Economic and Financial Bubbles: Definition, Theory and Recent History

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Abstract

This thesis is concerned with the systematic analysis of economic bubbles. This is done through a review of the relevant literature, but specifically through the analysis of mathematical models attempting to explain bubble behaviour. Such a thorough and methodological examination of mathematical bubble models is, to date, missing from the literature. Two broad approaches to the study of bubbles are distinguished. The first sees bubbles as exogenous phenomenon. Here, economic bubbles can only be created from outside the efficient economic system. The second approach allows economic bubbles to emerge from within the complex economic system through varying levels of system stability.

It is argued that among existing approaches there is a lack of a concise definition of economic bubbles. Beyond this, there are problems of methodology. One of the main issues identified throughout the literature but especially the mathematical models of economic bubbles is the assumption of equilibrium. It will be argued that the implied assumption of system stability leaves no room for bubble phenomena. And even if, in the case of the endogenous bubble literature, theoretically the equilibrium assumption is not needed to explain bubble behaviour, methodologically ***all*** examined models fall back on that notion.

This then leaves the question whether mathematical bubble models are appropriate when attempting to explain bubble episodes in real time. This thesis comes to the conclusion that, while an alternative paradigm to understand and explain bubble behaviour theoretically exists, methodologically, a paradigm shift away from calibrated mathematical models based in the natural sciences is needed if bubble episodes are to be explained in real time and real markets. The identification of varying levels of stability, employing real data, analysing economies in real time is proposed as a way forward in the explanation of bubbles.

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Chapter I: Introduction

The term ‘bubble’ describing an economic boom and bust episode was first used to identify the financial scheme created by John Law surrounding the Mississippi Company (Shiller, 2014), roughly spanning from 1716-1720. The Mississippi bubble was characterized by rapidly increasing prices, leverage and euphoria and ended suddenly after a run on banks, which led to a financial and economic crisis in France (Galbraith, 1993). When looking at such episodes on a general level (spatial and temporal considerations not included (Dymski, 1999)), it can be argued that periods of financial and economic distress can be found throughout history and across regions, characterized by reoccurring sequences of events during bubble episodes (Dymski, 2010; Dymski & Shabani, 2017). In this light, the 2007/2008 Subprime crisis is the result of the most recent occurrence of such an episode, on a much larger scale.

This thesis adds to the literature on financial and economic bubbles as it provides an in-depth and systematic engagement with bubble episodes both, at the level of theory as well as on the level of methodology from a Post-Keynesian point of view. This is done through a review of the relevant literature, but specifically through the analysis of mathematical models attempting to explain bubble behaviour. Such a thorough examination of mathematical bubble models on a methodological level is, to date, missing from the literature. However, and as pointed out by Colander (2000) the modelling approach to economic problems is the main element of modern economic theory. Specifically, within orthodox approaches, the mathematization of (complex) economic behaviour is at its core and most important for such approaches to the economy. Mathematical models are, at least in orthodox approaches the ‘language’ that is spoken and hence, must be understood. Therefore, mathematical models and their potency to explain bubble episodes must be considered within the bubble analysis. Two broad approaches to the study of bubbles are distinguished. The first approach sees bubbles as exogeneous phenomenon. Here, economic bubbles can only be created from outside the efficient economic system. The second approach allows economic bubbles to emerge endogenously from within the complex economic system via varying levels of system stability.

Theoretically, the thesis shows that, within the economics literature, different theoretical definitions of what constitutes a bubble episode are given. It will become clear throughout the thesis, that a coherent theoretical definition of bubble episodes is missing in the literature. It is argued that the difficulties in defining and explaining bubbles reflects on deeper issues of theory, not the least the reliance on notions of equilibrium. These theoretical issues predominantly exist within orthodox approaches to capitalist economies. Within such orthodox approaches, bubble episodes are either ignored or viewed as exogenously created whereas the term ‘bubble’ itself is extensively used throughout the theoretical analysis. Due to the underlying assumption of economic stability signalled by a general equilibrium setting of the economy, bubble episodes are understood to be extraordinary, random and single events, where disproportionally large economic fluctuations towards the equilibrium (or fundamental value) take place, after the economy is shocked out of its initial equilibrium state (Friedman & Schwartz, 1963; Friedman, 1968; Lucas, 1976b; Lucas & Sargent, 1979; Romer, 1993; Snowdon et al., 1994; Gordon, 1997; Visco, 2005; Shiller, 2005; Akerlof & Shiller, 2009; Mankiw, 2018). Since the economy is efficient and self-equilibrating, outside disturbances are needed to disturb the equilibrium setting and achieve the exceptional (price) fluctuations characterizing a bubble episode. Hence, bubbles are created **exogenously**. The responsible external disturbances causing the system to slip off the initial equilibrium are manifold and range from sudden changes in the (external) money supply (Friedman & Schwartz, 1963), to imperfect information (Romer, 1993; Shiller, 2005), and behavioural biases (Shiller, 2005; Akerlof & Shiller, 2009). In any case, external shocks must be large, powerful and convincing enough to be able to disturb the otherwise well-behaved economy in such a way (Kindleberger & Aliber, 2005). However, the isolated approach to economic bubble episodes (only parts of the economy are considered), the overbearing equilibrium assumption and the oversimplified approach to economies, where capitalist economies are portrayed to be simple barter economies without money and debt structures as well as the limited approach to economies in that the evolution of the economic system over time plays no role, all lead to the fact, that bubble episodes can, realistically not be accounted for. Hence, such theories fail to explain bubble behaviour in real economies.

An alternative theoretical approach is found in the heterodox literature. In this thesis specifically Minsky's Financial Instability Hypothesis (FIH), where bubble episodes emerge **endogenously**, is considered. In contrast to orthodox approaches, the bubble term is rarely used within this analysis (Dymski & Shabani, 2017). The reason for this is that an entirely different understanding of capitalist economies, and with that, economic bubbles is adopted. Minsky (1970, 1982, 1992, 2008b) sees the economy as an evolutionary complex system which is embedded within a greater socio-political system (Minsky, 1970, 1982, 1992, 2008b), that both evolve over time. Bubble episodes are understood to be one of many system states defined through varying levels of system stability (Minsky, 1970, 1982, 1992, 2008b). These changing levels of stability emerge endogenously over time (Minsky, 1982, 1992, 2008b) and are tied to the changing level of debt within the economic system. It is important to note that no external disturbances or shocks are needed to create such system behaviour (Minsky, 1992, 2008b). Instead, the inner workings of capitalist economies alone lead to boom-and-bust episodes. Due to the integrated approach to capitalist economies where both, the financial and real side of the economy are equally important and where money and debt are actively considered, the equilibrium notion is theoretically not needed as the economic system moves through time. Hence, and in contrast to the above mentioned orthodox approaches, Minsky's FIH (Minsky, 1970, 1982, 1992, 2008b) can, if extended for current developments theoretically account for bubble episodes though only on a general level. However, the focus on crises that are believed to follow bubble episodes, the missing placement of specific bubbles within geographical borders and historical context (Dymski, 1999, 2010; Dymski & Shabani, 2017) within the Minskian approach as well as methodological issues (to be discussed below) make the thorough consideration of bubble episodes in real time impossible.

On the methodological level, the same exogenous/endogenous bubble distinction arises. Within the exogenous model approach the classical dichotomy holds. Hence, models of the economy never represent all of the economy. Either the real side of the economy (sunspot models) or the financial side of the economy (rational bubble models) is analysed, but never both[1]. As pointed out above, this separation of the real and financial sphere is unsatisfactory when economic bubble episodes are to be analysed. Without considering the interrelation of financial and real markets, bubbles cannot be accounted for. Further, the equilibrium and stability assumption within the exogenous bubble models is even more apparent than within the accompanying orthodox literature. The corresponding stationarity belief of vaguely defied economic fundamentals and an equilibrium that is consistently approached leave no room for economic bubble episodes. The stability and equilibrium assumptions are so strong that mathematical models built on that idea are incapable of generating continuous endogenous fluctuations. From a modellers' point of view, this is a highly unsatisfactory outcome. For any fluctuation to occur, such models need continuous outside shocks. Otherwise empirically observable fluctuations within economies would, within these models, die out whereas the system would remain in an unchanging steady state (until the next external shock occurs). The oversimplified approach to economies on a theoretical level avenges itself on a mathematical level. While bubble movements within these models are artificially generated, this thesis argues that such models are incapable of accounting for economic bubbles. It is simply not enough to create temporary swings within an artificial, calibrated model representing an oversimplified and schematized version of an ideal economy that does not exist. Hence, such models must be discarded if bubble episodes are to be understood.

Mathematical models representing the economy as a complex system while being tied to Minsky's analysis are rare. With a strong background in Minsky's theory and leaning on the complex system approach, Keen (2013) attempts to model Minsky's hypothesis, including bubble episodes. Unfortunately, and similar to the exogenous bubble models, the notion of multiple equilibria persists. However, and as will be argued throughout this thesis, equilibrium assumptions and the calculations based on them are ill suited when trying to account for socio-economic, complex systems which evolve over time. The crux of such systems is that they are inhabited by people who act based upon biases and heuristics or conventions, who themselves change and who, through their (combined) actions,

[1] Though attempts to link those two spheres have been made by Farmer (2015) for sunspot and by Martin and Ventura (2017) for rational bubble models. However, without considering money and debt structures, a complete integration of those two spheres is impossible.

change their environment more rapidly than in any other naturally occurring complex system. ***All*** mathematical models portraying economies or economic bubbles however are derived from models initially representing natural phenomena, where equilibria naturally exist. Even Keen's Minsky inspired complex system model that attempts to portray varying levels of system instability relies on complex system calculations that accept the equilibrium notion blindly. Hence, as will be argued throughout the thesis, while a theoretical alternative paradigm exists in the form of Minsky's FIH[2], a paradigm shift is needed at the methodological level to account for economic bubbles as endogenously emerging properties of complex systems over time.

Hence, the contribution of this thesis is to show that, theoretically, but specifically with regards to methodology, new thinking is needed to define bubble episodes within capitalist economies. Therefore, it is crucial to systematically analyse and critically assess both, orthodox and heterodox mathematical models which attempt to portray bubble episodes. As mentioned before, such an analysis and assessment are, as of yet, missing. This thesis attempts to fill this gap. Therefore, throughout the three core chapters different mathematical models and mathematical models to economic bubbles will be examined and critically discussed. The result of this discussion is to establish the need for new thinking on the definition and explanation of bubbles.

Throughout the thesis, the term *bubble* will be used to describe episodes such as, for example, the Japanese asset price bubble in the early 1990s, the dot-com bubble in the US in the late 1990s or the US housing bubble leading to the Subprime crisis in 2007/2008 on a general and predominantly theoretical level. It is acknowledged that the term bubble itself is used extensively throughout the orthodox (mainstream) literature and very rarely within heterodox, especially within the Minskian approach to such episodes (Dymski & Shabani, 2017). Reason for the sparse usage of the term within this literature is, according to Dymski and Shabani (2017) an implied underlying fundamental (or equilibrium) value where the size of the deviations away from it are indicative of whether a bubble exists or not. This belief in fundamentals (or an equilibrium) is, as will become clear, in stark contrast to what will be argued throughout this thesis.

The justification for the usage of the term bubble in this thesis is the fact that, specifically this phenomenon, the time before a financial or economic crisis, where speculation and unsustainable finance patterns build up and take the place of (sustainable) growth and moderate finance, is of interest. While crises are the outcome of such financial and economic activities, and while crises are (in some instances) caused by bubble phenomena, they are not the main focus of this thesis – bubbles are. And as pointed out by Sornette (2003), during bubble and crash episodes, financial market return distributions differ in the symmetry and shape

[2] However, and as mentioned before, Minsky's theory needs extending in the form of financialisation to account for economic developments since the introduction of Minsky's hypothesis.

when compared to times, where bubbles and crashes do not occur. The return distributions not only differ from times where bubbles and crashes do not occur, they also differ for bubble and crash episodes themselves (Sornette, 2003). Hence, statistically the behaviour of economic variables (in this case financial returns) during bubble episodes is clearly different from the behaviour observable during crisis episodes. Therefore, the usage of the term bubble instead of crisis is justified. Additionally, adding yet another term to describe a phenomenon that has been recognized by both, orthodox (though not all) and heterodox economists to the already existing terms would, it is believed, only add confusion as to what this thesis really is about. While the understanding of bubbles, as will become apparent throughout this thesis, is clearly tied to heterodox views in the Post-Keynesian tradition, the usage of the bubble term itself, it is hoped, will draw interest from both, heterodox and orthodox economists. To guide the reader more easily through the various chapters of this thesis, the definition and understanding of bubbles employed within the thesis will be presented in the following section.

1. A proposed definition of financial and economic bubbles

1.1. Bubbles are a macroeconomic phenomenon

Within this thesis it is argued that economic bubbles are a macroeconomic phenomenon. This means that a single asset, commodity, firm or household and so on is not characterized as a bubble. Such assets and commodities, it is maintained, are simply overpriced whereas firms and households are either wealthier or more indebted than comparable counterparts in the same spatial region at the same (historic) time. It is maintained that economic bubbles can only occur if future profits (real and financial) as well as future employment levels (and possibly wages) are expected to rise on an aggregate (e.g. industry or market) level for a specific region or the whole economy, and not on an individual level (e.g. for one person or one firm). Hence, for a bubble to occur it is important that the economy has either grown successively or is expected to grow so that investment (real and increasingly financial) and the accompanying credit creation can take place. Some of the key drivers for expectations to rise fast (and possibly lead to bubble periods) are, while varying across regions and time, new technologies or new (scientific) discoveries, newly opened investment opportunities (e.g. into regions that were previously closed off to foreign investment), newly created financial instruments (e.g. securitisation instruments), the increased availability of liquidity (through increased inflow of foreign capital and/or through liberalisations within financial markets) as well as structural changes within the respective economic and political system (e.g. effects of financialisation).

1.2. Bubbles are an endogenous part of the complex economic system

The theoretical understanding of what constitutes a bubble episode within this thesis is a Post – Keynesian one and leans heavily on the FIH as well as on theoretical explanations of complex systems. In this view, the economy is understood to be a complex system, where various system states (boom, bubble, crisis, recession and so on) evolve endogenously over time. Bubbles are then not seen as rare, exogenously created outlier events. Instead, economic and financial bubbles emerge as one of the many possible system states endogenously. The differing system states are determined through the interactions within the micro – as well as within the macro – sphere of the system (Sornette, 2003; Rickles, 2011). Specifically the financial side of the economic system is understood to be a hierarchical network (Sornette, 2003) where the degree of homogeneity of the system nods (in this case profit seeking banks) as well as the level of connectivity between the various nods within the hierarchy are indicative of the degree of order within the system (Sornette, 2003; Scheffer et al., 2012). This means that the greater the financial flows from many investors on the bottom of the hierarchy to only few financial institutions (mega banks) on the top of the hierarchy and the greater the degree of homogeneity within the investment and trading strategies as well as profit and growth objectives among those mega banks, the greater will be the degree of order. A high degree of order on the other hand is indicative of a high level of instability for the overall system (Sornette, 2003). A high degree of system instability in turn hints towards emerging (or already existing) bubble episodes (Minsky, 1970, 1982, 1992, 2008b). The source of the changing stability levels of the overall economy can be found in financial markets (Dymski & Shabani, 2017) where, due to changing expectations, portfolio adjustments are responsible for such changes (Minsky, 1970, 2008b).

To link the theoretical findings of the complex system approach more clearly to today's bubble episodes, Minsky's FIH serves as a good starting point. The link between the micro – and macro – sphere as well as the link between the real and financial side of capitalist economies is made via the balance sheet approach mentioned in Minsky's writings. Hence, when looking at changing stocks and flows of an economy and with that, the changing nature of balance sheets for households, firms and banks over time, specifically with regards to liquidity and debt, changing levels of system stability can be identified, and with that, possible bubble episodes. In line with the FIH, it is agreed that one way of measuring stability levels is by using the debt-to-income ratio within an economy. However, and as will be emphasised below and in the conclusion of the thesis, the sole reliance on this ratio is not sufficient to identify bubble episodes in real time.

