and* increasing (*or* decreasing) with respect to the previous period, the mark-up will be adjusted by a positive (negative) number, μ_t^r, randomly drawn from a Folded Normal distribution with parameters $(\mu_{FN_3}, \sigma^2_{FN_3})$. Note that mark-ups adjust faster downward than upward. This is in line with results from empirical surveys pointing to the presence of asymmetries in price reactions to cost versus demand factors (see Alvarez et al., 2006). In particular, it is shown that prices respond more strongly to cost increases rather than decreases, while they react more to a fall in demand than to a rise. Furthermore, both for the U.S. and Europe, the size of price cuts are, on average, slightly larger than that of price increases. One of the reasons for asymmetric price adjustments lies in the fact that firms do not want to jeopardize the long-term relationship they report to have with customers by increasing prices too much in response to demand shocks.

Profits, dividends and net worth When the consumption good market closes, C-firms compute profits as the sum of sales and nominal variation of inventories minus wage bill, capital depreciation, interest payments on loans, R&D expenditure and inventories depreciation.[63] If positive, the firm distributes a fraction *div* of surplus to the owner in the form of dividend, net of taxes. The gross and net profits equations

[63] With regards to the interest payments, the rate on loans set by the bank for a specific firm can vary over time, therefore $\hat{r}$ is the weighted average of past interest rates with time-varying weights. The reader is addressed to Assenza et al. (2015) for a detailed explanation.

thus read

$$\pi_{it} = p_{it}Q_{it} + (inv_{it}p_{it} - inv_{it-1}p_{it-1}) - w_tN_{it} + \tag{4.19}$$
$$- \sum_{v \in K_{it}} \delta\omega^v_{it}k^v_{it} - \hat{r}_{it}L_{it} - RD_{it} - \delta^{inv}inv_{t-1}p_{it-1}, \tag{4.20}$$
$$\pi^{net}_{it} = \max((1 - div)\pi_{it}, 0).$$

Net profits (or losses) pile up to equity[64], which evolves as

$$E_{it+1} = E_{it} + \pi^{net}_{it}. \tag{4.21}$$

Whenever net worth turns negative or liquidity falls short of financial obligations, i.e., interests and debt installment, the firm goes bankrupt and exits the market. Given that, for simplicity, the number of firms is assumed to be constant over time, each bankrupted firm is substituted by a new entrant, recapitalized by means of the owner's wealth, while the cost of bad debt is born by bank's equity which is reduced accordingly.

Capital good firms

Innovation and imitation K-firms produce heterogeneous machine tools using only labor according to a Make-to-Order plan, meaning that the production orders are based on C-firms' investment demand, with no inventory accumulation. Following Dosi et al. (2010), each K-firm is characterized by a technology (A^v_{jt+1}, B^k_{jt+1}), where the former represents the productivity associated with the machine tool produced by firm j, while the latter indicates the labor productivity of firm j itself. Innovators strive to improve the 'quality' of their technologies and reduce the production costs. To do that, they invest a constant fraction, σ^k, of net profits in R&D to perform innovation and imitation activities, depending on parameter $\chi \in (0, 1)$, i.e.

$$RD_{jt} = \sigma^k\pi^{net}_{jt-1}, \tag{4.22}$$
$$IN_{jt} = (1 - \chi)RD_{jt}, \tag{4.23}$$
$$IM_{jt} = \chi RD_{jt}. \tag{4.24}$$

In line with the evolutionary tradition of technical change (Caiani et al., 2018b;

[64]To check that the balance sheet identity holds in every period, we compare the level of net worth as computed in equation 4.21 with the one resulting from the difference between assets and liabilities. Firms' assets are given by the sum of capital value and liquidity, while liabilities consist in corporate debt. Liquidity is updated by taking into account all cash inflows and outflows, including debt installments, as shown in the Appendix.

Dosi et al., 2010; Nelson and Winter, 1982), innovation and imitation activities follow a two-step stochastic process.

The first step determines whether or not the firm has the opportunity to innovate and imitate, defined as a random drawn from a Bernoulli distribution, with parameters Pr_{jt}^{inn} and Pr_{jt}^{imi}, i.e.

$$Pr_{jt}^{inn} = 1 - e^{-\varsigma IN_{jt}}, \tag{4.25}$$

$$Pr_{jt}^{imi} = 1 - e^{-\varsigma IM_{jt}}, \tag{4.26}$$

with $\varsigma > 0$. Hence, the probability to innovate and imitate is positively influenced by the scale of R&D investment.

In the second step, firms having the opportunity to innovate draw from a Folded Normal distribution a pair of technological innovations (Δ_A, Δ_B), defined as productivity gains of the respective production techniques, according to

$$A_{jt+1}^{v} = A_{jt}^{v}(1 + x_{jt}\Delta_A), \text{ where} \Delta_A \sim FN(\mu_{FN_1}, \sigma_{FN_1}^2), \tag{4.27}$$

$$B_{jt+1}^{k} = B_{jt}^{k}(1 + x_{jt}\Delta_B), \text{ where } \Delta_B \sim FN_2(\mu_{FN_2}, \sigma_{FN_2}^2). \tag{4.28}$$

Similarly to Cantner and Pyka (1998), in order to capture the role of past experience on the individual firm's innovative performance, we assume that the actual size of productivity gains is proportional to the firm's relative position in the technology distribution, i.e., $x_{jt} = f(\hat{A}_{jt}^{v})$.[65]

When a K-firm draws the opportunity to imitate, it will search among the Z_{imi} more technically advanced firms and randomly pick one of their technologies.

Finally, firms compare the technological opportunities arising from innovation and imitation process and choose to produce the techniques with the highest built-in productivity.

Labor demand To preserve the stock-flow consistency of the model, K-firms employ R&D expenditures to hire workers at the prevailing market wage w_t. If labor demand is greater than current workforce, K-firms post job vacancies on the labor market to cover the gap. In the opposite case, K-firms can get rid of excess workers at zero costs.

Price setting Similarly to C-firms, capital good producers set the price by charging a mark-up over the unit cost of production c_{jt}, being the latter defined as market wage

[65]In comparing the role of different idiosyncratic learning processes on industrial dynamics, Dosi et al. (2017) propose a similar formulation where the advancements in productivity, rather than being purely stochastic, depend upon the extant relative competitiveness of firms.

over labor productivity, B_j^k. However, differently from C-firms, the mark-up of K-firms is assumed to be fixed, as in Dosi et al. (2010). Hence, the capital good price is given by

$$p_{jt}^v = (1 + \bar{\mu}^k)c_{jt}, \tag{4.29}$$

where $\bar{\mu}^k$ is the mark-up, constant and uniform across firms, while $c_{jt} = \frac{w_t}{B_j^k}$ is the firm's unit labor cost.

Profits, dividends and net worth Profits (or losses) are computed as the difference between sales and variable costs. If positive, K-firms distribute a fraction *div* of surplus to the owner in the form of dividend, net of taxes. The law of motion of equity for K-firms is then updated by net profits or, if negative, losses, i.e. $E_{jt+1} = E_{jt} + \pi_{jt}^{net}$.

4.2.3 Household sector

The households sectors is composed by W workers and K capitalists. The capitalist is the single owner of either a consumption or a capital good firm, such that $K = F + N$. Each agent receives an after tax income, Y_{ht}, where

$$Y_{ht} = \begin{cases} (1-\tau^w)w_t & \text{if employed worker,} \\ sw_t & \text{if unemployed worker,} \\ (1-\tau^k)div \cdot \pi_{ft-1} & \text{if capitalist receiving dividends,} \end{cases} \tag{4.30}$$

where $h \in \{w, f\}$ indicates whether agent h is a worker or a capitalist, with $f \in \{i, j\}$ for consumption and capital good producers, τ^w and τ^k are the tax rates on, respectively, labor and capital income, while s is the unemployment subsidy rate, computed as a fraction of current wage. Workers supply one unit of labor in exchange for a wage. The latter is uniform across firms and evolves over time depending on the average productivity growth g_{A_t} according to

$$w_{t+1} = w_t(1 + \alpha g_{A_t}). \tag{4.31}$$

where α is the elasticity of nominal wage with respect to productivity. The assumption of uniform wages growing linearly with average productivity may be simplistic. In fact, there is extensive evidence pointing to, on the one hand, an emerging disconnect between productivity and wages, especially in recent decades, and, on the other, to large firms exerting their monopsony power with respect to their employees (cfr. Dosi et al., 2020). A deeper investigation of these features would certainly be interesting in the context of the issued analyzed in the present paper, as they are likely to influence the dynamics of concentration and aggregate demand. However, for reasons of simplicity, they are left for future research.

Capital income is given by the sum of dividends that capitalists receive both from their own business and the bank, split in equal shares amongst owners.

The household's demand for consumption goods is a linear function of disposable income and financial wealth. Based on the well-known Keynesian principle according to which the saving rate is increasing along the income distribution, we assume that workers and capitalists have different propensities to consume out of income, namely c_w and c_k, with $0 < c_k < c_w < 1$. Dynan et al. (2004) provides an empirical assessment of the propensities to save of individuals belonging to different quintiles and percentiles of the income distribution. The values of c_w and c_k that are adopted in this model are in line with those found by Dynan et al. (2004), under the assumption that the average worker belongs to the medium quintile of the distribution, while the average capitalist to the top 5%.[66] The resulting savings pile up to financial wealth, held in the form of bank deposits D_{ht-1}. The consumption budget can be specified as

$$C_{ht} = c_h(1-\tau)Y_{ht} + c_f D_{ht-1}. \tag{4.32}$$

where $c_h = \{c_w, c_k\}$ and $0 < c_f < 1$ is the uniform propensity to consume out of wealth.