1.3. Money plays a role

Bubbles cannot be understood if only part of the economy (real or financial) is looked at. Reason for this is that the real and financial side of the economy are two sides of the same coin, tied together by investment (real and financial) and financial commitments. Investment takes place via loans, which in the future need to be paid back. In line with the Post-Keynesian tradition of endogenous money creation it is argued that, with the creation of loans private banks are actively creating additional purchasing power. This newly created purchasing power will ideally be used for real investment leading to increases in output, employment and growth. However, once this additional purchasing power is increasingly used to finance financial investment, speculation and consumption, a boom phase can very rapidly turn into a bubble episode (Schumpeter, 1927). Quickly rising (asset) prices and surging levels of leverage both hint towards growing instabilities. And as argued above such increasing levels of instability hint towards bubble episodes. Hence, an active financial market that is tied to the real side of the economy and especially money and endogenous money creation all play an integral part in the bubble build-up and cannot be ignored. Thus, money is not only a neutral medium of exchange, instead it plays a crucial role in the generation of bubble episodes and thus must be actively considered.

1.4. Stylized facts or a spatialized approach

On a very general level, economic bubble episodes do exhibit observable patterns (stylized facts) which are applicable across regions and hold over time. However, it must be emphasized that in order to understand specific economic bubbles, this general approach, where economists focus on repetitive patterns and abstract from the distinct circumstances of time and space (Dymski & Shabani, 2017), is, on its own, not satisfactory. The peculiarities of economic bubbles depend on the structural properties of the socio-economic system within a spatial (geographical) region as well as on features of that system within a certain time frame. Hence, and in line with Dymski's and Shabani's (2017) argumentation, economic bubble episodes must be placed in time *and* space to be fully understood. Therefore, and to fully account for economic and financial bubble episodes, both, the stylized facts and special and historical considerations must play a role.

1.5. Historical context matters

As indicated above, to fully understand specific economic bubble episodes, the evolution of the socio- economic and political system through time matters. Thus, to be able to explain the increased frequency and magnitude of financial and economic bubbles since the 1980s in general, and to be able to comprehend specific bubbles that have occurred since then, political, economic and social changes taking place in real time have to be considered. For example, to be able to explain the housing bubble in the US leading to the Subprime crisis 2007/2008, the political and economic position of the US and the importance of the US dollar as a reserve currency since World War II, political changes and financial market deregulations since the 1980s and their implications, structural changes within the US (and other countries) and the emergence of new phenomena (such as financialisation) as well as changes in banking practices (towards fee based and predatory lending practices) and the deconstruction of the welfare state with its repercussions for inequality (to name a few) over (historical) time all need to be considered. Hence, to fully understand specific economic bubbles, it is not enough to look at the bubble episode in isolation - the historical context matters.

The proposed definition above then leaves the question as to what formal economic must include to realistically portray bubble episodes. Below section will briefly pick up on this question before the structure of the thesis is discussed.

2. The desired bubble model

The desired model depends of course on the entry point of the theorist and how he or she understands and sees the real world. Theorists in the neoclassical tradition see the world as a stable equilibrium system where markets are efficient and self-regulating. As will become clear throughout the thesis, for neoclassical theories no discrepancy between the underlying theory and the employed methodology exists. The desired model is in accordance with the assumption of equilibrium, partial analysis, the insignificance of money and debt as well overall generality, where considerations of time and space do not matter. The underlying theory links logically to the applied methodology. Hence, general equilibrium models portray what the neoclassical theorist understands to be a true representation of theory (and reality).

The desired formal model from a heterodox point of view however is a different one. The underlying theory (in this thesis especially in the Minskian tradition) reinforces the fact that, at least theoretically, the equilibrium assumption is not an adequate representation of complex, socio-economic, political systems, that the classical dichotomy (the financial and real side of the economy are analysed separately) is unsatisfactory and that money and debt play an integral part and must hence be considered. However, and as will become clear when discussing formalisations from a heterodox perspective, these very different theoretical assumptions are not reflected within the employed methodology. In fact, and as will be shown in chapter V, the mathematical model that is being produced is, at times, in contrast to the theoretical assumptions put forward.

For both, the orthodox and heterodox approach, the employed methodology is not questioned. While, as pointed out above, there is no reason for neoclassical approaches to challenge the methodology, this is problematic for the analysed heterodox model. When accepting the existing (neoclassical) methodology, even if only implicitly, changes within in the mathematical approach are minor. Such changes are, among others, adjustments in how a system is calculated (e.g. complex system calculations instead of linear calculations) or an extension of the employed calculations for different understandings of what bubble episodes really are (inclusion of financial markets, money and debt). Unfortunately, and as noted above, these modifications to the existing methodology cannot account for the obvious break from orthodoxy that clearly exists on a theoretical level.

With the understanding of bubble episodes set out in section 1 of this chapter, the implications for the desired model that realistically portrays economic bubble episodes set out here, are clear. To be able to portray such episodes, economic models must represent the whole economy. For this, an active producing sector, active labour markets as well as active financial markets where money is, via the loan process endogenously created, must be considered. Partial models cannot meet that requirement. Further, realistic models must be complex system models where the interrelations between the micro- and macrosphere cause varying system states and, tied to this, various levels of stability, to emerge endogenously over time. The interactions of market participants as well as financial flows play a crucial role in defining these interrelations. Hence, to be able to trace changing levels of system stability, financial stocks and flows must be included in such a model.

And as will be argued throughout this thesis, the notion of an equilibrium system portraying economies is uncalled-for. The understanding of capitalist economies as socio-political systems here is such that they evolve over, and move through time, without approaching, moving away from or being defined by an equilibrium state or process. The economic system is interpreted as neither stable (all the time) nor unstable (all the time) – it is both. There is not one system state that dominates all other system states and therefore the whole system. Reason for this conviction is the fact that the economic system is not a natural one which has evolved over millions of years, that is inhabited by particles which consistently behave the same over time and space[3], while at the same time the system is tied to some natural boundary that acts as an equilibrating force. Human-made, socio-economic political systems are inhabited by people whose behaviour is *not* consistent over time and space. Humans are not passive molecules reacting to a changing environment. Within a society, norms and accepted behaviour change over time whereas humans themselves actively change their surroundings in the process. Hence, and in combination with liberalised financial markets and deregulated economic systems where endogenous money creation is possible, it is argued that a natural ruler that would keep the system consistently stable, does not exists. And mathematical models attempting to realistically account for bubble behaviour must portray that.

Similarly, the hierarchical structure of financial markets plays just as an important part and could, via network theoretical approaches, be incorporated into a complex system model of the economy. And, in order to create a sensible model, real data should be used in real time. This of course presumes that everything that should be included in a model is measurable while at the same time, actual data would have to flow into the model equations somewhat instantaneously. Additionally, and as argued above, spatial considerations (such as the hierarchical position of a currency and the accompanying historical development for example) would ideally need including into such models. Same can be said about policy developments within economic and socio-political systems evolving over time. Hence, each model would have to be space and time specific. This would require that the profound changes from the 1980s onwards on a political, economic and social level would have to be included, at least for those countries that have gone through that process of deregulations and liberalisations. Only then could the evolution of the complex socio-political and economic system be accounted for. It is argued that different growth models (consumption driven vs. export driven) as well as varying financial systems (bank based vs. market-based systems) and differing types of

[3] This too is an oversimplification. For example, water does not always freeze at 0°C.

welfare states (asset based vs. governmentally regulated) across geographical regions are all indicative of the overall level of system stability. Measures of this kind would be needed to place economies or economic regions within the context of fragility which in turn would be indicative of whether certain economies or economic regions are more prone to bubble episodes. As noted above, the usage of one measure - the debt to income ratio - is not sufficient. Placing economies according to their fragility level would also allow to identify if especially fragile economies (e.g. consumption driven, market-based banking system and asset-based welfare states) would even go through the stable growth phases as suggested by the FIH or if such economies would consistently experience bubble growth (and crises).

Besides the complications arising from discrepancies between the theoretical and methodological gap within the analysed Minskian approach and the difficulties in finding one measure for above mentioned interdependencies, it is questionable if the increased complexity resulting from such additions is something that should be aimed for if the same methodology is maintained (mathematical models of the economy). This of course leaves the question of whether the existing methodology within (especially heterodox) economics is, when attempting to explain bubble episodes specifically and capitalist economies in general, appropriate. This thesis comes to the conclusion that, in order to account for the profound theoretical differences and to satisfy the definition of bubbles as well as the desired ingredients of a bubble analysis, a paradigm shift on the methodological level is needed. A shift away from the constraints imposed by the prominent neoclassical methodology towards a more inclusive and adjustable framework of key data enriched by space and time considerations where bubble episodes specifically and capitalist economies in general can be analysed in a timely manner.

3. The structure of the thesis

Each chapter is structured in a similar way and consists of a brief introduction to the respective theory or the mathematical bubble model, which is then followed by a critical appraisal of selected accounts of economic bubbles.

Chapter II provides a review of recent economic literature. The literature review first considers orthodox economic theories. These theories are organised in chronological order starting with the Neoclassical Synthesis and ending with New Keynesian macroeconomics as the most recent exogenous bubble theory. The critical comments highlight the inadequacy of exogenous bubble theories. The literature review is completed by the discussion of endogenous bubble theories, with the main focus being the FIH of Hyman Minsky (Minsky, 2008b). Minsky's approach is promising in that it is an inclusive and evolutionary approach to economic bubbles. Inclusive here means that the classical dichotomy is replaced by an all-encompassing approach to capitalist economies where both, active real and active financial markets matter and where economies are embedded within the overall socio-economic system.

Chapter III engages with examples of mathematical models of exogenous bubbles, in particular sunspot and rational bubble models. After a detailed discussion of their underlying assumptions and model structures, the thesis argues that ultimately, these models cannot account for bubble behaviour. The inadequacy of such models is firstly due to the unrealistic theoretical assumptions made, and secondly, due to the general insufficiency of mathematical models that rely on, and are built around, the equilibrium notion.

In chapters IV and V, mathematical approaches that see economic bubbles as endogenous will be considered. Chapter IV presents the Econophysics approach to financial market bubbles. The complex system approach stressed throughout Econophysics and the focus on empirical data rather than theoretical models is (at least at first) promising. However, the equilibrium assumption is maintained while the theoretical background in economics that would support a complex system approach to explain endogenously emerging bubbles within capitalist economies is missing. Unfortunately, Econophysics fails to meaningfully link their findings to a credible endogenous bubble theory à la Minsky and instead falls back on neoclassical assumptions and explanations.

Chapter V discusses Keen’s Minsky inspired model (Keen, 1995, 2011, 2013). While, out of all the examined mathematical approaches to bubble episodes, Keen’s model is the most advanced when connecting a credible theory to the complex system approach, unfortunately, Keen’s model considers equilibrium situations and is by no means a finished model. What is left after considering various mathematical models in detail is the question whether a model approach, where the behaviour of economies is imitated rather than explained is adequate when attempting to identify bubble episodes in real time. The outcome of the analysis of such models suggests that this is not the case. In the conclusion that follows in chapter VI, the argument is made that a methodological paradigm shift is needed if bubbles are to be analysed in real time, while possible future research opportunities are briefly highlighted.

Chapter II: The Literature on Economic Bubbles

1. Introduction

The structure of this chapter is based on this exogenous-endogenous distinction of bubbles explained in chapter I. The ensuing section will first discuss relevant literature that falls under the notion of the exogenous bubble literature (section 2 of this chapter). As previously mentioned, the presentation of the literature is in chronological order and starts with the Neoclassical Synthesis in section 2.1., followed by Monetarism in section 2.2. and New Classical Macroeconomics in section 2.3. The exogenous bubble part concludes with New Keynesian Macroeconomics in section 2.4. The endogenous part on economic bubbles (section 3 of this chapter) is mainly concerned with John M. Keynes in section 3.1. and especially Hyman Minsky in section 3.2. As stated in the thesis introduction (chapter I), the reason for the focus on Minsky is his contribution in the form of the FIH. Under the FIH, the economy is, theoretically approached as a complex system, which evolves over time while generating various system behaviours (including economic bubbles) endogenously. As mentioned earlier, Minsky's view of the economy, especially with regards to changing stability levels and endogenously emerging bubble episodes, is shared throughout this thesis. To finish the discussion of the endogenous bubble literature, financialisation as part of the Post - Keynesian research effort is discussed in section 3.3. Reason for the separate discussion of financialisation is the implications financialisation has for (economic) system stability and hence, bubble episodes.

Each section of this chapter is organised similarly. After a brief introduction of the relevant theory, a critical appraisal assesses the usefulness of the relevant approach when attempting to explain economic bubble episodes.

2. Exogenously created bubble episodes throughout the literature

2.1. The Neoclassical Synthesis (NCS) – a world in which bubbles do not exist

The term NCS itself was coined by Samuelson in 1955 (Goodfriend & King, 1997; Colander, 2000; De Vroey & Duarte, 2013) with the NCS evolving throughout 1950s and 1960s (Blanchard, 1991; Goodfriend & King, 1997; Leijonhufvud, 2009a). The NCS describes the consensus in economics at that time (Snowdon et al., 1994; Colander, 2000; De Vroey & Duarte, 2013), where an interpretation of Keynes' *General Theory* (GT) in the form of the IS-LM[4] model became the dominant perspective on how economies function (in the short run) (Roncaglia & Mario Nuti, 1985; Patinkin, 1988; Snowdon et al., 1994; Goodfriend & King, 1997; De Vroey & Duarte, 2013). However, and as will become clear throughout the presentation and the following discussion of the NCS, the theory itself does not consider bubble episodes. This can possibly be linked to the extraordinary period

[4] MPS models, which were much bigger and more sophisticated were also used at that time (at least by the Fed). The base assumptions of the IS-LM model were the foundations for those models (Blanchard, 1991; Goodfriend & King, 1997; Visco, 2005).

of the 1950s and 1960s, where bubbles (or major crises) did not occur (Minsky, 1970; Reinhart & Rogoff, 2009).

Various theoretical explanations for the NCS exist. According to Goodfriend and King (1997), within the NCS, the Keynesian analysis of the macroeconomy (specifically wage and price stickiness) is combined with an overall classical view of the economy, where the optimisation on an individual level is at the heart of the analysis. Snowdon et al. (1994) and Leijonhufvud (2009a) note that the theoretical approach to the economy remains classical, while the policy implications are Keynesian. Visco (2005) and De Vroey and Duarte (2013) maintain that, in the long run, the classical general equilibrium (GE) theory is applied while the short run is characterized by Keynesian fluctuations.

Reflecting their neoclassical roots, within this approach, the overall economic system is assumed to be stable. This assumption is supported by the idea that there exists an automatic tendency of the system to converge towards a full employment equilibrium in the long run (Kregel, 1983; Roncaglia & Mario Nuti, 1985; Blanchard, 1991; Snowdon et al., 1994; Visco, 2005; Leijonhufvud, 2009a; De Vroey & Duarte, 2013). However, in the short run, the economic system might depart from its long run equilibrium. According to Goodfriend and King (1997), this short run departure from the desired equilibrium is due to various types of externally created shocks to the economic system, while the departure from the equilibrium itself is representative of business cycles. Which type of shock could cause the system to be thrown off the equilibrium and lead to instability is not specifically defined on a theoretical level, though initially it was believed that changes in aggregate demand in combination with price and wage stickiness would cause ‘real’ fluctuations and could hence lead to business cycles in the short run (Goodfriend & King, 1997). The assumption, that disruptions from the real side of the economy could disturb the steady state of the overall economic system (Blanchard, 1991) was extended to institutional flaws, such as the mismanagement within the monetary system (Minsky, 2008a), and later to supply side shocks, such as rapid changes in the price for oil (Patinkin, 1988). Within the IS-LM model, shifts of the curves away from the initial equilibrium are caused by exogenous changes in investment, taxes or government spending for the IS curve, and exogenously given changes in money supply for the LM curve (Snowdon et al., 1994; Blanchard, 1991; Blanchard & Illing, 2006). However, as the economic system is assumed to be generally stable, it is not that critical to understand why the system departs from the ideal equilibrium. It is more important to understand the adjustment process towards the new, optimal (employment) equilibrium and how to possibly get there faster.

Since, in the short run, markets are assumed to not be efficient (Blanchard, 1991), since rigidities and frictions exist (Visco, 2005), and since, according to Keynes’ theory, wages and prices do not adjust instantaneously (Blanchard, 1991; Snowdon et al., 1994; Goodfriend & King, 1997; Visco, 2005; De Vroey & Duarte, 2013), the automatic adjustment towards the ideal equilibrium after an external shock is also not immediate. Hence, economic fluctuations (Goodfriend & King, 1997) and periods of underemployment can persist (Minsky, 2008b) for substantial amounts of time. Therefore, and since the tendency of the system to converge towards this long run equilibrium might be either affected by market forces, or the tendency of convergence might generally be weak (Roncaglia & Mario Nuti, 1985; Patinkin, 1988; Visco, 2005), countercyclical monetary and fiscal policy interventions are needed to achieve an efficient equilibrium outcome more rapidly (Roncaglia & Mario Nuti, 1985; Blanchard, 1991; Goodfriend & King, 1997; Minsky, 2008b).

Once the economy is shaken out of its efficient (steady) state, equilibrating tendencies set off towards the ideal equilibrium (Minsky, 2008a). These tendencies are assumed to be in the form of an iterative auctioneer process (Blanchard, 1991), which, within the NCS, is an attempt to link the short, to the long run (De Vroey & Duarte, 2013)[5]. The newly reached general equilibrium of the economy could be both, a short or a long run equilibrium. If the new equilibrium is an over - or underemployment equilibrium, meaning the labor market equilibrium is above or below the optimal labor-output constellation, then this equilibrium is a short run equilibrium triggering further adjustment processes towards the ideal equilibrium where the whole economy is in an optimal labor-output equilibrium. Once that is the case, the economy has arrived at the long-run equilibrium. The main adjustment mechanism is the classical price mechanism where prices (and wages) adjust according to supply and demand[6]. In the long run, prices and wages have enough time to adjust to changes in demand or supply and therefore a (new) market clearing equilibrium emerges (Blanchard, 1991; De Vroey & Duarte, 2013). This also implies that Say's law where demand always meets its supply holds in the long run.

Within the IS-LM model, equilibria on all markets are assumed to occur simultaneously and are determined through the labor market equilibrium (Snowdon et al., 1994; Minsky, 2008b) while money is exogenously given and neutral (Roncaglia & Mario Nuti, 1985; Patinkin, 1988). This means that the money stock is unresponsive to changes in money income and wages (Roncaglia & Mario Nuti, 1985). Furthermore, uncertainty as well as expectations are not included into the theory or the IS-LM model (Kregel, 1983; Roncaglia & Mario Nuti, 1985; Patinkin, 1988; Sims, 2000).

Having presented a quick overview of the NCS, a brief appraisal of the consideration of economic bubbles within the NCS will be given in the following.

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[5] However, how one would get from the short run to the long run is not explicitly worked out (De Vroey & Duarte, 2013).

[6] For the labor market this translates into shifts of the labor demand curve causing the LM curve to shift within the IS-LM model.

2.1.1. The consideration of economic bubbles

Generally, the NCS simply is not interested in explaining bubble episodes. The strong belief in an overall stable economic system and the exclusive focus on the way the economic system adjusts towards an ideal equilibrium not only highlights the firm connection to the neoclassical theory (Dymski, 2014), but it also makes the neglect of economic bubble episodes obvious. Additionally, the IS-LM model is a simple linear model, which makes it mathematically impossible to generate endogenous system fluctuations (see for example Gandolfo, 2009). On a theoretical level this finds expression in the assumption that only exogenous shocks can cause the system to deviate from its efficient equilibrium making shifts in the models' curves mathematically possible. However, and as will be argued throughout the thesis, this oversimplified approach to modelling capitalist economies is uncalled for.

In the following section these and other issues relating to economic bubble behaviour will be discussed further.

2.1.1.1. Equilibrium and exogenous shocks

Within the NCS, in the short run, the economic system can deviate away from the optimal equilibrium. However, this deviation can only be caused by exogenous shocks and is amplified through rigidities. Therefore, in the IS-LM model, it is theoretically possible to end up in an under - or overemployment equilibrium in the short run. Under - or overemployment could hint towards under - or overproduction as well as too low or too high levels of income when compared to the (long run) efficient and stable employment, production, and income levels of the economy. These different equilibrium states could point to previous boom or bubble episodes that have now caused a crisis or depression phase for the first and an ongoing boom or bubble episode for the latter equilibrium. However, those two possibilities are not considered and are hence, not further explored or described. It is more important to analyse the adjustment mechanisms towards the efficient, long run equilibrium than to consider and understand different system states that the economy goes through over time. With the strong emphasis on adjustment mechanisms towards the equilibrium, rather than focusing on the evolution of a system, and without the inclusion of (real) time into the underlying IS-LM model, the buildup of an economic bubble as well as the deflation of economic bubbles cannot be identified. However, it should be noted that the aim of the theoretical explanations and the mathematical model was never to identify and understand bubble episodes. Bubbles simply do not exist within this approach. Hence, the focus on managing the adjustment mechanism to reach the optimal full employment equilibrium faster, is justified.

Further, though it is acknowledged that in the short run equilibrating tendencies will set in towards the long run equilibrium, it is unclear how the system would evolve towards this equilibrium as time is not considered. If time was considered it would be possible to identify different system states. This could be an indication of possible cycle behavior – however very simplistic in the form of close or far from the long run equilibrium as center of attraction. Bubble episodes could potentially be identified in this very basic way. The further away the short run income, output and employment equilibrium from the hypothetical optimal income, output and full employment equilibrium in the long run is, the greater the bubble on the positive side (meaning too high a level of income, output and employment when compared to the optimal level) or the greater the crisis on the negative side (meaning too low a level of income, output and employment when compared to the optimal level).

Moreover, Visco (2005) implies that the need for policy intervention in the short run may indicate that the long run equilibrium as center of attraction may be too weak to actually pull the system back into equilibrium once the initial steady state has been disturbed. However, theoretically the NCS hints towards a long run equilibrium convergence of the economy which indicates that even if the center of gravity was weak, the economy would nevertheless end up in equilibrium (Visco, 2005; Minsky, 2008b; De Vroey & Duarte, 2013). This then makes it unnecessary to consider bubble episodes. A stable economic system simply implies that bubbles generally do not occur. Small disturbances due to rigidities within the labor market may cause the system to fluctuate, however these fluctuations will, in time converge towards the ideal equilibrium. Additionally, these fluctuations will never be so big that they could disturb the overall reigning stability of the system.

Furthermore, the stability assumption of the long run equilibrium implies that the economy is governed by stability and will reach a stable equilibrium with certainty. Hence, the future is certain and known. Without uncertainty, expectations about the future do not change. This in turn implies that portfolio decisions concerning future investment opportunities stop fluctuating in the sense that the return on capital is fixed and known. However, according to Minsky's interpretation of Keynes (Minsky, 2008a), it is these sometimes rapidly changing portfolio fluctuations (stemming from changes in future expectations) that not only cause cycles, but also bubble episodes and crashes. If these fluctuations cease to exist on a theoretical level, so do bubble episodes and economic cycles. Therefore, under above assumptions made by the NCS bubble episodes can, theoretically, not occur.

2.1.1.2. A passive financial sector and the neglect of system states

In capitalist economies credit is needed to finance investment and innovations which in turn lead to economic growth (Schumpeter, 1928; Minsky, 2008b; Keen, 2013). Within the NCS it is implicitly assumed that investment may be financed through loans (dependence of investment on the interest rate in the IS-LM model). However explicitly this connection is not made. In capitalist economies, credit can be generated through existing savings. However, generally only a fraction of a bank's deposits are backed by actual cash at hand (savings) (Leijonhufvud, 2009a). Hence, so goes the argument, banks give out loans and look for the needed reserves later. For the explanation of economic bubbles, it is important to note that, as soon as new loans are given out, new money (purchasing power) is created (Leijonhufvud, 2009a; Keen, 2013, 2017). The process of endogenous money creation is independent of the money supply by central banks and can hence not really be controlled (at least not in liberalised financial markets). The fractional reserve banking (Leijonhufvud, 2009a) mentioned above is not limited by the availability of a certain underlying monetary reserve (such as gold during the Bretton Woods era for example). Hence, money and with that, additional purchasing power, can be generated by commercial banks without bound, supporting inflating bubble episodes. When looking at the pro-cyclical development of credit (Kindleberger & Aliber, 2005) as well as the varying quality of loans (Minsky, 1982, 2008b) and rapidly increasing prices during a bubble episode, it becomes apparent that credit and endogenous money creation play a crucial part in changing stability levels of the economy. Hence, credit and endogenous money creation cannot be ignored if bubble episodes (or generally changing system states within the economy) are to be understood.

Further, and in order to provide means of financing for a production economy, a financial sector that is not purely intermediate is needed. If banks would not provide (productive) credit during boom times, it is questionable if a boom could even take place. If no economic boom was to take place economic bubbles would become an impossibility as they appear to be linked to (prolonged) boom phases (Kindleberger & Aliber, 2005; Minsky, 2008b). Similarly if banks would not continue to provide additional purchasing power throughout a boom phase, (consumption driven) booms, that evolve out of economic upswings and eventually descend into bubble episodes as soon as productive credit is replaced by credit for consumption (Schumpeter, 1927), would not be possible. If the financial sector is considered to not be an active part of the analysis while ignoring endogenous money creation, neither economic bubbles nor other stages of the business cycle can be identified or explained. At the same time, the effect that additional purchasing power has on the economy (via investment, income and consumption) questions the neutrality assumption of the money stock. This lack of analysis is a major shortcoming of the NCS.

As already indicated, neither financial nor debt structures are included in the NCS analysis. Through assigning the financial sector an intermediate role where the supply of money is exogenously given and where credit creation plays no role, the debt and financing structure of the system cannot be uncovered. From a Minskian perspective (explained in more detail in section 3.2. of this chapter) an understanding of this structure would be needed to indicate in which system state[7] the economy is in. Hence, considering changing debt structures and with that varying levels of system stability is indispensable when attempting to understand bubble episodes.

2.1.2. Conclusion

In the 1970s the critique of the NCS became louder due to increasing inflation and an increasingly unstable economic system. Though Leijonhufvud (1968, cited in

[7] Upswing or downswing, boom or recession, bubble or crisis.

De Vroey and Duarte, 2013: 7), Lucas (1976b), Lucas and Sargent (1979) and Minsky (1982) all criticized the NCS on theoretical and empirical grounds, the implication of their criticism for the synthesis differed widely. While Leijonhufvud (1968, cited in De Vroey and Duarte, 2013: 7) was certain that Keynes' *General Theory* (GT) was interpreted wrongly and that the NCS was not Keynesian, Minsky (1982) saw the main flaw of the NCS in the incapability to explain instability. Lucas and Sargent (1979) on the other hand asserted that the Keynesian revolution had been unsuccessful in tackling unemployment and inflation and should be replaced by the neoclassical, general equilibrium paradigm. According to Lucas (1976b) and Lucas and Sargent (1979) Keynesian models, though mathematically advanced, had failed and could easily be replaced by (dynamic) equilibrium models based on the equilibrium cycle theory. Lucas (1976a, b) dismissed the Keynesian based macro approach to the economy which made the necessity of a synthesis between two schools of thought obsolete (De Vroey and Duarte, 2013). Due to the development of (dynamic) equilibrium models (Lucas, 1976a) the neoclassical theory was, by its proponents, considered to be able to describe not only the short run, but also the long run (De Vroey & Duarte, 2013). New Classical Macroeconomics emerged as the 'counterrevolution' to the NCS. New Classical Macroeconomics and the consideration of economic bubble episodes within this approach, will be discussed after a brief encounter with Monetarism.

2.2. Monetarism

Throughout the 1950s and 1960s classical Monetarism emerged and became the prominent paradigm throughout the 1970s and early 1980s due to double digit inflation in most countries in the Western world of that time (De Long, 2000; Hafer & Wheelock, 2001). While the Keynesian synthesis appeared to be unable to tackle stagflation, Monetarism seemed to offer plausible explanations of high inflation and falling growth rates concentrating on short rather than long run dynamics (Hafer and Wheelock, 2001). Hence, this classical Monetarism emerged as a (monetary) counterrevolution and as a critique of the Keynesian policy prescriptions within the NCS (Kaldor, 1970; Leijonhufvud, 2009a). While both, the NCS and Monetarism are the two main economic schools of thought during the post-war era, Monetarism, other than the NCS, finds its theoretical base for policy implications in the pre-Keynesian, classical tradition (Roncaglia & Mario Nuti, 1985), where state intervention is counter-productive. The main proponent of classical Monetarism was Milton Friedman (Kaldor, 1970; De Long, 2000), who asserted that the business cycle is solely a monetary phenomenon (Friedman & Schwartz, 1963; Friedman, 1968; De Long, 2000).

The theoretical structure of Monetarism is similar to that of the NCS (Roncaglia & Mario Nuti, 1985) where markets are efficient, while the economy is understood to be a stable equilibrium system, which, in the long run, will automatically tend towards a full employment equilibrium[8] (Kaldor, 1970; Roncaglia & Mario Nuti, 1985; Jahan & Papageorgiou, 2014). Money is exogenously given and in the long run neutral. Stock holdings, financial instruments and credit creation are not considered. Different from the NCS, economic agents have adaptive expectations, which are formed on the basis of past values of the relevant economic variables (Snowdon et al., 1994; Laidler, 1986). NCS and Monetarism differ further when it comes to policy suggestions (Roncaglia & Mario Nuti, 1985). The NCS school opts for fiscal policy intervention whereas Monetarism is convinced that only monetary policy is effective, and then only in the short run. For example, when analysing the Phillips curve relation, the NCS asserts that expansionary (fiscal) policy will lead to permanently lower unemployment, below the rate of natural unemployment. Monetarism on the other hand stresses that any expansionary (monetary) policy only has transitory effects on real variables (such as unemployment) in the short run but permanent effects on monetary variables (such as inflation) in the long run (Roncaglia & Mario Nuti, 1985).

The conviction that the business cycle is a monetary phenomenon stems from Friedman's and Schwartz' (1963) observation that (rapid) changes in the money base have, in the past, led to macroeconomic instabilities and crises while, at the same time, the demand for money (velocity of money) remained stable (Friedman & Schwartz, 1963; Friedman, 1968; Kaldor, 1970; De Long, 2000; Hafer & Wheelock, 2001). They concluded that changes in the (external) money supply alone can cause economic fluctuations in the form of business cycles (including bubbles and crises) (Friedman & Schwartz, 1963; Friedman, 1968; Minsky et al., 1963; Hafer & Wheelock, 2001; Jahan & Papageorgiou, 2014). According to Friedman (1968), especially rapid fluctuations in the supply of money can lead to boom – and – bust episodes. Since the supply of money alone determines the demand for money and, with that, business activity and hence economic fluctuations (Friedman & Schwartz, 1963; Kaldor, 1970), the only way to stabilise the economy is through controlling the exogenous supply of money (Minsky et al., 1963; Friedman, 1968; Kaldor, 1970; De Long, 2000). Only through a steady and fixed monetary expansion, so the argument goes, can stable growth (with acceptable levels of inflation) be achieved while, at the same time, instabilities are eliminated (Friedman, 1968; Kaldor, 1970; Jahan & Papageorgiou, 2014). This conviction gives central banks an overly important role in that only they would be responsible for economic bubble episodes[9].

However, any government intervention, even with good intent, will disturb the efficiency of markets and will therefore create economic problems. Thus, a laissez-faire policy by governments should be adopted. Central banks on the other hand play a significant role in stabilizing the economy through controlling the exogenous

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[8] The full employment equilibrium in Monetarism is substituted by the notion of the natural rate of unemployment.