Having defined the consumption budget, the choice of the goods to buy is determined through the search-and-matching mechanism. Differently from the labor market, the partner's selection is not purely random, but is governed by a preferential attachment scheme, according to which consumers tend to be loyal to their previous seller. In particular, when the goods market opens, each household compares the price of the C-firm where she shopped in the previous period with the best price from $Z_c - 1$ randomly visited firms. If the new price is lower than the old one, the consumer will switch to the new supplier with a certain probability, Pr_s, which is increasing (in a non-linear way) with the price gap: the higher the percentage difference between p_{old} and p_{new}, the higher the probability of switching to the new partner, as in Delli Gatti et al. (2010). In symbols: $Pr_s = 1 - e^{-\lambda(p_{new} - p_{old})/p_{new}}$. The shape of the probability function is determined by λ, which represents the *intensity of choice*, i.e., how fast consumers switch to the most convenient supplier. It might happen that the amount of output supplied by the selected partner is lower than the household's demand for

[66] In particular, we set c_w=0.90 and c_k=0.60. Dynan et al. (2004) reports that the first quintile has a propensity to consume equal to 98.6%, the medium 91%, the last quintile equal to 76.4%, while the top 5% consumes on average 62.8% of its income. For a critical review of the various theories of consumption in relation with income distribution, see Van Treeck (2014).

consumption goods. In this case, the consumer will resort to the other firms in the list, sorted in ascending order based on price.

4.2.4 Banking sector

The bank collects deposits from households and firms at zero interest rate and provides loans to C-firms to cover the financing gap. The credit market largely borrows from our parental model (Assenza et al., 2015), to which the reader is addressed for a detailed illustration. Here we limit ourselves to provide a summary overview of its essential features.

After receiving credit demands from borrowing firms, the Bank determines both price and quantity of the loan for each borrower depending on her financial situation. The firm-specific interest rate is formulated as an exogenous risk free rate r charged with a mark-up increasing with the borrower's financial fragility. The latter is measured by the time-to-default, TT, which is inversely related to the firm's leverage l_{it}, i.e., the lower the leverage, the higher the time to default, the lower the interest rate, or

$$r_{it} = g(r, TT(l_{it})), \tag{4.33}$$

$$l_{it} = \frac{D_{i,t}}{E_{it} + D_{it}}. \tag{4.34}$$

Furthermore, the Bank sets a maximum amount of loans to be extended to each borrower on the basis of a tolerance level for the potential loss on credit, determined as a fraction on its own net worth. It follows that the bank may not be able to satisfy entirely firms' demand for loans, in which case, C-firms will be forced to re-scale the level of activity due to lack of funds.

4.2.5 Public sector

The Government levies a constant tax rate on labor and capital income and pays out unemployment benefits to non-working individuals. The unemployment subsidy is computed as a fraction, s, of the market wage. Whenever public expenditure exceeds tax revenues, the Government finances the resulting deficit by issuing Treasury bonds, bought by the Bank, at a fixed risk-free interest rate.

4.3 Simulation results

4.3.1 Calibration and initialization

To empirically validate the model, we follow a consolidated procedure in the macro ABM literature, also known as “output validation" (Delli Gatti et al., 2018). The goal is to establish a baseline scenario, against which we will evaluate the effects of alternative policies and institutional frameworks. To carry out this task, we calibrate the model such that it is able to replicate a wide ensemble of empirical regularities at different levels of aggregation. The parameters' values employed in the model's equations are summarized in Table 4.3 (in Appendix). Furthermore, another challenging task before resorting to computer simulations concerns the initialization of the model's variables. To comply with the stock-flow consistency principle, we require that the initial interrelated matrix of balance sheets among agents respects the double-entry bookkeeping system, according to which one agent's asset corresponds to someone else's liability. The initialization procedure involves the following steps:

- C-firms are endowed with an initial amount of capital goods such that aggregate output is associated with a desired rate of unemployment, i.e. 5%, given the initial value of labor productivity, A_0, and the constant capital-labor ratio $\bar{l}$.

- The value of C-firms' liquidity, held in the form of bank deposits, is set equal to the value of capital stock. Since we assume there is no private debt at $t = 1$, C-firms' net worth is given by the sum of capital value and liquid assets.

- Because K-firms use only labor, their net worth is simply equal to the value of liquidity, which is a fraction of C-firms' deposits.

- The financial wealth of households is held in the form of bank account and corresponds to 50 monthly wages, with $w_1 = 1$, in order to guarantee a sufficient saving buffer.

- Given that there are no initial corporate loans, the bank's balance sheet consists of Government bonds on the asset side and the sum of firms and households' deposits on the liabilities side. The initial stock of public bonds is a multiple of total deposits to make sure that the bank's equity is positive.

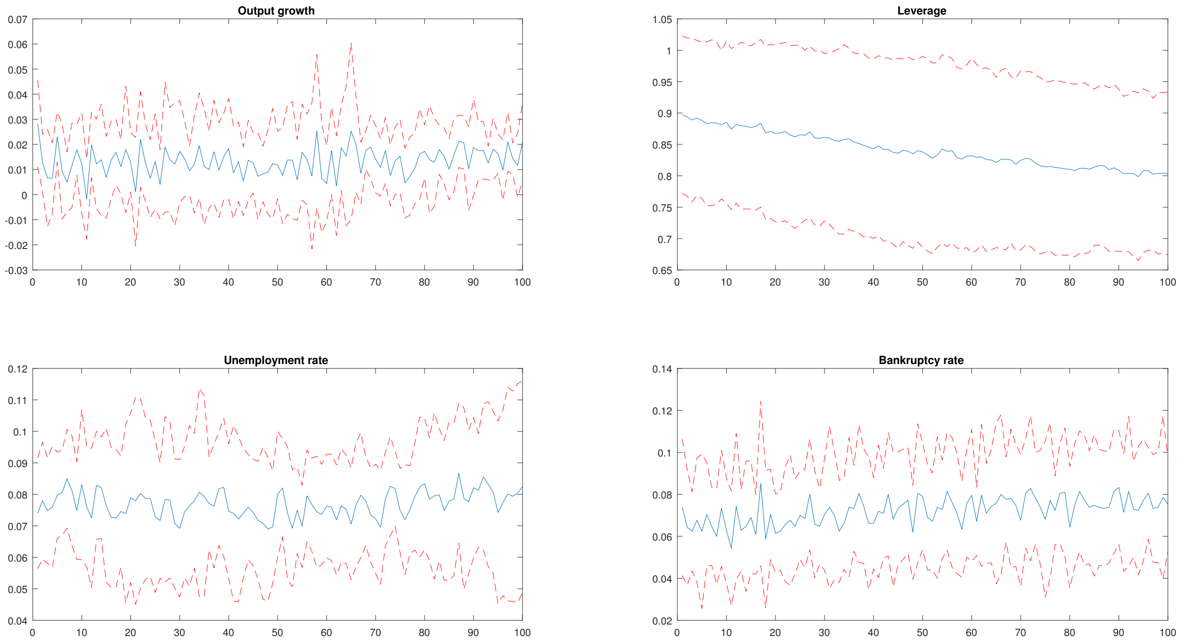


Figure 4.2: Time series of cross-MC means of selected macroeconomic variables. Last 100 periods are reported.

4.3.2 Empirical validation

Based on the parameter values and the initialization procedure described above, the empirical validation is performed by running a set of 25 Monte Carlo simulations with different random seeds for 1000 time periods. The artificial time series are constructed by taking averages across simulation runs and then compared with real data. Both simulated and real data are treated with the Hodrick-Prescott (HP) filter in order to isolate the cyclical component from the trend. The observed time series were downloaded from the FRED database and accounts for quarterly data ranging between 1955-2013 for unemployment, and from 1947 to 2013 for GDP, consumption and investment.

Figure 4.2 displays the last 100 periods for a selection of simulated time series. It can be seen that the model generates a regular self-sustained growth pattern, with ever-increasing trends in both real and financial variables characterized by persistent short-term fluctuations and recurrent bankruptcies. This is the result of the interplay of the Schumpeterian innovation-fuelled growth process and Minskyian instability-enhancing financial accelerator.