[9] While Friedman and Schwartz (1963) briefly mention that also other (context specific) factors could cause bubble episodes, they do not explore this possibility further.

money supply. As argued above, the main tool to control business cycles is monetary policy. Yet, Monetarism maintains that only monetary variables (such as the inflation rate, wages and prices) will be permanently affected by such policy interventions (Kaldor, 1970). Real variables (such as employment or output) will only be temporarily affected by changes in the money supply. Therefore, in the short run money is *not* neutral (Jahan & Papageorgiou, 2014). Due to a unique long run equilibrium for real variables, adjustments towards the natural rate of real variables will take place after the short term changes (Kaldor, 1970). Therefore, and since increases in money stock lead to a proportionate increase in inflation, the effect on real variables in the long run will be zero. Hence, money is neutral in the long run. While real variables such as output[10] are not affected by monetary policy (in the long run), it is argued that inflation is. Rapid growth in money supply today will lead to (permanently) high inflation levels in the long run (Hafer & Wheelock, 2001; Jahan & Papageorgiou, 2014).

Contrary to the NCS, Monetarism implicitly recognises that bubble episodes exist by referring to the crises or depression episodes that followed. And although Friedman and Schwartz (1963) and Friedman (1968) attempt to link their convictions to economic bubbles of the past, claiming that the Great Depression of the 1930s was a monetary phenomenon, solely caused by the wrong monetary policy of the Fed, it has to be questioned if this school of thought really yields the desired description for economic bubbles. In the following subsection, this will be briefly looked at.

2.2.1. The consideration of economic bubbles

Monetarism is, more than the NCS, influenced by pre-Keynesian economics, specifically when it comes to policy prescriptions (Roncaglia & Mario Nuti, 1985). Similar to the NCS, the economy is understood to automatically tend towards equilibrium. In combination with the assumption, that markets are efficient, bubbles can theoretically not emerge endogenously, especially if a laissez-faire approach by governments is adopted. Hence, external shocks in the form of changing levels of money supply are needed to explain big bubble episodes such as the Great Depression of the 1930s (Friedman & Schwartz, 1963; Friedman, 1968). According to Minsky et al. (1963), Monetarists assert that specifically for large movements within the business cycle (hinting towards bubble behaviour) their theory is adequate. The following subsections will show that classical Monetarism, contrary to their claim, is incapable of explaining bubble behaviour.

2.2.1.1. A passive real and financial sector making exogenous bubble creation necessary

Within Monetarism, economic bubbles are created exogenously and appear suddenly, with abrupt increases in the money supply. Under Monetarism, at least in the short run, the real side of the economy is assumed to simply respond to

[10] Output for example is determined by population growth and technological progress (Hafer & Wheelock, 2001).

external changes in money supply. There is no indication of active investment and production behaviour that stands at the core of capitalist economies and any bubble episode of the recent past. The link between financial market performance and the performance of the real side of the economy is not made. Hence, rapidly declining financial market prices would, contrary to empirical observations, in a Monetarist scenario not cause any serious depression or recession (Minsky et al., 1963). The key is monetary policy that would bolster possible recession or depression episodes (possibly by increasing the money supply) (Friedman, 1968; Kaldor, 1970; Jahan & Papageorgiou, 2014). The Keynesian belief that fluctuations in investment cause the ups and downs in business cycles is refuted by Monetarists (Friedman and Schwartz, 1963).

As indicated above, within Monetarism the financial sector also only plays a passive role. Kaldor (1970) points out that the actual mechanism through which exogenous changes in money supply influence economic behaviour and could hence lead to economic bubbles, is not explained. How this ‘extra’ money would get into circulation, who (rentiers, capitalists, workers) would use it and for what (savings, investment, speculation), is not touched up on. However, these are important factors that need considering if varying levels of economic instability and with that, bubble episodes, are to be analysed. Minsky et al. (1963) find that neither credit nor portfolio adjustments nor financial markets in general are considered in the analysis. If an active financial market (including financial investment, loan creation and speculation), is not considered in the investigation, it will be impossible to identify emerging bubble behaviour as well as varying levels of fragility.

Due to above explained shortcomings, Monetarism is not capable of identifying and evaluating the bubble behaviour of economies, where real and financial variables both play an important role in the endogenous creation, and destruction of economic bubbles. Simply controlling the money supply, while in reality very challenging, if not impossible, can also theoretically not lead to a more stable system if the evolution of the economy with its changing levels of fragility is deemed to not be important.

2.2.1.2. The equilibrium belief and stable velocity of money

Just like the NCS, Monetarism holds on to the idea that in the long run, an (optimal) equilibrium exists. The economy is understood to be an equilibrium seeking, self-regulating and self-correcting system. The inadequacy of such a conviction when looking at the economy as an evolutionary, complex system that evolves through various system states over time, cannot be overstated.

Within a generally stable system, large fluctuations in system variables observable during bubble episodes, cannot be accounted for. Due to the general stability assumption, such systems are incapable of generating endogenous fluctuations, and with that bubble behaviour. Hence only unpredictable outside shocks (here sudden changes in money supply) could cause the system to deviate from its naturally stable state. It becomes hard to see how empirically observable extended periods of bubble build up could be explained under such assumptions. And even if such an external shock could cause bubble behaviour, the economic system automatically adjusts towards its optimal equilibrium level. This implies that bubble episodes are only short lived and correct themselves. Again, empirically this has not been observed. Whereas in a Minskian and within the complex system approach bubbles emerge endogenously and are one of many possible system states, the overbearing importance of the equilibrium belief in Monetarism and the NCS makes it unnecessary to consider those different system states and accompanying varying levels of instability. Instead it is maintained that only due to mistakes made by the central bank a bubble can occur (Friedman & Schwartz, 1963; Friedman, 1968). However, and again, in ignoring different system states of the economy, bubbles cannot be explained.

While extreme episodes are observed by Monetarists, they are not identified as economic bubbles. The closest Monetarists get to explain a bubble is when deep depression cycles are mentioned. However, only the downturn is of interest here, especially in combination with a declining money supply which is identified to be the only cause of the crisis. What Monetarism misses is that the crisis is part of the same process that not only triggered the bubble to emerge and then burst, but that also induced the crisis.

Additionally, the velocity of money (depicting the demand for money) is assumed to be stable. The velocity of money measures how fast a currency travels through the economy. If consumption and/or investment increase, the velocity of money will increase. Hence, during times of economic expansion, the velocity of money rises (Kaldor, 1970). If this is the case and if it is assumed that economic bubbles are tied to and characterized through financial and economic expansion, the claim of stable velocity does not hold. During boom, but especially bubble episodes, the demand for additional purchasing power (in the form of endogenous money) for investment, consumption and, in later stages, speculation and debt payments, is procyclical and rises at an increasingly rapid rate. Hence the assumption of stable velocity does not allow for economic bubble behaviour that is created endogenously and through the demand side of the economy. Monetarism ignores the inherent instability of velocity of money (Jahan & Papageorgiou, 2014) and with that, reoccurring boom, bubble and crisis episodes.

2.2.2. Conclusion

Empirical findings made by Monetarism were tied to a specific (short) period of time (Kaldor, 1970). As soon as surrounding factors, which were not considered by Monetarism changed, so did the perceived underlying regularities. For example, the stable velocity of money during the 1970s broke down in the 1980s, possibly due to financial liberalisation and beginning financialisation tendencies (Hafer & Wheelock, 2001). The breakdown of underlying regularities throughout the 1980s led away from Monetarism and towards real business cycles, efficient markets and rational expectations. However, as De Long (2000) notes, Monetarism did not vanish. Its ideas, such as the analysis of the economy within a stochastic context or the emphasis on identifying specific policy measures for specific external shocks, were incorporated into the new theory. In the following, the emerging school of New Classical Macroeconomics will be looked at in more detail.

2.3. New Classical Macroeconomics the Real Business Cycles and the Efficient Market Hypothesis

The new classical revolution evolved throughout the 1970s (Laidler, 1986; Mankiw, 1989; Plosser, 1989; Snowdon et al., 1994; Stadler, 1994) and brought about the return of the business cycle analysis (Plosser, 1989; Stadler, 1994) that had been prominent before Keynes' GT (Snowdon et al., 1994). This explicitly non-Keynesian approach (Lucas, 1976b; Lucas & Sargent, 1979) not only focuses on economic micro-foundations when explaining the aggregate behaviour of the economy (Laidler, 1986; Plosser, 1989; Snowdon et al., 1994; Stadler, 1994), but it also stresses, other than the NCS and Monetarism, the dynamic evolution of economies over time via the utilization of stochastic time series (of economic variables) (Lucas, 1976b; Lucas & Sargent, 1979; Plosser, 1989; Snowdon et al., 1994; Stadler, 1994). Specifically, the nature and causes of economic fluctuations within a general equilibrium setting of the economy are of interest (Lucas & Sargent, 1979; Mankiw, 1989; Snowdon et al., 1994; Stadler, 1994). The equilibrium (real) business cycle theory developed by Lucas, where fluctuations in employment and output are explained through external shocks causing adjustments via aggregate supply channels stands, so Snowdon et al. (1994) argue, at the core of New Classical Macroeconomics (NCM). However, as Lucas and Sargent (1979) point out, the equilibrium meaning changed from a static equilibrium considered under the NCS and Monetarism to a multivariate stochastic process (random walk) that the economy follows under NCM. With this, multiple equilibria are possible.

Two phases through which NCM and the accompanying business cycle research evolved, can be identified (Snowdon et al., 1994). Within early models of the NCM, fluctuations only occur through (external) aggregate demand side shocks, predominantly in the form of unanticipated changes in the money supply. However, external changes in the money supply will, just like under Monetarism, only have short term implications. In the long run money is neutral[11]. The short run changes in money supply lead, so goes the explanation, to the 'confusion' of rational agents with limited knowledge with regards to relative and general price[12] movements (Lucas, 1976b; Lucas & Sargent, 1979; Laidler, 1986; Mankiw, 1989; Stadler, 1994). Since (forecasting) errors made concerning the rational formation of price expectations are random, fluctuations of employment and output around their natural rate will also be random (Snowdon et al., 1994). In later business cycle models, aggregate demand shocks leading to economic fluctuations are replaced

[11] In later models of the RBC, money is completely irrelevant (for example Mankiw, 1989).

[12] Relative price movements are movements of one price relative to all other prices. A general price movement is the movement of all prices (such as price movements caused by inflation).

by supply side shocks, predominantly caused through technological change, which itself is random. These models are Real Business Cycle (RBC) models and will be explained in section 2.3.1. of this chapter.

Main tenets of NCM are, among others, the rational expectations assumption of representative agents and continuous market clearing in perfectly competitive markets (Lucas, 1976b; Lucas & Sargent, 1979; Laidler, 1986; Mankiw, 1989; Snowdon et al., 1994; Stadler, 1994). The assumption of rational expectations of agents is in accordance with Muth's (1961) description by which agents' subjective expectations of economic variables do, depending on the available information, coincide with the true value of those variables (Lucas, 1976b; Snowdon et al., 1994). However, within early NCM and the accompanying equilibrium business cycle models, it is recognized that economic agents form their expectations under imperfect knowledge (Lucas & Sargent, 1979; Laidler, 1986; Mankiw, 1989; Snowdon et al., 1994; Stadler, 1994). Hence it is accepted that optimizing, rational agents make mistakes when forecasting prices. These forecasting errors, while on average made by everyone (Lucas & Sargent, 1979), are however random and not systemic (Lucas, 1976b; Laidler, 1986; Snowdon et al., 1994). And since rational agents use limited information optimally (Lucas & Sargent, 1979), on average, forecasts are correct (Snowdon et al., 1994). It is important to point out, specifically with regards to economic bubbles, that rational expectations of agents can only work if the Keynesian notion of uncertainty is replaced by (calculable) risk, where the probabilities of re-occurring events defining business cycles are well defined (Lucas, 1976b).

Continuous market clearing is the result of optimal supply and demand responses by rational agents to their perception of real prices (not nominal prices) (Snowdon et al., 1994). At each point in time, market outcomes are in a Walrasian equilibrium where supply equals demand (Lucas, 1976b; Laidler, 1986; Mankiw, 1989; Snowdon et al., 1994). In contrast to the NCS and Monetarism (discussed in the previous sections), which both allowed for short term disequilibria due to slowly adjusting prices, NCM assumes perfect price flexibility, where prices adjust instantaneously (Mankiw, 1989; Snowdon et al., 1994) to equilibrate markets (Laidler, 1986). As Mankiw (1989) points out, fluctuations in the business cycle can then be explained as changing Walrasian equilibria. This in turn implies that fluctuations within the economy as a response to external shocks are optimal, while the economy itself is Pareto-efficient at each point in time (Mankiw, 1989; Plosser, 1989; Snowdon et al., 1994). Hence, bubble and crash episodes can be explained as optimal responses to real prices by rational agents so that outcomes of bubble and crash episodes would always be Pareto-efficient.

While the equilibrium cycle theory dominated the research agenda throughout the 1970s, especially in the US (Snowdon et al., 1994), increasing empirical issues became evident. The assumption that only unanticipated changes in money supply would lead to (short run) fluctuations in the economy and the conviction that rational agents are confused about the difference between the nominal and real price level (Mankiw, 1989; Snowdon et al., 1994) were questioned which led to a restructuring of the theory and models towards Real Business Cycle models. While the main tenets of NCM (rational expectations and continuous market clearing) were maintained and developed further, from the early 1980s onwards, the focus of NCM shifted from monetary to real factors in explaining fluctuations in business cycles (Mankiw, 1989; Snowdon et al., 1994).

2.3.1. Real Business Cycle Theory

Real Business Cycle (RBC) theory made substantial adjustment to the prominent theory of equilibrium business cycles propagated by Lucas. The emphasis on imperfect knowledge of rational agents regarding the price level was abandoned (Snowdon et al., 1994). Similarly, the analysis of the short and long run which was an indispensable feature of the NCS, Monetarism and early business cycle models of the NCM, became obsolete as the neoclassical growth theory (Solow growth model) was integrated into the theory of (business cycle) fluctuations (Plosser, 1989; Snowdon et al., 1994; Stadler, 1994). The integration of the Solow growth model into business cycle models led to the development of the earliest dynamic stochastic equilibrium (DSGE) models (Blanchard, 2016a), which as quantitative, calibrated models, attempt to mimic the behaviour of economies. Money remains not only neutral within RBC (Snowdon et al., 1994), but money, in contrast to Monetarism and equilibrium business cycle models, has no role at all (Summers, 1986; Mankiw, 1989; Plosser, 1989; Leijonhufvud, 2009a). The assumption that only external shocks to the economy can cause business cycle fluctuations is maintained. While both demand[13] and supply[14] side shocks are believed to cause fluctuations within the business cycle (Plosser, 1989; Snowdon et al., 1994), emphasis is given to supply side shocks, and here specifically to technological change. (Laidler, 1986; Mankiw, 1989; Plosser, 1989; Snowdon et al., 1994; Stadler, 1994). Hence, RBC models are purely real models where predominantly real factors are considered to have an influence on real quantities (such as output, employment and investment for example) (Plosser, 1989). It should be mentioned that fluctuations in technological change are erratic and sudden leading to sudden shifts in productivity, which in turn leads to economic fluctuations (Mankiw, 1989; Plosser, 1989; Snowdon et al., 1994; Stadler, 1994).

Within the RBC theory, it is understood that forces that cause a growth trend are the same as those that lead to business cycle fluctuations (Plosser, 1989; Snowdon et al., 1994). Whereas within the NCS, Monetarism and equilibrium business cycle models, short term departures from the trend are only temporary and would adjust back to the underlying trend in the long run, within RBC, output and many other economic time series follow a random walk (stochastic trend)

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[13] Varying taste or preferences and government expenditure are defined as demand shocks (Mankiw, 1989; Plosser, 1989).

[14] Natural disasters (earthquakes, floods, droughts and so on), significant changes in energy prices, war, political and labour unrest and technological change are defined as supply side shocks (Snowden et al., 1994).

(Plosser, 1989; Snowdon et al., 1994; Stadler, 1994). The stochastic trend, so Plosser (1989) argues, exhibits growth but does not, as assumed by earlier (and later)[15] schools, fluctuate around a deterministic path. The fluctuations in trend are due to a number of external shocks to the trend and do not represent fluctuations around a trend (Snowdon et al., 1994). This then implies that changes in output are permanent, and that there exists no tendency for output to return to its former underlying trend once hit by an external shock (Plosser, 1989; Snowdon et al., 1994). Since economic time series (such as output) can be represented via random walks (Plosser, 1989), each shock to that path will determine a new growth path. Nevertheless, the assumption that the economy is in a Walrasian equilibrium where fluctuations are Pareto-efficient is maintained (Plosser, 1989).

Before the adequacy of RBC theory with regards to economic bubbles is analysed, the Efficient Market Hypothesis will be presented. Similar to the equilibrium business cycle and the RBC theory, the EMH is anchored in the underlying assumptions of NCM.

2.3.2. The Efficient Market Hypothesis

The Efficient Market Hypothesis (EMH) advanced throughout the late 1960s and 1970s (Shiller, 2005; Palan, 2009), and can be traced back to the works of Eugene Fama (Fama, 1970, 1991; Stracca, 2004; Leijonhufvud, 2009b; Palan, 2009), who stressed the efficiency of financial markets. In line with the theoretical underpinnings of NCM, the EMH holds on to the rational expectations hypothesis (Blanchard & Watson, 1982; Fama, 1991; Shiller, 2005) and the market clearing condition, implying continuous and efficient equilibria (Fama, 1970, 1991; Jovanovic & Schinckus, 2013). Hence, the integration of assumptions made by the EMH into RBC (such as rational bubble models[16] and later more complicated DGSE models) was easily done which made the EMH an integral part of modern finance theory (Leijonhufvud, 2009b).

Under the strong market efficiency assumption, financial market prices always reflect all available information (Fama, 1970, 1991; Stracca, 2004; Palan, 2009; Varoufakis, 2013). This leads to the conclusion, that financial assets are always priced correctly (Shiller, 2005) by displaying the asset's fundamental value (Blanchard & Watson, 1982). However, according to Fama (1970, 1991), this strong version of market efficiency is false and should only act as a benchmark model. The weak version of market efficiency is, according to the author, economically more meaningful. Here, financial market prices express available information to a point, where the marginal benefits of acting on (new) information (attempting to make a profit) outweigh the marginal costs of obtaining and acting upon that information (Fama, 1991). For both versions, weak and strong, only new information can lead to price changes in financial markets (Fama, 1970; Sornette,

[15] For example, in heterogenous agent-based models of the financial market, it is assumed that asset prices fluctuate around an underlying trend which itself is represented by a Brownian motion (random walk).
[16] Discussed in chapter III section 3 of this thesis.

2003) as average stock prices adjust quickly and efficiently to new information (Fama, 1991).

Further, under the assumption of efficient markets, market participants cannot, given all available information, increase financial profit through reallocations within their portfolios. Such so-called arbitrage opportunities simply do not exists (continuously) (Blanchard & Watson, 1982; Malkiel, 2003; Stracca, 2004; Shiller, 2005; Varoufakis, 2013). Financial market traders, so goes the argument, utilise all available information efficiently and by doing so, will buy assets which are under - priced (and sell over - priced assets). This in turn drives assets to their true (equilibrium or fundamental) value (Shiller, 2005). Hence, market efficiency prevails on average while over - or under - valuations of financial assets occur by pure chance (Stracca, 2004), are random and uncorrelated (Sornette, 2014).

Additionally, it is assumed that financial returns are normally (Gaussian) distributed (Fama, 1970; Leijonhufvud, 2009b; Jovanovic & Schinckus, 2013). Such Gaussian return distributions are the mathematical representation of financial market outcomes by rational, utility maximizing agents (Leijonhufvud, 2009b) and imply overall economic stability where bubble episodes are mathematically not possible.

The EMH explanation of financial market prices is anchored in a random walk model (Sornette, 2014), with modern portfolio theory being based on Gaussian return distributions (Jovanovic & Schinckus, 2013). The Black and Scholes formula, the Markowitz portfolio theory, the capital asset pricing model (CAPM) or the value at risk (VaR) model (Kirman, 2009; Jovanovic & Schinckus, 2013; Sornette, 2014) are all based on Gaussian returns. However, when assigning financial returns a (log) normal distribution, larger than usual market fluctuations become outliers (Sornette, 2003). Such outliers are often referred to as abnormal returns within the EMH literature (Malkiel, 2003; Sornette, 2003). As Sornette (2003) points out, the definition of abnormal returns, however, depends on the frequency distribution used to analyse such returns. For example, while a 10% drop of returns in financial markets should, according to an underlying Gaussian distribution, never occur, a 10% drop in returns under an exponential distribution would not be extraordinary (Sornette, 2003: 50)[17] and hence, such financial returns would not be outliers. While this explanation shows the mathematical complications in explaining economic bubble episodes, where rapidly increasing (and decreasing) returns are one sign for the inflation (or implosion) of a financial market bubble, empirically it has also been shown numerous times that returns are by no means normally distributed (for example Cont, 2001; Sornette, 2003; Jovanovic & Schinckus, 2013). When looked at empirically, using real market data, return distributions are fat tailed distributions - a finding which refutes the fact that

[17] It should be noted that it is still not quite clear which frequency (or density) distribution best represents returns.

markets are as stable as suggested by the EMH. Then, ‘abnormal’ returns seem to be more the rule than the exception.

In the following this and other issues arising within the RBC and EMH literature will be discussed. The discussion of RBC and the EMH with regards to their appropriateness in explaining economic bubble episodes will be, due to the shared NCM base, mostly a joint discussion.

2.3.3. The consideration of economic bubbles

One notable improvement of NCM when compared to the NCS and Monetarism is the non - stationarity of economic variables (Stadler, 1994). Unlike the NCS and Monetarism, NCM is interested in the evolution of economies over time, analysing time series data. While this might be an improvement on a mathematical level, theoretically NCM is more stringent with regards to the equilibrium assumption than the other two approaches. What implications this more extreme view of economic equilibrium has for the explanation of economic bubbles will be discussed in the following subsections.

2.3.3.1. Equilibrium and exogenous shocks

Theoretically it is maintained that the economy is best captured by a competitive, general equilibrium (GE) framework, where an equilibrium *always* prevails. For this extreme equilibrium assumption to hold, economic agents all have to be rational utility optimisers, whereas one market participant is representative of all other market participants (Stadler, 1994; Kirman, 2009). According to Kirman (2009), the reason for the creation of such a rational, optimising agent in this one-person (representative agent) equilibrium setting is to ensure the existence of a stable equilibrium. In combination with an ever prevailing market equilibrium (Sornette, 2014) the rationality assumption implies that economic fluctuations are (Pareto-) optimal responses of said agent (Summers, 1986; Mankiw, 1989; Leijonhufvud, 2009a; Sornette, 2014). While this conviction could not be further from observations of bubble episodes, the strong belief of NCM in a stable and efficient equilibrium makes it impossible for the RBC theory as well as the EMH to even consider economic bubble episodes. With such an emphasis on optimising behaviour leading to equilibrium instantaneously and with certainty, bubbles can theoretically not be accounted for. The objection of Eugene Fama (implicitly in Fama, 1970, 1991 and explicitly in an interview with Cassidy, 2010) to even acknowledge the existence of bubble episodes in real economies is representative of the efficient market equilibrium belief.

Additionally, for the RBC theory, the continuous stable equilibrium assumption makes it impossible to account for unrealized gains from trade occurring after a bubble has burst (Summers, 1986; Mankiw, 1989). However, most firms not being able to sell their products or most workers not being able to find employment are indicators for an economic downturn which, depending on the magnitude of the downturn, could have been triggered by a bubble episode in real market economies. Hence, with the RBC theory being unable to account for recession (or depression) episodes which are preceded by bubble episodes, bubbles themselves cannot be explained.

NCM assumes that the internal workings of the markets will, if left alone, always yield stable equilibrium outcomes. Hence, the only way the market equilibrium can be disturbed is through outside forces in the form of technological shocks (for RBC) or new information (for EMH). Then it follows that recessions within the RBC theory are explainable via technological regress (Mankiw, 1989; Stadler, 1994), again, pointing towards the incapability of RBC to account for bubble episodes. As Stadler (1994) indicates, the critique towards technological regress was recognized by RBC theorists who then adjusted the theoretical explanation. Economic downturns are now caused by regulatory pressure (e.g. consumer and environmental protection) via the legal and institutional framework, which reduces the incentives of firms to adopt new technologies. Increasing regulation can then be interpreted as negative technological shock. However, empirically this conclusion is highly questionable. As Summers (1986), Sornette (2003) and Shiller (2005) point out, there exists no empirical evidence for either technological shocks, new information or fiscal regulation that would be large, extreme and sudden enough to cause economic bubble episodes in real markets. Additionally, when ignoring the possibility that interactions on a micro scale by heterogenous market participants who are not hyper-rational (Shaikh, 2016) lead to changing macroeconomic behaviour, endogenously emergent macroeconomic behaviour such as economic bubbles cannot be credibly accounted for[18].

2.3.3.2. Partial system analysis and the neglect of an active financial sector

Like the NCS and Monetarism, NCM ignores the existence of an active financial market where banks, independent from central bank money, are able to endogenously create money. As explained in earlier sections on NCS and Monetarism, the endogenously created additional purchasing power via loans and in the form of money going to firms and households, in combination with increasing debt levels of both, firms and households, is indicative of emerging bubble episodes. This is especially important when the additional purchasing power is not used for productive investment, but instead for financial speculation, consumption and debt payments. As argued before, when looking at the changing level and quality of debt in combination with the usage of the endogenously created money, different stages of the business cycle (stable to unstable), and with that bubble episodes, can be identified over time. However, this necessitates the consideration of active financial markets as well as the consideration of money. While the NCS and Monetarism both did not mention endogenous money creation, it was acknowledged that money, especially changing levels of money supply and

[18] A more detailed explanation of the behaviour of economies from the micro to the macro scale with regards to economic bubbles will be given in chapter IV section 2.

demand, do exert a great influence on the economy. NCM, and with that both, RBC and the EMH, deny this importance.

Without an active financial market and money, it is questionable if a cyclical behavior of the economy would even emerge. Increasing investment during boom episodes leading to increasing levels of debt to finance this investment could not take place. Similarly, increasing debt levels to a point where debt payments exceed the generated income inducing a downturn could also not occur. Hence, without the cyclical behavior of economies, where the economic system goes through various stages of system stability, bubbles, as endogenous part of these cycles, would also not emerge. Again, the non-consideration of active financial markets, the interplay between the real and the financial side of the economy as well as the neglect of money all make it impossible for RBC and the EMH to understand, portray or even consider economic bubble episodes.

2.3.3.3. The issue of calibrated models and missing empirical evidence

While, as shown in the subsections above, theoretically NCM, and with that RBC and the EMH are not convincing, especially with regards to economic bubbles, similar problems arise empirically (Summers, 1986; Stadler, 1994; Cont, 2001; Sornette, 2003, 2014; Shiller, 2005; Leijonhufvud, 2009b; Palan, 2009; Jovanovic & Schinckus, 2013). Obvious deviations in empirical observations from the NCM theory are, by its proponents, justified by the lack of data or the lack of (statistical) measurement tools (Summers, 1986). According to Summers (1986) proponents of NCM argue that with improved measurements and data, the observed deviations from theory could possibly vanish in the future. However, to date, this has not happened which points further to the fact that the assumptions within NCM do not hold.

Additionally, and as already previously mentioned, there is no empirical evidence for large and economy wide shocks that would theoretically be required to drive RBC models (Summers, 1986; Stadler, 1994; Sornette, 2003; Shiller, 2005). As pointed out by Summers (1986), parameters used in RBC models are empirically not valid and appear to be chosen randomly to generate the desired outcomes. For example, the importance assigned to intertemporal substitution in the models cannot be accounted for in reality. Summers (1986) argues convincingly that fluctuations in labor supply in real markets cannot be explained when holding on to intertemporal substitution.

Similarly, the observed anomalies within financial market returns when the EMH is employed hints towards the inadequacy of that hypothesis (Cont, 2001; Shiller, 2005; Palan, 2009). Especially the assumption of normally distributed returns in combination with the random walk model, implying general and consistent market stability by ruling out all events larger than a few standard deviations from the mean (average price changes) (Sornette, 2014), has been proven wrong. In fact, return distributions are by no means normally distributed. Instead, fat tailed distributions can be observed for financial returns (Cont, 2001; Sornette, 2003, 2014;

Leijonhufvud, 2009b; Jovanovic & Schinckus, 2013). The empirically higher than assumed variability of financial market prices (Shiller, 2005) not only neglects the notion of everlasting stability (Cont, 2001), it also hints towards the fact that price movements of the magnitude observed during financial market bubbles are likely and therefore support the notion of bubble episodes. Hence, when abandoning the notion of Gaussian return distributions, bubbles not only become possible (Cont, 2001), economic bubbles are then also not outlier events, at least when looking at their frequency of occurrence (Sornette, 2003).

2.3.4. Conclusion

From above discussion it has become clear that empirical observations of economies cannot be accounted for by the theoretical underpinnings and assumptions of NCM. Especially with regards to bubble episodes, neither the RBC theory nor the EMH even attempt to comprehend bubble phenomena. Due to the overbearing stability and efficiency belief, bubble episodes are imagined away. Hence when trying to understand bubble episodes as an endogenously emerging property of economies, one has to look elsewhere. Therefore, in the following subsection, New Keynesian Macroeconomics and the appropriateness in explaining economic bubbles will be investigated.

2.4. New Keynesian Macroeconomics

After the breakdown of the NCS, mainstream economics split into two schools of thought: the RBC school discussed in the previous section and New Keynesian Macroeconomics (NKM) (Romer, 1993; Leijonhufvud, 2009b; De Vroey & Duarte, 2013). NKM evolved during the 1980s to address the critiques towards Keynesian models of the NCS brought forward throughout the 1970s, specifically with regards to the missing micro - foundations (Mankiw, 1991, 2018; Snowdon et al., 1994; Gordon, 1997). Though NKM models were developed to accommodate the neoclassical claim of missing microeconomic foundations and hence, appear to be more neoclassical than Keynesian (Mankiw, 1991), they differ from the models of NCM and the RBC as NKM strongly opposes the idea of continuous market clearing (Mankiw, 1991; Greenwald & Stiglitz, 1993; Romer, 1993; Snowdon et al., 1994; Gordon, 1997).

This New Keynesian view of non - market clearing is generally referred to as market failure (Mankiw, 1991) and can, according to the NKM theory, be traced back to real world market imperfections (Greenwald & Stiglitz, 1993) such as imperfect competition, imperfect knowledge (due to asymmetric information), sticky prices and wages that do not adjust immediately (Mankiw, 1991; Greenwald & Stiglitz, 1993; Romer, 1993; Snowdon et al., 1994; Gordon, 1997) and incomplete markets (Mankiw, 1991; Greenwald & Stiglitz, 1993; Romer, 1993; Snowdon et al., 1994). According to Romer (1993), these imperfections are central when explaining macroeconomic fluctuations. While independent external demand and supply side shocks (Snowdon et al., 1994; Gordon, 1997) cause the economy to deviate from its equilibrium values, the actual source of these shocks is not important. The response of the economy to such shocks, however, is of great interest (Snowdon et al., 1994). It is maintained that above mentioned imperfections exaggerate external shocks, leading to (large) economic fluctuations (Snowdon et al., 1994). And to explain economic fluctuations, much research centres around explanations for sticky prices and wages.