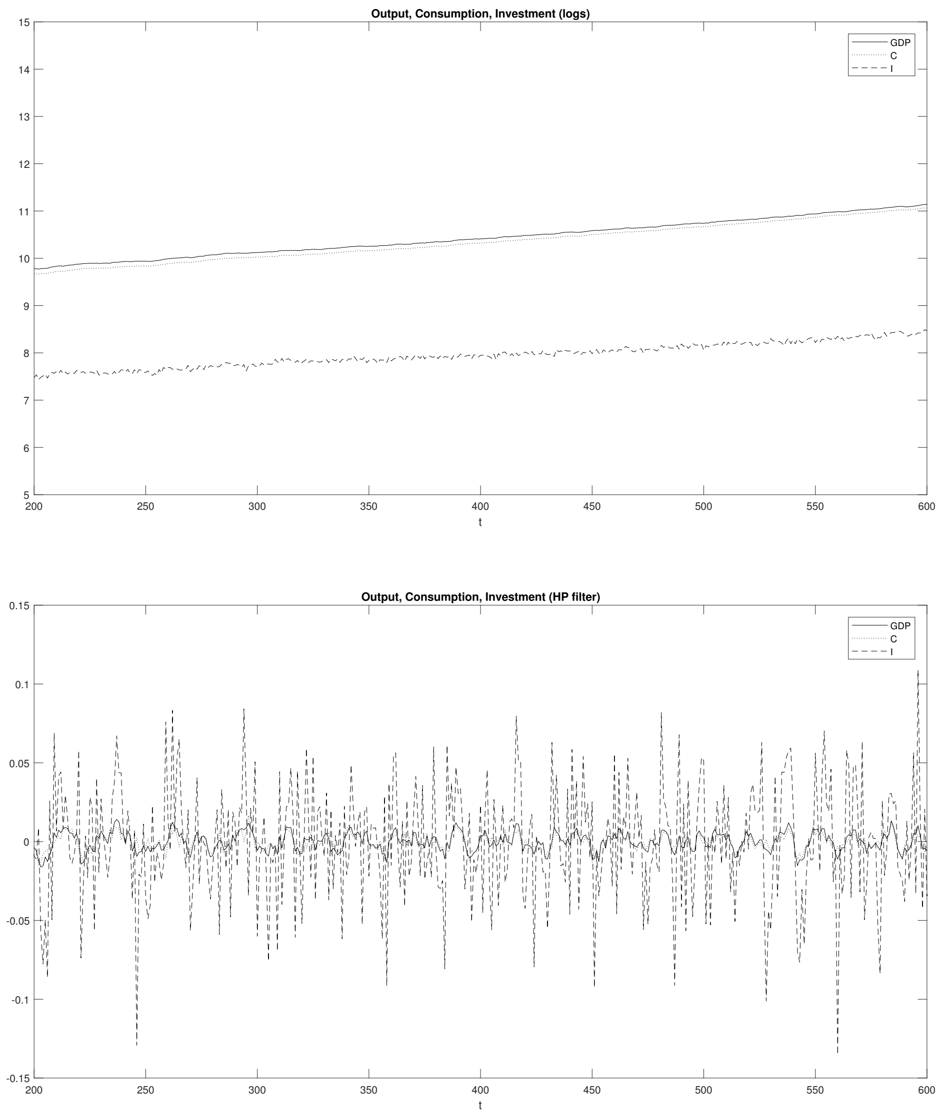


Figure 4.3: Cross-MC average of real GDP, consumption and investment. Trend and cyclical components are obtained by applying the HP filter.

To better appraise this figure, it is worth looking at the time series of trend and cyclical components separately, obtained after applying the HP filter to a set of macroeconomic variables, as shown in figure 4.3. The plot illustrates that, in line with the empirical evidence on business cycle (Stock and Watson, 1999), investment is systematically more volatile than GDP and consumption, with all of them growing at positive steady rates.

Following Assenza et al. (2015), figure 4.4 compares the autocorrelation and cross-correlation of GDP, consumption, investment and unemployment obtained from simulated data with their empirical counterparts. The autocorrelation structure of the

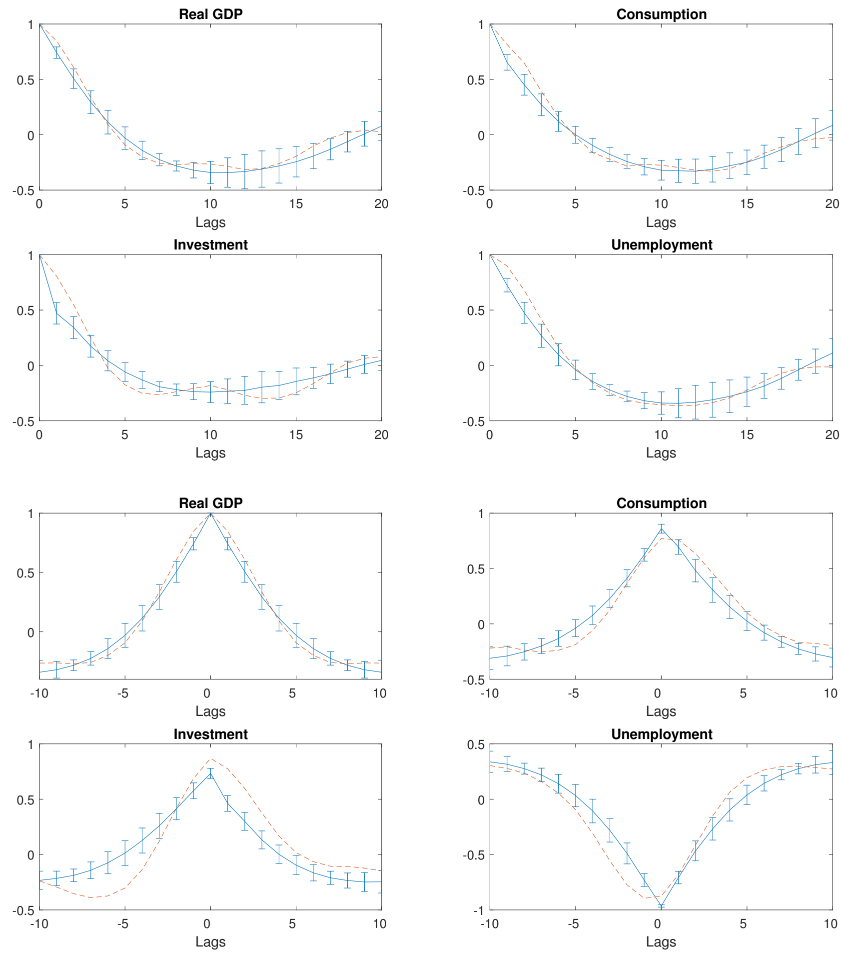


Figure 4.4: Autocorrelation (top) and cross-correlation (bottom) of GDP, consumption, investment and unemployment for simulated (solid blue) and empirical (dashed red) data. All variables are treated with the HP filter to isolate the cyclical component.

two series look remarkably similar. The cross-correlation plots show that consumption and gross investment are pro-cyclical with respect to GDP, while unemployment rate is anti-cyclical, as evidenced in observed data. From this validation exercise, we can safely say that the model does a fairly good job at reproducing the selected empirical regularities for the U.S. economy.

4.3.3 Economic analysis

Given the complex structure of interaction amongst heterogeneous agents and the multiple non-linear dynamic equations, the model does not lead to a closed-form analytical solution. Hence, to address our research question, we resort to the tool of computer simulations. The main goal of this paper is to analyse the underlying causes of the

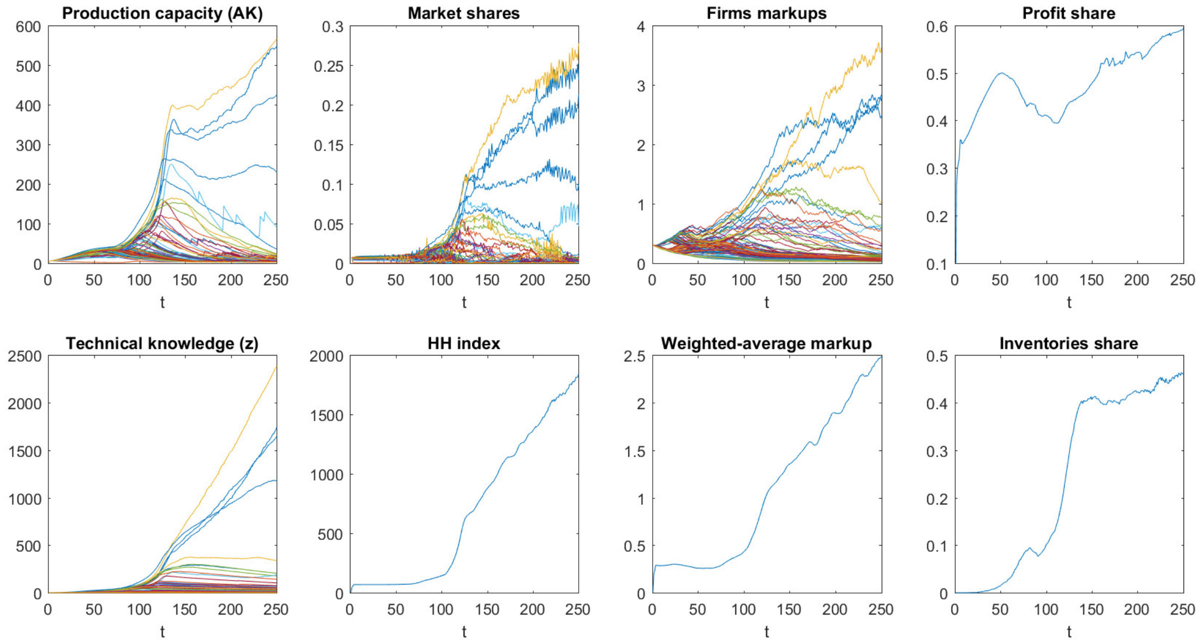


Figure 4.5: Dynamics of selected aggregate and firm-level variables; first 250 periods from one representative simulation.

endogenous formation of market concentration and its macroeconomic consequences, both in the short and long run. Therefore, first we are going to inspect the emergent dynamics of the model in the first 250 periods from one representative simulation. Afterwards, we perform Monte Carlo simulations to examine the long-term macroeconomic dynamics and following policy implications.

The story of concentration: a short run focus

Figure 4.5 collects a set of plots displaying the time series of both aggregate and firm-level variables in the first 250 periods from one representative simulation of the model. This allows us to dig into the microeconomic mechanisms underlying the macroeconomic dynamics.

In every simulation run, after a short period of transition, the model endogenously generates a wave of market concentration, that is a situation in which a relatively small number of firms ends up holding a vast share of the market, causing a sharp increase in the Herfindahl-Hirschman index. From the left-hand panels, we notice that the process of concentration is determined by a reallocation of market shares towards more productive and knowledge-intensive firms. The leaders, in fact, are those firms that manage to use their accumulated technical knowledge to invest in more efficient machines, thus achieving faster productivity gains and large market shares.