Two main sources for price and wage stickiness are identified in the literature: menu costs (Mankiw, 1991, 2018; Greenwald & Stiglitz, 1993; Romer, 1993) and coordination failures (Mankiw, 1991, 2018; Greenwald & Stiglitz, 1993; Romer, 1993; Snowdon et al., 1994; Gordon, 1997). The *menu cost* explanation for sticky prices has at its heart the idea that firms do not constantly adjust prices. According to assumptions made within the menu cost theory, this is due to the fact that price adjustments are costly for firms who would have to print new catalogues and price tags and who would have to spend substantial amounts of money to inform the customers of new prices (Romer, 1993; Mankiw, 2018). Therefore, prices do not change as quickly as they would need to (after external shocks) for markets to clear.

However, according to Snowdon et al. (1994), for many new Keynesians the fundamental causes of economic instability, can be traced back to *coordination failures*. Gordon (1997) claims that coordination failures are at the core of macroeconomic fluctuations and constitute the basis for NKM models. Mankiw (2018) asserts that economic recessions result from coordination failures. The explanation for coordination failures exaggerating external shocks and leading to recessions goes as follows: after the economy is hit by a negative shock, each firm must decide if it cuts its prices to maintain its level of profit. The firm's profit however does not solely depend in its own pricing, but also on the decisions of other firms facing the downturn (Mankiw, 2018). Hence the optimal strategy of one firm depends on the strategies adopted by other firms (Snowdon et al., 1994), where each firm influences the set of outcomes for the other firms (Mankiw, 2018). And in the case of a negative shock, all firms should cut their prices (Snowdon et al., 1994; Gordon, 1997) to avoid a recession. However, as no firm can be certain of the actions of the other firms and since imperfect markets generate asymmetric information (Greenwald & Stiglitz, 1993; Snowdon et al., 1994), firms respond asymmetric to exogenous shocks and set prices in an uncoordinated fashion (Greenwald & Stiglitz, 1993). This lack of coordination by firms however leads to market failure[19]. In the example here, non - coordination would mean that not all firms cut their prices (proportionally to the shock) which leads to an inferior overall outcome on the macroeconomic level.

Overall, and in tune with NCS, Monetarism, NCM and RBC theory, the economy is portrayed to be a stable equilibrium system (Romer, 1993; Snowdon et al., 1994), in which the long-run equilibrium and a natural growth rate exist (Gordon, 1997). Money and active financial markets are, just like in the approaches

[19] And in later dynamic stochastic equilibrium models to multiple possible equilibria (Romer, 1993; Mankiw, 2018).

discussed previously, ignored. Mathematical models within NKM are IS-LM, general equilibrium type models (Mankiw, 1991; Greenwald & Stiglitz, 1993; Snowdon et al., 1994), where different curves shift up and down after a (negative or positive) external shock. Economic agents are rational utility and profit maximisers (Romer, 1993; Snowdon et al., 1994; Gordon, 1997). Nevertheless, and in contrast to Monetarism, NCM and RBC theory, NKM holds that governmental intervention to stabilize the economy is, due to market imperfections, needed (Greenwald & Stiglitz, 1993; Romer, 1993; Snowdon et al., 1994).

2.4.1. The New Neoclassical Synthesis

The absence of a sound theoretical framework within NKM and empirical difficulties within the RBC theory led to the merger of those two approaches during the 1990s (Visco, 2005; Leijonhufvud, 2009a, 2009b; Blanchard, 2016a; Mankiw, 2018). At the heart of this New Neoclassical Synthesis[20] (Leijonhufvud, 2009a, 2009b; De Vroey & Duarte, 2013; Mankiw, 2018) is the representation of the economy as a dynamic general equilibrium system (Blanchard, 2016a; Mankiw, 2018), within which only exogenous shocks could cause the otherwise self-equilibrating and stable system to deviate from its efficient equilibrium level (Visco, 2005; Leijonhufvud, 2009a; De Vroey & Duarte, 2013; Mankiw, 2018). In tune with NKM assumptions, frictions and rigidities (in prices and wages) can both cause and enhance these external shocks (Leijonhufvud, 2009a; De Vroey & Duarte, 2013). Hence, a recession (which follows a bubble episode) is seen as a departure from the usual efficient functioning of the markets which itself is caused by an economy wide market failure (Mankiw, 2018).

Models portraying such dynamic equilibrium economies are dynamic stochastic general equilibrium (DSGE) models (De Vroey & Duarte, 2013)[21]. As an off-shot from RBC models, DSGE models are organized around a microeconomic structure, specifically with regards to the behaviour of economic agents (Blanchard, 2016a), and are based on the neoclassical (Solow) growth model (De Vroey & Duarte, 2013). And similar to RBC models, DSGE models are estimated and calibrated models of the economy (De Vroey & Duarte, 2013; Blanchard, 2016a). However, modifications to the pure RBC models were made (De Vroey & Duarte, 2013; Blanchard, 2016a) to maintain the new Keynesian element of frictions and market imperfections. For example, perfect competition found in RBC models is replaced by monopolistic competition in NKM DSGE models (De Vroey & Duarte, 2013). Additionally, to see the dynamic effects on the general equilibrium properties of the economic system, distortions to the dynamic model are added (Blanchard, 2016a).

The overall economy is understood to be a stable and self-regulating dynamic system (Leijonhufvud, 2009a), where effective market forces will ensure that the system moves towards or around the underlying equilibrating process of that

[20] Also referred to as New Consensus or 2nd generation New Keynesians (De Vroey & Duarte).

[21] Selected models of this type will be looked at in more detail in Chapter III of this thesis.

system. This underlying equilibrating process, usually some type of a Brownian motion (random walk), also ensures that there exist not one, but multiple possible system equilibria (Romer, 1993; Mankiw, 2018). Money, or any financial structure for that matter, is not considered (Leijonhufvud, 2009a) while a sound microstructure and the rationality assumption of economic agents is maintained (Visco, 2005; De Vroey & Duarte, 2013; Blanchard, 2016a). However, as De Vroey and Duarte (2013) mention, some NKM economists were very critical specifically towards the rationality assumption. Economists such as Alan Kirman (1992, 1993), Robert Shiller (2005) and George Akerlof (Akerlof & Shiller, 2009) for example, went on to broaden the definition of market imperfections via psychological factors. This line of research within NKM paradigm has become known as behavioural economics and behavioural finance.

2.4.2. Behavioral economics and behavioral finance

In behavioural economics and finance, insights from psychology (Stracca, 2004; Shiller, 2005, 2014; Akerlof & Shiller, 2009; Young, 2018) and decision research are used to explain macroeconomic fluctuations and economic bubbles (Stracca, 2004; Shiller, 2005, 2014, 2017; Johnson & Tellis, 2005; Akerlof & Shiller, 2009). In fact, decision research started out as a critique towards economics during the 1970s especially with regards to the rational expectation paradigm. Daniel Kahneman (2010, as cited in Young, 2018) has identified two different systems of behaviour which influence people's decisions: system one and system two. System one is the automatic, ever prevailing system which controls unconsciously basic emotions, resulting in gut instinct and intuition. System one is effortless and therefore runs all the time. It focuses on the short term and immediate gratification. System two on the other hand is slow. It is here where complex and reflexive thinking, rationality, planning and control takes places. The long-term is considered here and gratification can be deferred. However, system two is associated with effort and toil, and hence cannot run all the time. This may be one of the reasons why in many instances system one takes over (Young, 2018), leading to automated responses or decisions that feel right.

Besides these two underlying systems, there are a number of heuristics influencing human behaviour. Heuristics are rules of thumb, or mental shortcuts especially used when decisions are made in (highly) complex environments and are based on uncertain outcomes (Tversky & Kahneman, 1974; Kahneman & Tversky, 1979; Stracca, 2004; Young, 2018). While these rules of thumb can reduce the complexity of the problem at hand, they also lead to systematic errors in the prediction of future values (Tversky & Kahneman, 1974).

Loss aversion and framing are among the first heuristics that were discovered. Loss aversion implies that losses are felt more severely than gains of a similar amount (Kahneman & Tversky, 1979; Stracca, 2004; Young, 2018). Framing shows that, depending on how a choice is presented to people, preferences differ. Hence, and in combination with loss aversion, if a choice is framed in terms of a loss, people become risk seeking whereas if that same choice is presented as a gain, people become risk averse (Kahneman & Tversky, 1979; Stracca, 2004; Akerlof & Shiller, 2009; Shiller, 2017; Young, 2018). It could also be shown that certain gains are valued higher than probable losses (Heath & Tversky, 1991; Young, 2018). Preferences are therefore asymmetric (Young, 2018) and not, as assumed under the rational expectation (RE) hypothesis, consistent.

Tversky and Kahneman (1974) identified other heuristics such as the representative heuristic, availability heuristic as well as adjustment and anchoring. The representative heuristic shows that people draw general conclusions even from very small, non-representative samples (Tversky & Kahneman, 1974; Young, 2018), indicating that people are biased towards prejudices or assumed representativeness. (Tversky & Kahneman, 1974). Two biases resulting from this heuristic are the so called gambler's fallacy (Tversky & Kahneman, 1974; Young, 2018) and the hot hand (Tversky & Kahneman, 1974; Croson & Sundali, 2005). According to Johnson and Tellis (2005), both, the gambler's fallacy and the hot hand can explain economic bubbles with rapidly increasing and suddenly dropping prices in financial markets. Under the influence of the gambler's fallacy, people generally believe that pure chance, or luck, is a self-correcting process. Hence, deviations in one direction must be followed by a deviation in the opposite direction. For the economy this simply means that investors expect a reversal of the observed trend (Johnson & Tellis, 2005), whereas long streaks of a specific trend are perceived to be more likely to rebalance (Rabin, 2002). This concept of a rebalancing effect is indicative for a steady state preference and an underlying equilibrium concept (Stracca, 2004). The tendency to compare current wealth with wealth at a specific point in time rather than with the evolution of wealth over time and the need to anchor expectations has the same implication (Stracca, 2004).

At the same time however, people predict future outcomes according to the best representation of input. If it is representative for (financial) prices to increase, then it is expected that prices will continue to increase into the future. The greater the degree of representativeness in input, the greater is the confidence of people with regards to future expected outcomes (Tversky & Kahneman, 1974). The hot hand describes the tendency of investors to project the current and the recent trend in prices into the future (trend-extrapolation). If in addition the price trend of the recent past has been positive, confidence will be positively impacted which could lead to overconfidence (Stracca, 2004; Johnson & Tellis, 2005) and bubble episodes. (Croson & Sundali, 2005). Both, trend-extrapolation and trend-reversal depend on the length of the sequence in question (Johnson & Tellis, 2005).

Under the availability heuristic, decisions are influenced by experiences of the recent past or by occurrences that come to mind easily. For example, when a stock of a certain company has been doing exceptionally well over the last few months, this then is generally projected onto other stocks, the whole market or even the whole economy, even if the data suggests otherwise. Anchoring and adjustment show that people anchor their expectations or value estimations around certain numbers, even if those numbers are random and unrelated to the decision

(Tversky & Kahneman, 1974; Kahneman & Tversky, 1979; Young, 2018). People then later fail to adjust their estimation accordingly. Tversky and Kahneman, (1974) also found that a chain-like structure (sequence) leads to overestimations of future values. When looking at increasing asset prices in financial markets one could argue that these prices follow a sequence. Future expectations of asset returns would then consistently be overestimated, while at the same time an adjustment of prices does not occur once the expected value has not materialized. Hence, consistently increasing asset prices could be explained via this heuristic.

Over the years, innumerable heuristics and biases have been uncovered (see for example Stracca, 2004 and Johnson & Tellis, 2005). It has also become clear that various heuristics are present all the time. Hence, several heuristics will constantly influence each and every decision made.

Economists started to introduce these psychological insights into the financial and economic theory as well as into models of the economy after the 1980s (Shiller, 2014) in an attempt to explain market fluctuations and, beginning in the early 2000s, bubble episodes (Shiller, 2005; Akerlof & Shiller, 2009). Especially for financial economics, the turn towards psychological factors in explaining asset price movements was an extension of the critique towards the EMH in finance and its claim, that markets are fully rational and that prices represent the fundamental value alone (Stracca, 2004; Shiller, 2014).

According to Shiller (2005, 2014, 2017) and Akerlof and Shiller (2009), heuristics and biases and other psychological factors drive the economy and cause not only macroeconomic fluctuations, but also bubbles. They are, what Keynes referred to as Animal Spirits (Shiller, 2005, 2014; Akerlof & Shiller, 2009). Animal Spirits arise due to ambiguities in (financial) markets caused by uncertainties surrounding such markets (Akerlof & Shiller, 2009; Shiller, 2014). Hence, changes in aggregate stock prices are indicative of inconsistent perceptions of future stock values owing to Animal Spirits (Shiller, 2014). Based on the conviction that Animal Spirits drive market economies, Akerlof and Shiller (2009) attempted to identify the most important and influential Animal Spirits for bubble episodes. They classify five Animal Spirits leading to bubble and crash episodes: confidence, fairness, corruption and bad faith, money illusion and stories.

In this context, confidence is tied to trust. The greater the trust of people in the current and future economic performance, then the higher will confidence be. When, so Akerlof and Shiller (2009) argue, the economy is in a positive equilibrium, confidence is high leading to increasing asset values and a booming economy. However, when the economy finds itself in a negative equilibrium, trust is low leading to decreasing asset prices and diminishing economic performance. Hence, confidence is pro-cyclical. Fairness, as stated by the authors, acts as a major motivator for economic decisions. It is tied to confidence and overrides rationality. It can account for people being willing to pay more for goods, services and assets, depending on the economic setting. Corruption and bad faith assert a bad influence on the economy so Akerlof and Shiller (2009) argue. According to the authors, corruption and bad faith not only caused major recessions in the past, but also determined the severity of each crisis. Similar to confidence, corruption and bad faith is pro-cyclical. Money illusion does, contrary to what the EMH claims, prevail (Akerlof & Shiller, 2009). People generally do not account for inflation which becomes evident when looking at wage and loan contracts as well as savings, so Akerlof and Shiller (2009) argue.

The final animal spirit causing bubble episodes is 'stories'. Market fluctuations over time are tied to different mind sets of that time, shared beliefs and values (Shiller, 2014). Stories are, according to Shiller (2017) corner stones of these shared beliefs. They are also the basis for macroeconomic fluctuations (Akerlof & Shiller, 2009; Shiller, 2017). The collective memory of important occurrences such as the Great Depression of the 1930s is indexed around stories and the retelling of simple, entertaining narratives enforces the memory of those (historic) episodes (Akerlof & Shiller, 2009; Shiller, 2017). Stories that are not retold will be forgotten (Akerlof & Shiller, 2009; Shiller, 2017) which possibly explains the short memory regarding bubble episodes (Galbraith, 1993). Akerlof and Shiller (2009) explain that due to this short memory, stories of stock market booms are always stories of surprise. Hence, the build-up of a bubble occurs simply because the media and popular talk no longer enforce the (negative) memory of the previous bubble episode (Shiller, 2014).

Stories are likewise related to framing and the representative heuristic (Shiller, 2017), as people will also form expectations around an ideal story which acts as a moral as well as a quantitative anchor (Shiller, 2005) for future expectations. Moral anchors justify decisions made by constructing simple reason for buy and sell decisions, especially during bubble episodes (prices have gone up and will continue to do so justifying the decision to buy stock or house prices have never fallen justifying the investment in housing during a housing bubble) (Shiller, 2005). Quantitative anchors are anchors around the nearest milestone (for example a memorable year such as 2000 or a new market high such as 26.000 points for the Dow Jones Industrial Average (DJIA)[22]). According to Shiller (2005) such anchors can be used to explain the IT bubble of the late 1990s in the US as well as other bubble episodes. Stracca (2004) states that investors in financial markets anchor their expectations around current prices, perceiving them as normal (equilibrium) prices even if these prices might in fact be overvalued (during a bubble) or undervalued (during a recession). Investors will, so the author argues, deem the information most noticeable to them as most important to form their expectations and valuations of prices. Hence, investors' beliefs about current and future prices also depend on the information used (framing) in estimating those prices (Stracca, 2004).

[22] The Dow Jones Industrial Average hit the 26.000 points mark on 16.01.2018 (Popina, 2018).

The nature of stories is also that certain feelings (good and bad) will be attached to different narratives (affect heuristic) (Shiller, 2017), influencing confidence (Akerlof & Shiller, 2009) and therefore expectations (Stracca, 2004). Inspirational stories about a stock market boom will lead to an increase in confidence (Akerlof & Shiller, 2009). Especially new era stories during boom episodes (Akerlof & Shiller, 2009) seem to positively influence confidence leading to bubble episodes (Galbraith, 1993; Shiller, 2005). During a bubble, the contagion rate of popular stories having to do with the boom, increases due to rapidly increasing market prices (Shiller, 2017). Hence, negative stories about World War I, resource exhaustion, influenza and stories about fear of communism via the affect heuristic all contributed to the end of the 1920s bubble and to the Great Depression (Shiller, 2017). Similarly, negative stories about bank runs and job insecurities just before the recession were partially responsible for the 2007/2008 recession, so Shiller (2017) argues.

It should be noted that, while heuristics and biases are extensively researched to be included into more realistic NKM models that could consider economic bubble episodes, the underlying NKM theory or the EMH for that matter are generally not questioned in a way that would see the replacement of both paradigms. The economic system remains an equilibrium system (Akerlof & Shiller, 2009) where money does not matter (Galí, 2018) and (financial) markets are nearly efficient since arbitrage opportunities are rare (Stracca, 2004; Shiller, 2014). Bubble episodes can be caused externally via stories (Shiller, 2017) as well as internally, via non-economic, psychological factors (heuristics) (Shiller, 2005; Akerlof & Shiller, 2009). And in tune with NKM, heuristics can exaggerate external shocks leading to market failure (economic bubbles). In the following section, the capability of NKM to consider economic bubble episodes will be looked at in more detail.

2.4.3. The consideration of economic bubbles

As indicated above, NKM is an extension of the neoclassical paradigm (Mankiw, 1991) as it holds on to the self-equilibrating and, to some extent, the efficiency assumption of markets (Mankiw, 1991, 2018; Greenwald & Stiglitz, 1993; Romer, 1993; Snowdon et al., 1994; Gordon, 1997; Visco, 2005; Akerlof & Shiller, 2009; Leijonhufvud, 2009a, 2009b; De Vroey & Duarte, 2013; Shiller, 2014; Blanchard, 2016a), the assumption, that the analysis of the microstructure will shed light on macroeconomic fluctuations (Mankiw, 1991; Greenwald & Stiglitz, 1993; Romer, 1993; Snowdon et al., 1994; Gordon, 1997; De Vroey & Duarte, 2013; Blanchard, 2016a), and the initial acceptance of the rational expectations' paradigm (Snowdon et al., 1994; Gordon, 1997; Visco, 2005; Shiller, 2009; De Vroey & Duarte, 2013; Young, 2018). Mostly, economic bubbles are not considered within this approach (Shiller, 2009) which is possibly due to above mentioned underlying assumptions. Similar to all the previously discussed approaches, NKM too does consider the real and financial side of the economy separately (if at all), while money, debt creation and financial structures are ignored (Galí, 2018).

2.4.3.1. Equilibrium and exogenous shocks

As discussed throughout previous sections, the equilibrium belief is due to the underlying stability assumption of the overall economy, not adequate when attempting to analyse economic bubble episodes. In this stable environment, only exogenous shocks can cause a deviation from the ‘natural rate’ (equilibrium). Endogenously emerging bubble episodes (within the rational expectation NKM) are an impossibility. And even if the economic system is shocked out of its initial equilibrium, it is argued that the system would, without continuous external shocks, adjust its values towards their natural rates (equilibrium values). Similar to the NCS, frictions and rigidities, in the otherwise efficient markets, only delay that adjustment process. An exception here is behavioural economics that, though holding on to the equilibrium theory, allows for the endogenous emergence of bubble episodes due to heuristics. Needed structures as well as economic and financial developments supporting and creating bubble episodes are, however, not considered.

While the discussion on the inadequacy of the equilibrium assumption is very similar to the discussions in the previous approaches, behavioural economics and behavioural finance may (unknowingly and unwillingly) give insights as to why the equilibrium assumption for socio-economic systems is so persistent (besides the fact that model calculations are much simpler within equilibrium systems) (see for example Stracca, 2004). This thesis argues the equilibrium assumption could simply represent a heuristic that humans fall prey to. The tendency of people to have a need to rebalance observed trends (gambler’s fallacy) (Tversky & Kahneman, 1974; Rabin, 2002; Croson & Sundali, 2005; Johnson & Tellis, 2005) hints towards an internal preference for an equilibrium, where things are balanced and stable, even if such a system state may never exist (at least not for socio-economic systems). Additionally, the need for people to anchor around a (stable) reference point and assess (market) values at specific points in time instead of the evolution of those values over time (Stracca, 2004) further hints at biases causing an equilibrium belief (Tversky & Kahneman, 1974; Kahneman & Tversky, 1979; Stracca, 2004; Young, 2018). Hence, it can be argued that the equilibrium assumption regarding economic systems is nothing other than a heuristic which, like any other heuristic leads to systematic errors when attempting to theoretically understand and explain, and mathematically recreate economic behaviour.

2.4.3.2. Animal Spirits and sticky prices

While it should be noted that Keynes’ definition of Animal Spirits differs substantially from that of Akerlof and Shiller (2009), it is also questionable in how far the inclusion of psychological factors into a neoclassical theory really helps in understanding bubbles. Though it has to be welcomed that it is acknowledged that individuals do not form expectations according to Muth's (1961) definition (discussed in section 2.3. of this chapter), the question, which heuristics are at work in each time step for each individual remains (to date) unsolvable. However, and in order to build a credible and consistent theory based on psychological factors with which predictions about the state of the economy could possibly be made, these issues need to be addressed and solved. Considering that multiple heuristics are present at all times, and not just during bubble episodes, this appears to be an impossible task. Since, with the underlying economic models and theories, bubble episodes cannot be detected, researchers would only be able to investigate possible heuristics after the bubble has burst. But then of course, those heuristics cannot be uncovered any longer.

Additionally, psychological factors are considered on an individual basis. It is believed that single decisions of individuals on the micro scale can simply be summed up to account for macroeconomic behaviour. Research regarding heuristics stemming from social or group pressure changing individual behaviour (Handgraaf et al., 2013), and with that, macroeconomic behaviour is ignored. The complex system's insight that macroeconomic behaviour, though it depends on the micro-structure of the system, evolves over time and is different from that on the micro scale, is also ignored. Similarly, it is unclear how psychological factors can be credibly added into underlying (neoclassical) models. It surely is not enough to appoint error terms or free parameters to specific trading strategies or utility functions in order to mimic little understood psychological factors. With an appropriate macroeconomic theory and model, it will be enough to know that people are not rational. The specific heuristics and biases do not matter in that context and would not have to be identified since system states, specifically with regards to changing system stability, could be identified via, for example a balance sheet approach tracking stocks and flows over time.

Further, the assumption that price (and wage) stickiness might be responsible for economic fluctuations is questionable. In fact, the opposite might be true. Keynes himself elaborated on the likelihood that rapidly changing prices have the potential to wreck the financial system during a downturn (Greenwald & Stiglitz, 1993; Snowdon et al., 1994; Leijonhufvud, 2009b). As Leijonhufvud (2009b) points out, recent bubble episodes can always be linked to rapidly changing financial market prices affecting the real side of the economy. Indeed, the notion of rapidly changing (financial market) prices is generally used when defining economic bubble episodes (see chapter I). Hence, the NKM belief and policy proposition that flexible prices would avert any bubble episodes not only points towards the strong neoclassical roots of that school of thought, it also cannot be supported when looking at markets in reality.

2.4.3.3. Ignoring bubble episodes

As Shiller (2009) notes, bubbles are generally ignored within NKM. Hence, the emergence of bubble behaviour and the evolution of bubbles is of no interest. The main focus lies on recessions, why a downturn has occurred and how the economy adjusts. Though it is believed that shocks can cause the economic system to deviate from its equilibrium level, the source of the shock is of no interest (Snowdon et al., 1994). Similarly, behavioural economics, while interested in the underlying psychological factors causing economic fluctuations, can equally not account for the evolution of an economic bubble.

The incapability to account for the emergence of economic bubbles is also due to the fact that the real and financial side of the economy are not considered to be equally important and are looked at in isolation, whereas active financial markets, endogenous money creation and debt are ignored. However, without considering the interdependencies of the financial and real side simultaneously, and neglecting (endogenous) money and debt creation, the overall evolution of the economic system cannot be portrayed or understood.

Therefore, endogenously occurring, different levels of system stability, which can give insights on whether the system is entering a bubble phase (increasing instabilities), cannot be detected. Hence, it becomes impossible to confirm or even recognize bubble episodes. It is simply not enough to focus on adjustments within an oversimplified economic setting. In doing so, bubble episodes will remain unpredictable outlier events. The failure of such approaches was demonstrated by the incapability to predict or even understand the Subprime crisis and the following Great Recession (for example Leijonhufvud, 2009a; Shiller, 2009; Varoufakis, 2013).

2.4.4. Conclusion

In line with all the previously discussed approaches NKM cannot be used to understand the behaviour of capitalist economies, and with that, economic bubbles. The impracticality of this approach can be traced back to the strong neoclassical base as well as unrealistic and oversimplified theoretical (and model) assumptions. Exogenous bubble theories fail in recognizing the complexity of the economy and with that, the possibility of endogenously emerging bubble episodes. In the following section, an alternative take on capitalist economies and economic bubbles will be presented.

3. Endogenously created bubble episodes within heterodox approaches

From the discussion throughout section 2 of this chapter, it has become clear that theories stemming from a neoclassical understanding of economies are incapable of accounting for economic bubble episodes within real capitalist economies. The reason for this is twofold. Firstly, economies are portrayed to be barter economies where trade occurs without money. Secondly, the overbearing stable equilibrium assumption of the overall economic system, the belief in the efficiency of markets, the neutrality of money where endogenous money creation is ignored, and tied to this, the dichotomy of the financial and real sphere all make it impossible to account for bubbles in real markets. Hence, in order to understand fluctuations and bubble episodes that are part of an evolutionary, complex system moving through time, a radically different theory, where money plays a role, where people are not rational and where economic bubble episodes emerge organically from within, has to be considered. Keynes and Post-Keynesians, who follow Keynes' theory most closely, offer such an alternative[23].

Post-Keynesians maintain that, when attempting to understand economic fluctuations, the analysis of a general equilibrium, barter economy is not sufficient (Snowdon et al., 1994). Money as well as the possibility of market shattering crises on a macroeconomic scale must be considered. Therefore, especially with regards to bubble episodes, and in contrast to all previously discussed neoclassical approaches, Post-Keynesians are capable of understanding such episodes and recognize the underlying causes for the following crises (Keen, 2015). As stated in Keen (2015), Post-Keynesian theories, especially Minsky's FIH and Godley's stock flow consistent method, not only hold up empirically, but both, the FIH and the Godley's stock flow consistent approach, were also capable of anticipating the 2007 crisis (Keen, 2015). This is because Post-Keynesians take an inclusive approach to business cycles within the overall socio-economic system. Inclusive here means that bubble episodes, though outliers in magnitude (size), are by no means outliers in the frequency of occurrence. However, it should be noted that the term 'bubble' itself is mostly neglected. Post-Keynesians fall back on the notion of 'crisis' to explain possible preceding bubble episodes within the economy. Then, the severity of the crisis is key to uncovering whether a bubble existed prior to the crisis (exceptions here are Minsky but more clearly Keen who follows Minsky's approach). And though it is recognized that there exist basic commonalities defining business cycles, it is also understood that economies differ by region and that the economy is evolving over time. Hence, time and space specific factors also determine observable business cycles and with that, bubble episodes (Keynes, 1930, 1936).

In the ensuing sections, first an interpretation of Keynes' contributions in understanding economic bubbles will be presented (section 3.1.), which is followed by an analysis of Minsky's FIH (section 3.2.). The analysis of the FIH includes references to Keynes' liquidity preference, Fisher's debt deflation cycle as well as Schumpeter's interpretation of credit-financed investment. The focus on Minsky is due to the sole and outstanding theoretical contribution the FIH has made when attempting to interpret bubble episodes in combining the real and financial sector of the economy. The section on Minsky will then be followed by an analysis of current Post-Keynesian understanding of economic bubbles (in section 3.3). This section (3) concludes the literature review and hence will be followed by the chapter conclusion (section 4) with an appraisal of the presented material throughout chapter II with regards to economic bubbles.

[23] It should be mentioned that Marxism, specifically with regards to the evolution of a complex socio-economic system over time is also worth looking at. However, unfortunately due to space constraints, this was not possible for this thesis and remains a reference point for future research.

3.1. John Maynard Keynes

Keynes describes capitalist economies as disequilibrium systems (Fontana, 2003; Minsky, 2008a) within which business cycles emerge endogenously from structural characteristics of such economies (De Antoni, 2010). Hence, it is endogenous factors that cause instability (Keynes, 1936; Minsky, 2008a) and multiple (transitory) system states (boom, crisis, deflation, stagnation, expansion) (Fontana, 2003; Minsky, 2008a). To be able to explain such different system states and the accompanying economic fluctuations, money cannot be neutral and exogenous, but has to play an active role (Snowdon et al., 1994; Fontana, 2003; Detzer & Herr, 2014). The main cause for economic fluctuations, that is fluctuations in output, employment and income, as well as different system states, can be traced back to cyclical variations in investment (Fontana, 2003; Minsky, 2008a; De Antoni, 2010). This instability in investment is explained through unstable portfolios and financial relations (Minsky, 2008a), but especially through changing profit expectations and changing confidence levels (Keynes, 1936; Fontana, 2003; De Antoni, 2010) of investors, both in real and financial capital (Keynes, 1930, 1936; Detzer & Herr, 2014).

A central role in explaining the changing confidence levels of the monetary production economy that Keynes is describing (Snowdon et al., 1994; Detzer & Herr, 2014) is assigned to uncertainty (Keynes, 1936; Snowdon et al., 1994; Minsky, 2008a; Detzer & Herr, 2014). Under the assumption of uncertainty, future events cannot be known (Snowdon et al., 1994; Minsky, 2008a; Detzer & Herr, 2014) and hence, risk is neither measurable nor insurable (Keynes, 1921 and Knight, 1921 as cited in Snowdon et al., 1994: 376; Chang, 2014) which means that probability models or probability functions to overcome uncertainty are of no use (Snowdon et al., 1994; Detzer & Herr, 2014). According to Minsky (2008a, 2008b), uncertainty prevails when expectations about the future are formed and portfolio decisions are to be made. Keynes (1936) maintains that, besides calculations and psychological expectations (Animal Spirits) needed for any investment (Chang, 2014), confidence levels are a major factor when investment decisions are made. Therefore, Snowdon et al. (1994) argue that the existence of uncertainty and the accompanying changing levels of confidence explain the high volatility in investment with Minsky (2008a, 2008b) adding that sudden shifts in investment are caused by factors that are influenced by future expectations. Confidence is tied to uncertainty in such a way that confidence levels will be high the more certain the (near) future appears to be with expectations being positive, while confidence levels will be low if the future appears more uncertain and expectations are pessimistic (Chang, 2014).

In order to manage decisions in an uncertain world, investors adopt conventions (Keynes, 1936; Snowdon et al., 1994), which represent certain techniques and specific behaviour of economic agents (Detzer & Herr, 2014). Keynes (1936) defines conventions as an agreed upon rule where the assumption that the past is a usable guide for future events (Snowdon et al., 1994), where the current state of affairs is projected indefinitely into the future (Keynes, 1936; Snowdon et al., 1994) and where the judgement of the rest of the world is more reliable than one's own judgement, lie at the core (Detzer & Herr, 2014)[24]. As long as conventions hold, stability (in confidence) and continuity (in investment) can be attained (Keynes, 1936). The only risk an investor faces are changes in the existing knowledge. Changing circumstances influencing the economy will change the convention and can cause a re-evaluation of investment[25]. Since the conventional valuation of future profits is established via mass psychology (Keynes, 1936), sudden and large economic fluctuations and waves of optimism and pessimism are simply the outcome of abrupt changes in investors' opinions about future events (Keynes, 1936). These waves of optimism and pessimism destabilize the economy as they affect both production and financial markets (Keynes, 1930; De Antoni, 2010).