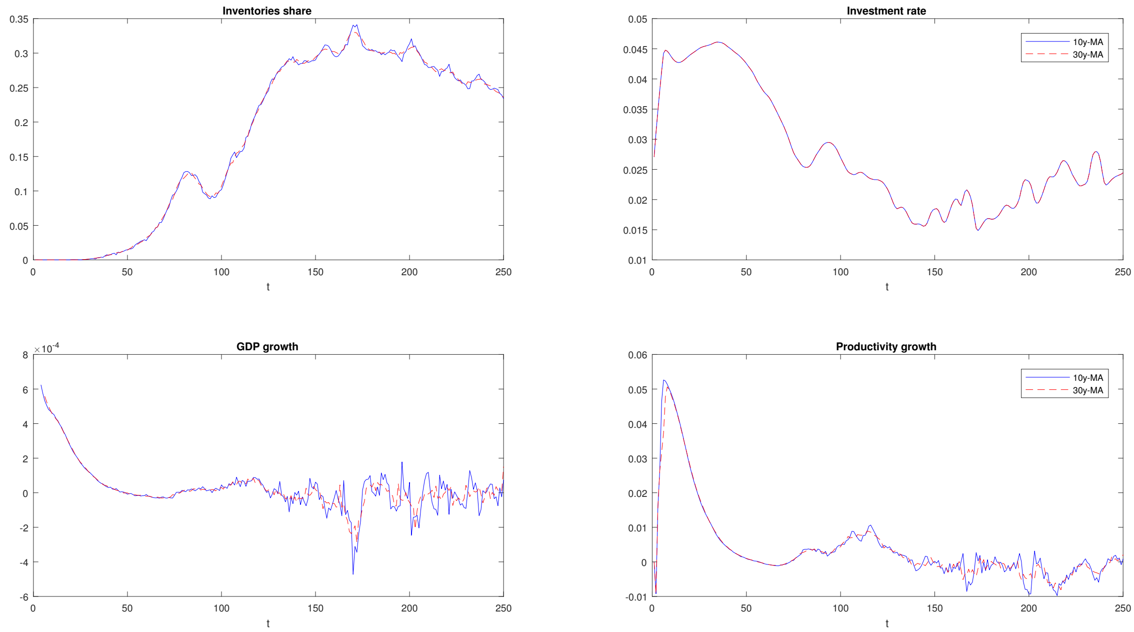


Figure 4.6: Inventories and investment share (5- and 20-years moving average); GDP and productivity growth rate (30- and 50-years moving average).

This outcome is reminiscent of the notion of “superstar" firms by Autor et al.’s (2020). Yet, while the basic assumption of their standard model is that firms are endowed with different productivity levels, in our agent-based model superstar firms endogenously emerge from the bottom up, without resorting to different initial conditions. In the jargon of complexity theory, this is an *emergent property* of the system. In fact, the source of concentration lies in the fact that firms do not have equal access to capital-embodied innovation, as this depends on the “knowledge gap": in the capital goods market, firms with greater technological knowledge are more likely to choose the best vintages of capital goods. It follows that, in the absence of consistent knowledge spillovers and as long as capital goods remain considerably different from each other, technical progress that generates “technological discontinuities" (Sylos Labini, 1967), as reflected in the growing differentials in productivity across C-firms, thus resulting in a higher industry concentration.

Having explored the underlying causes of rising concentration, let us now shift the focus on the second half of the story, that is the macroeconomic consequences. From the right-hand panels in figure 4.5, it can be seen that firms with larger market shares are able to increase their profit margins. Remind from the pricing rule in equation (4.18) that the mark-up is set according to the firm’s degree of monopoly power. In particular, one firm adaptively reviews the mark-up upwards if its market share is high and increasing over time. This is evidently the case for leading firms, which, thanks to the improved productive capacity and low unitary costs, can raise their mark-ups without incurring in a loss of market share. Moreover, as the weight of large firms grows over the economy, the increase in the weighted-average mark-up, adjusted by individual shares, leads to an increase in the profit share, which goes from 30% to 45% of total income – approximately the magnitude of the change in income shares that western countries have witnessed in the last four decades (Autor et al., 2020). In so far as wage and profit earners have different marginal propensities to consume, a redistribution of income from the bottom to the top implies a decline in the aggregate consumption expenditure, as reflected in the rising share of unsold goods (bottom-right panel).

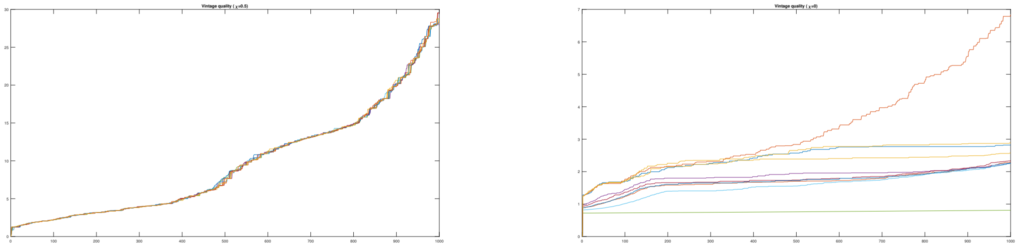
Consequently, C-firms interpret the higher inventories share as a symptom of a shortage in aggregate demand and review the capacity utilization rate accordingly. Indeed, from equation (4.1), an increase in the warehouse stock has a negative impact on the desired scale of production, which, in turn, affects the utilization rate of the existing plants, as defined in equation (4.4). In a context of low demand and excess capacity, C-firms do not have incentive to invest in new capital formation. As a result, the slowdown of capital accumulation gives rise to a tendency to stagnation, as manifested in the falling growth rates of output and productivity in figure 4.6.[67] Following the lessons from Sylos Labini (1967) and Steindl (1976), therefore, the economic system may spontaneously reach a state of stagnation as a result of changes in market structure and income distribution, triggered by technical progress and market power. As Steindl (1976) put it, "[t]he tendencies towards oligopoly discovered at the microeconomic level will cause a tendency towards stagnation at the macroeconomic level."

Long-term dynamics: the role of legal entry barriers

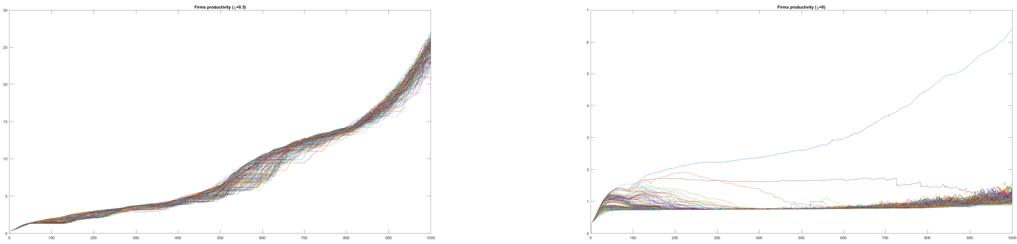
It has been shown that, in the early stage of a representative simulation, the model endogenously generates a wave of market concentration, driven by technical change, which impacts on income distribution and economic dynamics. A natural question is: what happens next?

To explore the model properties in the long run, we confront the benchmark case with an alternative scenario in which K-firms are not allowed to imitate. More specifically, the parameter χ in equation (4.24) is set equal to 0, from 0.5 in the baseline setting, so that the entire R&D budget is spent on innovation. We can think of the

[67] This analysis of investment allows to combine Keynes's theory of effective demand and business cycle with Schumpeter's theory of innovation and economic development, as previously proposed by Dosi et al. (2010).



(a) Vintage quality of K-firms



(b) Labor productivity of C-firms

Figure 4.7: Imitation (left) vs no-imitation (right) scenarios

alternative scenario as a situation in which a strict innovation patent system is in place, whereby legal entry barriers prevent K-firms from imitating their competitors' technologies. This simulation experiment allows us to fully appraise the role of both knowledge gap and technological discontinuities on the process of market concentration and its long-term effects on the economic performance.

Before looking at the model dynamics at the aggregate level, it is worth dwelling on the dynamics of K-goods' technology and C-firms' productivity from one representative simulation. Figure 4.7 shows that the imitation activity carried out by K-firms brings about a convergence in the capital goods' productivity (a-left), causing a significant reduction in the technological discontinuities among C-firms (b-left). On the other hand, in the no-imitation scenario, such a convergence does not occur and, consequently, the productivity differences across C-firms increase over time (b-right).

Interestingly, it emerges that a strict correlation exists between the technological evolution in the capital good sector and changes in market forms in the consumption good sector: in presence of relatively homogeneous capital goods due to the imitation activity by K-firms, large firms in the C-sector are not able to exploit their "knowledge advantage" to buy relatively more efficient techniques than their competitors, allowing the laggards to catch up. Conversely, a persistent heterogeneity among capital goods makes the "knowledge gap" mechanism more effective, leading to growing differences in productivity and technological structure across C-firms.

Therefore, we find that in order for technological discontinuities to be high and

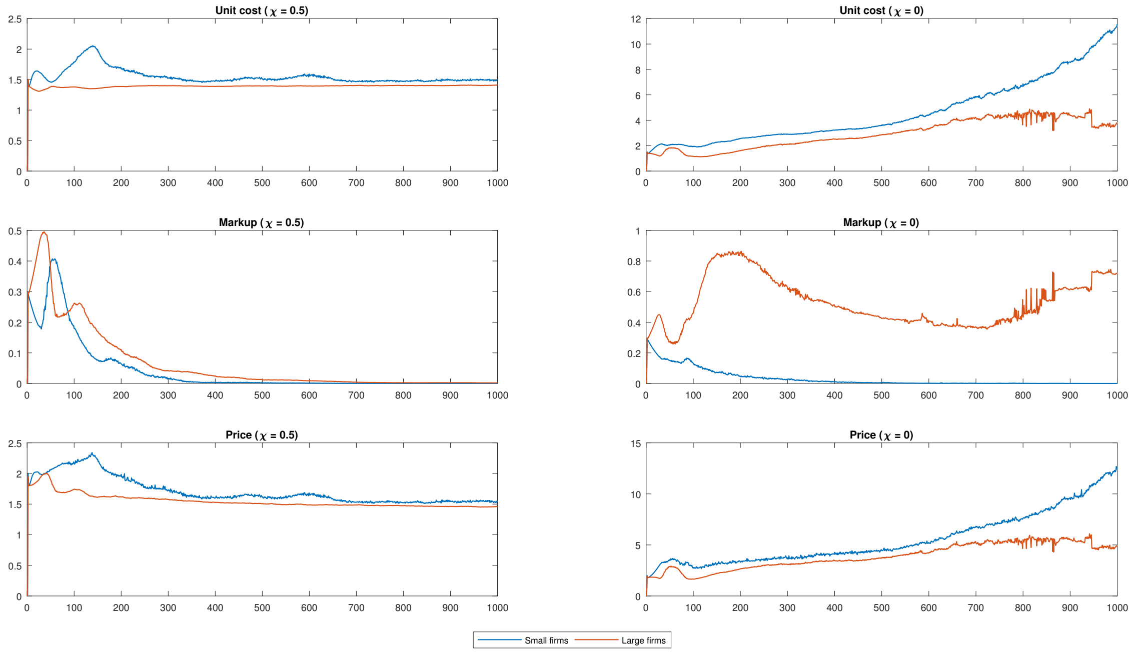


Figure 4.8: Evolution of unit costs, mark-ups and price of large (orange) and small (blue) firms in the imitation (left-hand) and no-imitation (right-hand) scenario. Mean values across 25 Monte Carlo simulations.

persistent over time it is necessary that capital goods remain considerably different from each other, that is to say, the imitation activity by capital good producers is limited.

These differences in the technological structure across C-firms in the two scenarios are reflected in the evolution of unit costs, mark-ups and prices displayed in figure 4.8. For the sake of clarity and in order to exploit the granularity of our model, we split the population of firms in two groups with respect to size, i.e., very large and very small firms, depending on whether their level of sales is above the 90% or below the 10% percentile. In both scenarios, the rise in technological discontinuities that occurs during the initial wave of concentration generates a discrepancy in costs and mark-ups among groups of firms. Then, whereas such differences are soon re-absorbed when imitation is allowed (left-hand panels), in the no-imitation scenario (right-hand panels) large and small firms experience two diverging trends shaped by the increasing differences in the technological structure. On the one hand, nominal wages growth and weak technical advancements determines rising unit costs for small firms. On the other hand, large productive firms can set higher mark-ups without this translating into a loss of market shares. In fact, the laggards fail to recover competitiveness despite low mark-ups as they are forced to increment prices to cover the rising costs.

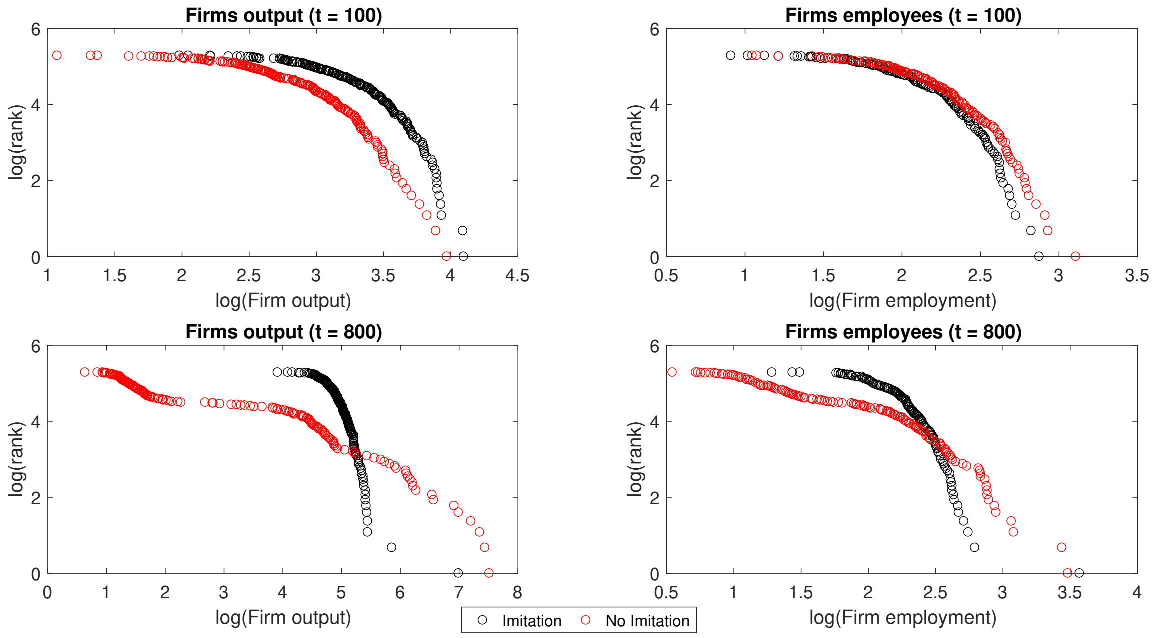


Figure 4.9: Distribution of firms size in terms of output and number of employees at t=100 (top half) and t=800 (bottom half) in the imitation (black) and no-imitation (red) scenario. Mean values across 25 Monte Carlo simulations.

The same pattern emerges by looking at the evolution of market structure over time, as illustrated in figure 4.9. Here we show the distribution of firm size measured in terms of output and number of employees in different time periods of the simulation, i.e., $t = 100, 800$. Firm size distribution is averaged over all Monte Carlo runs: at the selected time, for each rank the mean value of the considered variables across the runs is depicted on a log-log scale.

Comparing the two scenarios, we observe that, after 100 periods (top panels), in the midst of the first concentration wave, the firm size distribution exhibits similar properties in terms of fat tails and substantial heterogeneity for both variables. As time passes, however, the baseline scenario with imitation is characterized by more homogeneous firms, while the firm size distribution becomes even more skewed in the alternative scenario, especially with regard to firms output, while somewhat lower in terms of number of employees. This means that there is a smaller number of firms producing increasingly larger output levels with relatively small workforce. A similar trend can be observed in real data for the U.S. economy. For instance, Autor et al. (2017) find that sales concentration has gone hand-in-hand with employment concentration, which also increased but less than proportionally, suggesting that firms achieve larger market shares by employing a lower share of workers. In fact, "the industries that are becoming more concentrated are those with faster growth of productivity and

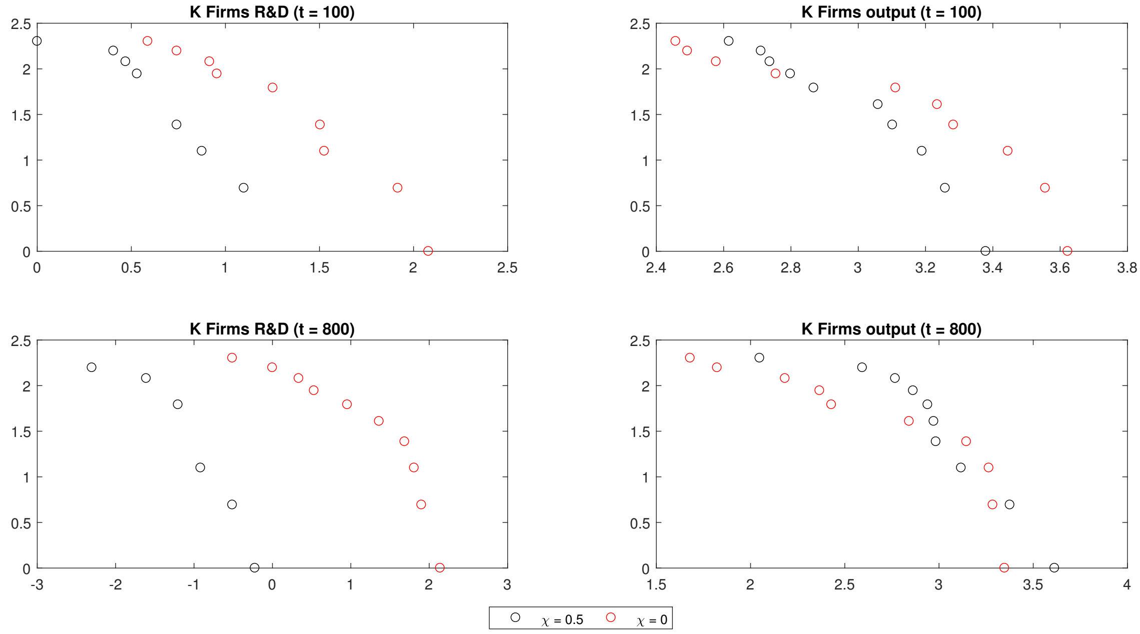


Figure 4.10: Distribution of K-firms size in terms of output and R&D investment at t=100 (top half) and t=800 (bottom half) in the imitation (black) and no-imitation (red) scenario. Mean values across 25 Monte Carlo simulations.

innovation" (Autor et al., 2017).

Furthermore, it is interesting to see what happens in the K sector in terms of size distribution. Figure 4.10 shows the size distribution in terms of R&D efforts and output. Whereas with respect to output, capital good sector does not manifest a clear tendency towards concentration, if we focus on the R&D efforts by K-firms, the figure clearly shows a concentrated sector. Hence, under the no-imitation scenario, the production of technical knowledge is far less shared among innovators. This constitutes both a cause and a consequence of the concentration level among consumption good firms, which reflects the importance of the knowledge gap. The more concentrated the C-sector, the more heterogeneously distributed the demand for capital goods.

It will soon become clear that such differences in the technological patterns and market forms across firms and sectors entail important macroeconomic consequences in terms of income distribution and economic growth. Figure 4.11 collects a set of plots displaying aggregate time series, averaged across 25 Monte Carlo repetitions, for both imitation and no-imitation scenario. In this way, we are able to assess the role of legal entry barriers on macroeconomic dynamics in the longer run.

It can be seen that, after the initial wave of market concentration, in the imitation scenario (black curve), the economy quickly returns to a competitive stage, characterized by low HH index and mark-up, as well as high wage share and consumption.

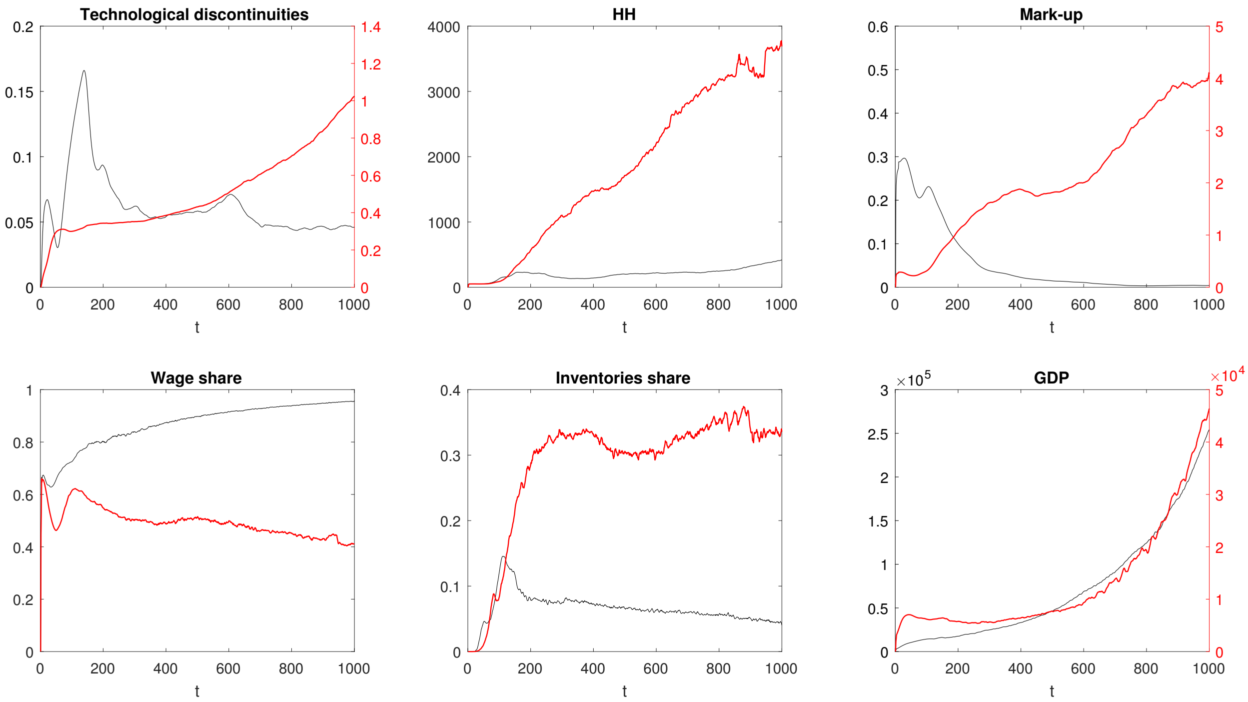


Figure 4.11: Time series of selected macro variables in the imitation (black) and no-imitation (red) scenario. Mean values across 25 simulations.

By contrast, when imitation is not allowed (red curve), the process of market concentration experiences an upward trend, driven by rising technological discontinuities[68], determining a steady increase in the mark-up, profits and inventories share, while GDP is significantly lower compared to the baseline scenario. The duration of market concentration, thus, depends on the corporate sector's ability to reproduce technological discontinuities within the system, which, in turn, is related to the process of diffusion of technological innovations amongst K-firms and C-firms' possibility of exploiting knowledge differentials.

Indeed, by reducing the knowledge gap with respect to all machine tools available on the market, the convergence between heterogeneous capital goods brought about by the imitation activity by K-firms undermines the dominant position of oligopolistic firms, which eventually loose their market power and thus their ability to extract larger profit margins. As a result, the ensuing reduction in income inequality strengthens aggregate demand and fosters a competitive and self-sustained growth process. Such a counter-tendency does not occur in the no-imitation scenario. In this case, in fact, the persistent character of technological discontinuities enables giant firms to consolidate

[68]We measure technological discontinuities as the standard deviation of labor productivity for consumption good firms over the average industry productivity.

their market position to the extent that the ever-growing concentration can unfold its negative effects on income distribution and aggregate demand also in the long run.

Table 4.1 provides a quantitative comparison of the model outcomes under different scenarios. We can see that, in the presence of legal barriers to imitation, the concentration index is nearly one magnitude higher than in the baseline scenario, which implies a higher mark-up and a lower output growth. Also, under the no-imitation scenario, the chronic excess capacity due to lower demand leads to a twice higher unemployment rate and, consequently, a steep increase in the deficit-GDP ratio.[69] In line with Sylos Labini (1967) and Steindl (1976), our findings suggest that tendency to stagnation arising from an oligopolistic market structure requires a more expansionary fiscal policy. In other words, the economic system is increasingly dependent on external stimuli to compensate for the structural deficiency in aggregate demand due to the unequal distribution of income. Albeit from a different framework, the modern theorists of the secular stagnation hypothesis reach remarkably similar policy conclusions.[70] We will further explore the role of fiscal and other policies in the next Section.

Finally, it is interesting to note that aggregate leverage is somewhat higher in the no-imitation scenario, leading to a jump in the rate of bankruptcy from 3.79% to 14.29%. This is due to the recurring defaults by a considerable number of small unproductive firms which fail to catch up with the leaders.

4.3.4 Policy experiments

This section aims at identifying which policies or institutional regimes might be potentially able to attenuate the concentration dynamics and/or to curb the resulting stagnation tendency. In particular, we carry out a labor market policy to further explore the nexus between inequality, innovation and growth as well as an innovation policy to examine how the process of diffusion of technological knowledge affects industry concentration and GDP. For each policy experiment, we run 25 simulation runs with different random seeds. The cross-MC averages for selected variables are collected in Table 4.2 and compared with the baseline scenario, the one with imitation activity (i.e., $\chi = 0.5$).

Labor market policy. We start with a labor market reform aimed at weakening

[69] Note that, in these simulation settings, the Government is not subject to any fiscal constraints: public budget is left free to adapt to business fluctuations and the resulting public bonds are entirely purchased by the Bank. In the next Section, the effects of alternative policy regimes will be explored.

[70] See Summers (2014) and Krugman (2014) for a discussion about the 'new secular stagnation hypothesis'. For a critical review of its neoclassical theoretical underpinning, see Di Bucchianico (2020).

	Imitation	No Imitation
GDP growth rate (%)	1.6172	0.64
	(0.0012)	(0.0049)
GDP std	0.0259	0.0355
	(0.0019)	(0.0110)
Unemployment rate	0.0711	0.1424
	(0.0068)	(0.0966)
HH index	207.7052	1839.0279
	(0.5493)	(13.0502)
Mark-up	0.0556	2.0653
	(0.0025)	(1.0424)
Profit share	0.1316	0.5057
	(0.0095)	(0.0907)
Consumption/GDP	0.9185	0.6459
	(0.0053)	(0.0912)
Inventories/GDP	0.0657	0.2857
	(0.0048)	(0.1172)
Public deficit/GDP	0.0283	0.1947
	(0.0035)	(0.0642)
Leverage	1.3903	2.1651
	(0.1160)	(0.6599)
Bankruptcy rate	0.0379	0.1429
	(0.0049)	(0.1189)

Table 4.1: Statistics for selected variables in the two scenarios: cross-simulation mean and standard deviation (in parenthesis).

trade unions power. This is captured by a reduction in parameter α governing the wage-productivity elasticity in equation (4.31), i.e., the degree to which the nominal wage responds to a change in productivity. As in Dosi et al. (2010), in the baseline scenario we have $\alpha = 1$, meaning that trade unions are able to fully pass on any increase in productivity to nominal wages. In Experiment 1.1, we set $\alpha = 0.90$.

We find that a weaker labor union leads to higher mark-ups and fosters a profit-led growth. This should not come as a surprise in that in our model R&D investment, which affects the probability to innovate and imitate for K-firms as well as the accumulation of technological knowledge for C-firms, is a function of realized profits, contrary to, e.g., Dosi et al. (2010) where R&D depends on past sales. This makes the relationship between demand, distribution, innovation and growth less trivial. It should also be noted that the enhanced output growth comes at the cost of a higher unemployment rate. By fostering the adoption of more efficient techniques, in fact, technical progress forces a considerable fraction of workers out of the production process, which is not fully re-absorbed because of the slowdown in wages and demand.

The drop in employment, however, does not impair the growth process because the resulting expansion of public deficit meant to finance unemployment subsidies provides support to aggregate demand.[71] To assess the role of fiscal policy in a weak labor union environment we replicate the experiment by shutting off the Government spending on unemployment subsidies. In this case (Experiment 1.2), the economy experiences a collapse in GDP and employment, higher output volatility and, despite the lack of unemployment benefits, an explosion of public deficit due to interest payments on (initial) outstanding bonds and declining tax revenues. Hence, this experiment shows that in presence of weak labor unions, fiscal policy is essential to support aggregate demand and thus guarantee a profit-led growth, otherwise the economy would remain stuck in a high unemployment-low growth trap.

Innovation policy. We now want to get further insights on the process of knowledge accumulation, which, as seen in the previous section, plays a fundamental role in the choice of capital vintage, thus influencing the emergence of technological discontinuities and market concentration. First of all, we explore the effects of a change in the degree of intra-industry knowledge spillovers, represented by ψ in equation (4.6). This parameter captures the extent to which other firms' R&D effort affects the accumulation of technological knowledge by the individual firm. In other words, a high value of ψ means that the R&D activity carried out by one firm increases the pool of technological knowledge available to all firms (Cohen and Levinthal, 1989).

In the first high-knowledge spillover policy (Experiment 2.1), ψ is increased from 0.1 (benchmark value) to 0.9. Unsurprisingly, this policy does not entail any significant effect on the model outcomes. This is because, in such a scenario, the ability to exploit outside knowledge spillovers, i.e., the *absorptive capacity*, is still endogenous to firms' R&D experience, as shown in equation (4.7): notwithstanding the availability of technological information, in presence of an endogenous absorptive capacity, smaller firms do not have the necessary technical skills to exploit them, failing to reduce the technology distance from the leaders.

For the sake of completeness, we investigate the effects of the same innovation policy under an institutional regime characterized by exogenous absorptive capacity ($\gamma = 1$). We can think of it a (hypothetical) situation in which all firms not only have access to the same pool of technological information, but are also endowed with the necessary technical ability to process them, so that knowledge differentials substantially disappear. In such a scenario (Experiment 2.2), an high-knowledge spillover policy has a positive impact on the economy in terms of lower unemployment and higher

[71] Note that, unless specified otherwise, in all policy experiments we keep active the engine of fiscal policy.

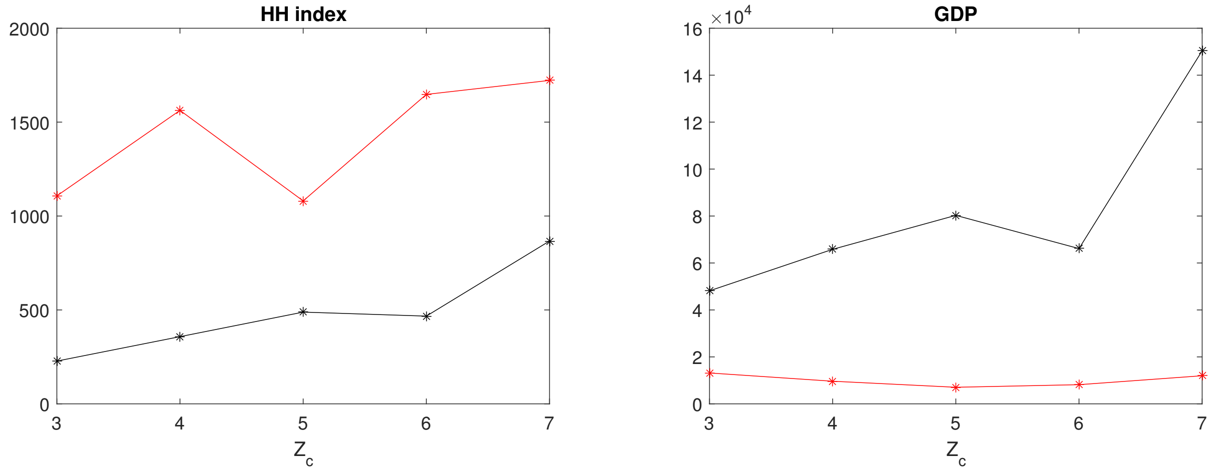


Figure 4.12: Effects of a higher market competition, Z_c, on average HH index and GDP level under imitation (black) and no-imitation (red) scenario.

output growth, although the last period GDP level is insignificantly different from the benchmark.

What we can learn from this policy exercise is that a top-down innovation policy, if not coupled with alternative measures aimed at directly or indirectly tacking the roots of market concentration and/or compensating for the negative effects it produces on income distribution and aggregate demand, is likely to be ineffective in stimulating economic growth.

4.3.5 Can concentration be good for the economy?

The analysis carried out so far has shown that, in the absence of legal entry barriers, the initial wave of concentration is gradually re-absorbed due to the decline in technological discontinuities stemming from imitation activity, thus paving the way for a competitive and self-sustained growth process. On the other hand, the presence of legal barriers to imitation is associated with a high and persistent market concentration, with long-lasting detrimental effects on income distribution and economic growth. The reason is twofold. On the demand side, greater profit margins resulting from the enhanced marker power cause a progressive shift in the income distribution from wages to profits, which, as long as profit earners have a lower propensity to consume than wage earners, leads to a reduction in aggregate consumption and demand. On the supply side, limited imitation activity in the K-sector, by curbing the diffusion of the best innovations among capital good firms, hampers technical change and productivity growth.

However, in the ongoing debate on the causes and consequences of rising concentration, some authors have stressed that a competition-driven concentration, by reallocating market shares towards more productive firms, may have a positive impact on output and productivity growth (Autor et al., 2017, 2020). Among the causes behind the increase in market competition, a special emphasis was given to the role of the improved search technologies in providing consumers with a greater availability of price comparisons on the internet (Akerman et al., 2021). According to this view, therefore, market concentration is considered to have efficiency-enhancing effects that improve the overall economic performance.

The remaining part of this paper aims to investigate whether and under which conditions this hypothesis is verified in the framework of the present model. In particular, we want to explore, by means of a sensitivity analysis, the impact of an increase in the degree of competition, captured by parameter Z_c, i.e., the number of firms visited by consumers on the goods market, on concentration and aggregate production and how such a relationship is affected by entry barriers. The experiment is performed by running 25 Monte Carlo simulations for each value of Z_c going from 3 (benchmark case) to 7; the mean values of HH index and GDP, averaged over time and across simulation runs, is then collected and displayed in figure 4.12. To assess the role of entry barriers, we replicate the experiment under the no-imitation scenario, i.e., $\chi = 0$.

It can be seen that in the imitation scenario (black curve), a higher degree of competition leads to an increase in both concentration level and total output. By contrast, in the presence of legal entry barriers (red curve), as Z_c increases, GDP remains roughly constant in spite of rising HH index. Therefore, it emerges that whereas in the imitation scenario a competition-driven concentration stimulates the economy, such efficiency-enhancing effects are canceled out by the presence of entry barriers. In fact, we have seen that when imitation is not allowed, the scarce diffusion of technological innovations allows large firms to consolidate their dominant position and thus exploit the market power generated by technological discontinuities. This interpretation is further corroborated by figure 4.13, which shows the evolution of the degree of variation in market shares, an index measuring the average number of ranks a firm moves up or down along the market share distribution in each period (Dawid et al., 2021). The higher the index, the more frequently firms change positions in the market, the higher the business dynamism. We can see that in the no-imitation scenario the degree of variation in market shares is systematically lower compared to the case in which imitation is allowed, both over time (left panel) and by Z_c (right panel). This means that the presence of legal entry barriers is associated not only with higher but also more persistent market concentration.

Considering the positive impact of an increase in competition-driven concentration on GDP in the absence of legal barriers, these findings suggest that it is the degree of

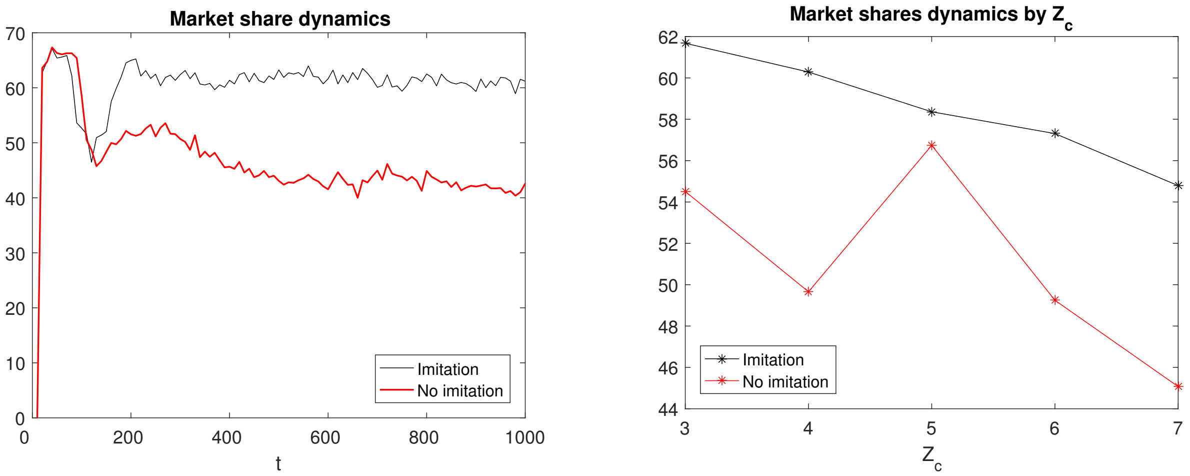


Figure 4.13: The degree of persistence in market shares over time and by Z_c under imitation and no-imitation scenario.

persistence, more than the level per se, that determines whether or not market concentration benefits the economy. A high and volatile concentration may foster growth as long as competitive forces bring about a continuous reallocation of market shares towards more productive firms, without them having the opportunity to consolidate and exploit a dominant position. Conversely, a persistent market concentration triggered by the presence of legal barriers enables large firms to exert the enhanced market power to extract higher rents, with negative effects on income distribution and GDP.

4.4 Conclusion

Building on the recent debate on rising concentration, stagnation and inequality (De Loecker et al., 2020; Stiglitz, 2019; Syverson, 2019), this paper aims at exploring the causes and consequences of rising market concentration, by focusing on the interplay of technical change and market power. We do this by developing a macro-evolutionary agent-based model with innovation dynamics in the capital good sector and knowledge accumulation in the consumption good sector. K-firms perform innovation and imitation activities to improve the productivity embodied in the capital goods they produce by means of labor. C-firms produce a homogeneous consumption good by employing labor and heterogeneous capital and perform R&D to accumulate technological knowledge. The choice of capital vintages by C-firms depends upon the "knowledge gap", i.e., the difference between the degree of capital good's technical advancement and the firm's level of technological knowledge.

Simulation results have shown that, in the short-run, the introduction of new innovations in the market generates a spontaneous wave of concentration in so far as firms with greater accumulated knowledge are able to exploit them, thereby achieving productivity gains and larger market shares. Operating under oligopoly conditions, the emerging “superstar" firms seek to exert the enhanced market power by extracting higher profit margins. As the weight of large firms grows over the economy, the increase in the weighted-average mark-up leads to a shift in the income distribution from wages to profits (Kalecki, 1942), which eventually undermines demand and growth (Keynes, 1936; Steindl, 1976). A stagnation tendency, thus, endogenously arises out of the normal functioning of an oligopoly economy characterized by knowledge-based technical entry barriers. Yet, the dynamics of industry concentration in the long-run is not straightforward. Indeed, further simulation experiments reveal that, whereas the first wave of concentration is triggered by technical entry barriers, which constrain firms' access to technological innovations, the evolution of concentration over time crucially depends on the presence (or lack thereof) of legal entry barriers, which affect the process of diffusion of technological innovations, thereby influencing the firms' ability to consolidate their position and exploit their market power.

From additional policy experiments, we find that labor market reforms aimed at weakening labor unions, by boosting profit margins and innovation, can foster a profit-led growth. Yet, the following slowdown in wages and demand has to be compensated by an anti-cyclical fiscal policy, in the absence of which the economy would remain stuck in a high unemployment-low growth trap. Moreover, while in the absence of entry barriers a reduction of transaction costs may promote a competition-driven concentration which benefits growth, innovation policies geared to spurring knowledge spillovers across firms risk to be ineffective as long as the technical ability to process them remains unequally distributed in a concentrated industry. Finally, a restrictive fiscal policy that prevents a fully anti-cyclical management of the public budget accentuates the stagnation tendency which eventually results in higher concentration, as the reduced demand is largely satisfied by a fewer number of firms.

Policy experiment	GDP gr.(%)	GDP std.	U	HH	Avg. Mu	Π/GDP	GDP_ly	C/GDP	Inv/GDP	Def/GDP
0. Baseline	1.6172	0.0259	0.0711	207.7052	0.0556	0.1316	1	0.9185	0.0657	0.0283
	(0.0012)	(0.0019)	(0.0068)	(0.0025)	(0.0095)	(0.0053)		(0.0048)	(0.0035)	(0.1160)
1. Labor market policy										
1.1 Weak labor union	0.0208	0.0226	0.3374	130.8289	0.6874	0.3446	3.0288	0.8767	0.1111	0.2174
	(0.0007)	(0.0017)	(0.0185)	(0.1054)	(0.0989)	(0.0196)		(0.0118)	(0.0121)	(0.0133)
1.2 Weak labor union + no subsidy	-0.0679	0.0325	0.7329	90.7648	0.0643	0.1707	0.0150	0.9417	0.0379	0.6689
	(0.0325)	(0.0026)	(0.0103)	(0.1346)	(0.0094)	(0.0109)		(0.0022)	(0.0027)	(0.0645)
2.1 High knowledge spillovers	1.6051	0.0256	0.0722*	194.7644*	0.0577	0.1326*	0.9505*	0.9177*	0.0667*	0.0289*
	(0.0014)	(0.0016)	(0.0069)	(0.3418)	(0.0029)	(0.0081)		(0.0046)	(0.0033)	(0.0021)
2.2 High knowledge spillovers + ex. AC	1.8072	0.0258	0.0524	193.7532*	0.0633	0.1378*	1.0580*	0.9135*	0.0704*	0.0307*
	(0.0014949)	(0.0014297)	(0.0099921)	(0.39317)	(0.021808)	(0.011793)		(0.011527)	(0.011646)	(0.0068388)

Table 4.2: Cross-simulation mean and standard deviation (in parenthesis) for selected variables under different policy regimes. A two-sample t-test for equal means with respect to the baseline model is performed: the symbol * indicates that the null hypothesis is not rejected. Variables description: *GDP gr.*, growth rate of GDP; *GDP std.* GDP volatility; *U*, unemployment rate; *HH*, Herfindahl-Hirschman index; *Avg. Mu*, weighted-average mark-up; Π/GDP, profit share; *GDP_ly*, GDP level in the last simulation period; *C/GDP*, consumption share; *Inv/GDP*, inventories share; *Def/GDP*, public deficit-GDP ratio.

Appendix 4.A Accounting and balance sheets

In what follows we describe the agents' balance sheets and micro/macro accounting identities of the model.

The balance sheet for C-firms respects the following accounting identity

$$b^k_{it}K_{it} + D_{it} + p_{it}inv_{it} = L_{it} + E_{it}, \tag{4.35}$$

where $b^k_{i,t}K_{i,t}$ is the book value of capital, D_{it} is the firm's deposits, $p_{it}inv_{it}$ is the inventories of C-goods valued at the current price, L_{it} is outstanding debt and E_{it} is equity, or net worth.

C-firms hold cash liquidity in forms of bank deposit, which evolves as follows:

$$D_{it} = D_{it-1} + \pi_{it} + \Delta L_{it} - \theta L_{it} - p_{jt}I_{it} - div_{it} - RD_{it}, \tag{4.36}$$

where π_{it} is the firm's profits, θL_{it} the debt installments, $p_{jt}I_{it}$ is the cost of new capital evaluated at current price of capital goods. div_{it} is the dividend payments.

When the firm's equity turns negative, the firm is bankrupted and exits the market. Then, the owner uses his own wealth to recapitalize her.

For the sake of simplicity, K-firms do not borrow from the bank and employ only labor as input of production. Therefore, the balance sheet of K-firms reads

$$D_{jt} = E_{jt}, \tag{4.37}$$

where their liquidity evolves as follows

$$D_{jt} = D_{jt-1} + \pi_{jt} - div_{jt}. \tag{4.38}$$

Households' wealth E_{ht} coincides with their deposit D_{ht}, which evolves by adding up their income and subtracting the consumption expenditure.

$$E_{ht} = D_{ht}, \tag{4.39}$$

$$D_{ht} = D_{ht-1} + Y_{ht} - C_{ht}. \tag{4.40}$$

As far as the bank is concerned, her balance sheet is given by

$$R^b_t + L_t = D_t + E^b_t, \tag{4.41}$$

where R_t^b are the bank's reserves, L_t are total loans provided to C-firms and the Government, D_t are households' deposits and E_t^b is the bank's net worth.

Bank's profits are the sum of interest payments of N_F^s solvent borrowers, including the Government; there are no costs, since deposits are not remunerated:

$$\pi_t^b = \sum_{s=1}^{N_F^s} r_{st} L_{st} + rB_{t-1}. \tag{4.42}$$

The bank's equity is updated as follows:

$$E_{b,t+1} = E_{bt} + (1 - div_b)\pi_{bt} - BD_t, \tag{4.43}$$

where div_b is the constant fraction of dividends paid by the bank to capitalists. BD_t stands for bad debt, and is the total value of interest payments due by N_F^n insolvent borrowers, i.e. $BD_t = \sum_{n=1}^{N_F^n} L_{nt}$.

The following set of equations illustrate the system of interrelated aggregate balance sheets:

$$R^b = D^H + M^I + M^J + E^B \tag{4.44}$$
$$M^I = D^I - L^I \tag{4.45}$$
$$M^J = D^J - L^J. \tag{4.46}$$

where $M^I = E^I - (K + \Delta)$ and $M^J = E^J - \Delta^J$ are money in the hands of, respectively, C-firms and K-firms.

Appendix 4.B Parameter setting

Symbol	Description	Value
W	Number of workers	2000
F	Number of C-firms	200
N	Number of K-firms	10
Z_c	Number of C-firms visited by consumer	3
Z_u	Number of firms visited by unemployed workers	5
Z_{imi}	Number of K-firms visited by imitators	4
$\bar{l}$	Capital-labor ratio	2
α	Wage-productivity elasticity	1
$\bar{\omega}$	Desired utilization rate	0.85
κ	Desired inventories rate	0.1
ρ	Sales adaptive expectation parameter	0.25
$\{c_y^w, c_y^k\}$	Marginal propensity to consume out of income	{0.80, 0.20}
c_f	Marginal propensity to consume out of wealth	0.05
υ	Unemployment subsidy rate	0.40
$\{\tau^w, \tau^k\}$	Tax rate on labor and capital income	{0.04, 0.02}
div	Firms-bank payout ratio	0.20
δ	Depreciation rate of capital	0.03
δ^{inv}	Depreciation rate of inventories	0.30
δ^z	Depreciation rate of knowledge	0.005
$\sigma^{c,k}$	R&D investment propensity	0.30
χ	R&D allocation between innovation-imitation	0.50
ζ	Search capabilites parameter	0.30
η	Absorptive capacity parameter	0.03
ψ	Degree of knowledge spillovers	0.1
β	Intensity of choice of K-good	30
λ	Intensity of choice of C-good	1
s	unemployment subsidy rate	0.4
r	Refinancing rate	0.01
μ_b	Bank gross mark-up	1.2
β_b	Bank loss parameter	1.2
A_0	Initial value of C-firms productivity	1/3
B_0	Initial value of K-firms productivity	1/2
$\{a_1, a_2\}$	Effective productivity parameters	{1, 1.2}
$(\mu_{FN_1}, \sigma^2 FN1)$	Folded Normal Distribution parameters for product innovation	(0.03, 0.008)
$(\mu_{FN_2}, \sigma^2 FN2)$	Folded Normal Distribution parameters for process innovation	(0.02, 0.008)
$(\mu_{FN_3}, \sigma^2 FN3)$	Folded Normal Distribution parameters for mark-up	(0.02, 0.008)

Table 4.3: Benchmark parameter setting

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