A loss of faith in a convention is the base for speculation and therefore, induces instability (Keynes, 1936). Both, a (speculative) boom or crisis can result from this change with both scenarios stemming from the real (and not financial) side of the economy via productive investment and increases (or decreases) in output (effective demand failure[26]) (Keynes, 1930; De Antoni, 2010). It should be noted that Keynes mostly focusses on the economic downturn rather than the speculative boom phase (possibly due to the historic backdrop of the Great Depression of the 1930s). Hence, only the crisis scenario will be considered here. The tipping point in a speculative boom and the onset of a (severe) crisis, so De Antoni (2010) argues, is reached as soon as overoptimistic forecasts of profits are not realised. Likewise, Leijonhufvud (2009b) notes that the downturn is initiated once future expectations decline due to current capital accumulation. Firms cut back on their investment which has negative effects on employment and output leading to an even further decline in expectations and investment. As mentioned before, the crisis that stops the boom can be found in the real sphere (De Antoni, 2010) and entails a collapse in the marginal efficiency[27] of capital (Keynes, 1930; De Antoni, 2010), where the total cost of production far exceeds the incomes of the public (Keynes, 1930). However, Keynes (1930) and Leijonhufvud (2009b)[28] indicate that depleting confidence levels not only affect firms but also banks, worsening the subsequent crisis. Keynes (1930) argues that the lack of capital goods, output and new enterprises during a crisis can be traced back to pessimistic lenders and

[24] These conventions are now known as heuristics which are discussed in section 2.4.2. of this chapter. As was pointed out in that section, there exists an innumerable amount of heuristics. However, Detzer & Herr (2014) maintain, only those three mentioned here are analysed by Keynes.

[25] Keynes (1936) refers to a "…genuine change in the news *over the near future*,…" which can be broadly understood as a future change in circumstances influencing the market, not specific news which appears to be the general neoclassical as well as Shiller's (2005) understanding.

[26] Effective demand consists of investment and consumption. While both will be affected and themselves affect output and hence the business cycle, the driving force of a business cycle for Keynes is investment.

[27] Marginal efficiency in Keynes' interpretation can be defined as the present value of capital assets, calculated via expected future income streams generated by the made investment.

[28] Leijonhufvud (2009b) makes clear reference to Keynes' *Treatise on Money*.

borrowers. The missing confidence on both sides, the fact that borrowers are increasingly unable to repay their loans due to falling profits and the fact that lenders with low confidence levels attach more stringent conditions to new loans so that firms cannot afford loans for new investment anymore, all worsen the crisis (Keynes, 1930). This process of deleveraging is understood to be a part of any business downturn. It is important to point out that the decline of expectations, investment and eventually output causes deleveraging (and not the other way around) (Leijonhufvud, 2009b). The reason for the behaviour of banks and firms, so Keynes (1930) maintains, is solely of psychological nature. A restoration of confidence (via government and central bank interventions) is needed to end any economic crisis. Later, Minsky (2008b) improved this analysis via the balance sheet approach which makes the explanation for the unwillingness to borrow and lend quantifiable. However, Keynes did not make that connection as distinctly. Leijonhufvud (2009b) believes that this missing systematic analysis of balance sheets is the greatest shortcoming in Keynes' analysis. Minsky's approach including the balance sheet approach will be discussed in more detail in section 3.2. of this chapter.

As Snowdon et al. (1994) argue, Keynes clearly linked the real and the financial side of the economy. Fontana (2003: 237) points out that in *Treatise on Money* (1930), Keynes distinctly characterized a credit cycle. Similarly, Leijonhufvud (2009b) notes that in *Treatise on Money*, Keynes specifically deals with the financial side of an economic downturn. Keynes recognized that productive investments have to be financed externally (via loans and company shares) (Snowdon et al., 1994; Chang, 2014). However, the then necessary separation into producing and financial markets increases economic instability (Keynes, 1936; Chang, 2014; Detzer & Herr, 2014). The argument goes as follows: financial markets do not only provide money for real investment, they also provide money for speculation (Chang, 2014). Speculators in financial markets generally know less about future prospects of companies and markets than entrepreneurs in such markets (Detzer & Herr, 2014). Hence, to each (financial) investment, optimistic expectations about future returns (profits) (Keynes, 1936) as well as expectations of what other investors expect of the future are attached (Chang, 2014). This, so Chang (2014) argues, leads to herd behaviour which makes financial markets inherently prone to speculative boom and busts. Keynes (1936) clearly recognized the dangers of speculation when stating that "…the position is serious when enterprise becomes the bubble on a whirlpool of speculation. When capital development of a country becomes a by-product of the activities of a casino, the job is likely to be ill - done."(Keynes, 1936, 12: VI). It must be pointed out that this inclusive consideration of the financial and real side of the economy differs substantially from all previously discussed approaches. As Detzer and Herr (2014) point out, the classical dichotomy between the real and monetary sphere dissolves under Keynes' interpretation of business cycles making endogenous fluctuations and bubble episodes possible.

Moreover, money is important for Keynes when attempting to explain business cycles. Money is, in contrast to all previously discussed approaches in section 2 of this chapter, endogenous. And since money affects trade and production over time, it cannot be neutral (Snowdon et al., 1994). Money plays a key role in dealing with general uncertainty as it provides liquidity to firms and investors in order to be able to respond to changes in conventions quickly (Snowdon et al., 1994; Chang, 2014). As Minsky (2008a)points out, money for Keynes has attributes of an insurance policy. Money is not only held to meet financial payments and payments that reflect the production process (Minsky, 2008a), but money is also held for protection against (unexpected) payments that may have to be made[29]. Generally, so Snowdon et al. (1994) argue, in an increasingly uncertain environment with falling levels of confidence, the amount of money that is held increases (the liquidity preference rises). Minsky (2008a) points out that the opposite is true for increasing confidence levels (the liquidity preference falls). However, though Keynes recognizes the role of money in producing economies, the exact liability structure within the economy is not spelled out in detail (Minsky, 2008a). This leads Keynes to conclude that, though speculation in financial markets can take place and possibly influence the economy, speculative boom, but especially the following crisis episodes are dominated by the real side of the economy.

It was Human Minsky who added a more distinct analysis of the financial sector and the linkages to the real sector to Keynes' theory. In considering the liability structure and the evolution of endogenously created purchasing power (via loans) to firms, it becomes possible to recognize varying system states of the economy, including bubble episodes. The following section will elaborate on this.

3.2. Hyman Minsky

Hyman Minsky combined the works of Keynes, Schumpeter and Fisher to develop his theory of a finance driven business cycle (Minsky, 1992, 2008b; Keen, 2013) where economic booms, bubbles, crises and recessions are innate to the (system) behaviour of the economy (Minsky, 1970, 1982, 1992, 2008b; De Antoni, 2010). Capitalist economies, according to Minsky, not only have a tendency towards cycles (De Antoni, 2010; Keen, 2017), but they are, due to the link to financial markets, also inherently unstable (Minsky, 1970, 1982, 2008a, 2008b, Keen, 1995, 2011, 2013). This fundamental instability of capitalist economies is upward (De Antoni, 2010; Keen, 2017), which simply means that such economies have a tendency towards boom phases (Minsky, 1970). Periods of extended economic growth, signalling economic stability and future growth will inevitably, due to overoptimistic future expectations of banks, firms and households, lead to emerging instabilities ending in an economic downturn and possible economic crisis, even with big governments and active central banks (Minsky, 1970, 1982,

[29] The preference to hold money or near money financial products is also called liquidity preference.

1992, 2008b). For Minsky, the changing level and quality of private debt[30] over the course of a cycle plays a central role in this development (Keen, 2017).

In tune with Keynes, the main driver for growth and business cycles remains productive investment. Leaning on Schumpeter, Minsky (1982, 2008b) maintains that, since most investment must be financed via debt (in the form of bank loans and financial market debt), the level of investment is not only determined by the level of expected future profits, but also by the availability of loans and hence, the lending and borrowing conditions of an economy. Financing investment via loans also means that firms take on payment commitments that will have to be met via future cashflows through the then realized profits (Minsky, 2008b). The relationship between cash payments and commitments on debt as well as the current cash receipts through profits determine the course of investment (Minsky, 1982) and hence influence confidence and future expectations (of profit).

Minsky's analysis of the economy starts when the economy is stable and growing (Keen, 1995, 2011, 2013). Firms and banks are conservative in their investment and lending behaviour. Firms will only invest in safe projects, while banks only give out loans to finance low risk investments and to bridge temporary cash flow shortages. The reason for this prudent behaviour on both sides of the lending relationship is explained through the memory of a recent economic crisis, where both, banks and firms incurred losses (Keen, 1995, 2011, 2013). During this initial boom period, downtimes in production for firms due to possibly emerging recessions are considered when, in order to decide on investment, present value calculations of future profits take place (Minsky, 1970). The combination of a growing economy and moderate finance and investment strategies lets most projects succeed. Most debt can be met since firms' and financial institutions' balance sheets are sufficiently liquid to meet debt repayments, even if cash receipts were to fall short (Minsky, 1970). And even if not enough cash was at hand to meet debt during stable times, Minsky (2008b) argues that firms are able to easily obtain funds in order to meet temporary shortages in payment receipts. However, the continued economic success leads to changing risk perceptions and future expectations of banks and firms, who, according to Minsky, in an uncertain world, extrapolate current trends within the economy into the future[31] (Minsky, 2008b; Keen, 2017). Refinancing of debt as proportion of total debt increases during the boom episode. This not only leads to increasing asset prices and investment, but also to a worsening of the firm's and banks' balance sheets. The boom period turns into a speculative boom which will lead to the emergence of instabilities. Speculative finance, so Minsky (2008b) argues is characteristic of (increasingly) unstable systems. As initial investments lead to rising output and decreasing unemployment levels, firms and financial institutions come to believe

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[30] Only firms are considered when debt is created. Private debt of households is not mentioned.

[31] Mathematically this behaviour is expressed through the (geometric) Brownian motion where future prices not only depend on the current price level but also on the development of prices in the (recent) past.

that speculative finance is a safe and successful investment strategy (Minsky, 2008b).

The growth in speculative investment and the rapidly increasing asset market prices can also be traced back to the increasing purchasing power of firms. This increased purchasing power means nothing less than that more money is available for investment first and later speculation, adding to the speculative boom and the already increasing asset prices (Minsky, 2008b). This money however is not created (or controlled) by financial authorities (central banks) as assumed by neoclassical approaches such as Monetarism. Rather, this newly created money stems from the loans that are generated by (commercial) banks and given to firms. Hence, money is created endogenously via the loan process, independent of the base money (Keen, 2011, 2013, 2017). According to Post-Keynesians, banks generally extend credit and attempt to raise the needed reserves at a later date (for example Leijonhufvud, 2009a).

The emerging view that uninterrupted, continuous growth and rising asset prices can be expected while recessions are considered an impossibility, marks the beginning of an euphoric boom phase (Minsky, 1970). During the euphoric phase, lenders and borrowers believe that most investments will succeed, asset prices and securities (for loans) are revalued upwards while the quality of investments and loans decline over the course of the boom (Keen, 1995, 2011, 2013). The present value of profits considering possible future recessions is replaced by present value calculations of continuous growth which increases the overall value of expected profits[32]. Similarly, the present value of real capital increases as there is no more expected downtime for plant or machinery (Minsky, 1970). Since, during a euphoric episode, recessions seem unlikely, protection against such an event appears unnecessary (Minsky, 1970). The willingness to buy (less liquid) assets increases which leads to a liquidity decreasing restructuring of firms' and financial institutions' portfolios (Minsky, 1970). While the established debt to equity ratios rise (pointing towards continuous credit growth) (Keen, 1995, 2013; De Antoni, 2010), the portfolio and liability structure of both, banks and firms, changes towards more risk seeking portfolios (Minsky, 1970, 2008b). During the euphoric boom phase, so Minsky (1970) argues, balance sheet commitments increase faster than income receipts which means that total commitments rise relative to income. The position of banks during a bubble episode evolves from an asset management position to a position of liability management (Minsky, 2008b) again, signalling increasing financial instability.

All of the above – the re-evaluation of future profits and fixed capital, the liquidity decreasing restructuring of portfolios, the increasing indebtedness of economic units as well as the expanding risk seeking behaviour of banks and firms – all increase the instability of the (financial) system over time which jeopardizes the

[32] This can be easily seen once one considers that discounted cashflows are used to calculate the present value.

euphoric boom. With financial layering (in the form of leverage) rising over the boom period, financial payments and income receipts move closer together. And since the liquidity in portfolio positions has also decreased dramatically, small interruptions of financial flows or marginal changes in financial market rates can quickly lead to financial trouble for all economic units (Minsky, 1982). Thus, and in contrast to Keynes' explanation of a downturn, a crisis in the Minskian framework originates from the financial side of the economy (De Antoni, 2010).

Eventually rising market based[33] interest rates and the increasing debt to equity ratios affect business operations in such a way, that new investment cannot be financed anymore which in turn threatens the boom and triggers an economic downturn[34] (Minsky, 2008b; De Antoni, 2010). Conservatively financed projects become speculative projects. Speculative projects turn into Ponzi projects while Ponzi projects start to fail: "A firm is in the Ponzi group if its anticipated operating income is not likely to be sufficiently large to pay all of the interest on its indebtedness on the scheduled due dates; to get cash the firm must either increase its indebtedness or sell some assets." (Kindleberger & Aliber, 2005: 28). Since the balance sheets of nearly all economic units, including financial institutions, are inferior and unfit to deal with an economic downturn, refinancing becomes very difficult. And as the supply of loans decreases, the money supply decreases (Minsky, 2008b), while at the same time the liquidity preference of economic units increases (Minsky, 1970). With more and more firms attempting to sell (illiquid) assets to meet their debt, the increase in the number of sellers relative to buyers in (financial) markets puts a stop to the asset price growth which, in this highly fragile system, induces a debt deflation, leading to a financial and economic downturn. And as first debtors fail to meet their debt payments, banks increase their interest rates to balance their losses. This however raises the pressure on more firms who have taken on debt during the euphoric phase. Increasing numbers of sell orders with stagnating and falling buy orders in financial markets lead to a (rapid) downward trend of asset prices inducing a recession or depression, with the severity of the downturn depending on the level of debt (Keen, 2017). Changing views regarding confidence and future expectations and the need to meet current debt lead to a changing portfolio structure, first towards more liquid assets and later towards assets that are believed to be safe (such as government bonds)

[33] Market based interest rates are interest rates offered by commercial banks to their customers for deposits and loans. Those interest rates are based on demand and supply as well as the amount deposited, the quality of securities offered (for loans) and the duration of the agreement (deposit and loans). Actions of big government or active central banks are not considered in this explanation.

[34] Arguably, a contractionary monetary policy leading to increasing central bank interest rate to dampen a boom by an active central bank would have the same effect. However, according to Minsky (2008a), Keynes believed that a downturn would be caused by increasing market interest rates rather than by active central banks. From this thesis' point of view both appears to be true.

(Minsky, 1970). The restructuring of portfolios in such a way is one of the factors inducing a crisis which may lead to a severe recession (Minsky, 1970).

Minsky (1970) points out that the occurrence of such a financial crisis is not accidental but occurs due to the attributes of the overall system. Increasing instabilities within financial markets over the course of a boom and hence the underlying liability structure, so Minsky (2008b) argues, is an important indicator for the evolution of the system and can give clues as to which direction it is heading (boom or crisis). The likelihood of financial crises depends on the extent of how close income receipts to and cashflows from an economic unit are timed. The shorter the time-lag between those two, the more fragile the system is. Instability also depends on the weight of safe assets within in a portfolio. Safe assets are those assets that can always be sold. The smaller the weight of such assets is, the greater is the instability. And finally, the extent to which continued growth and increasing asset prices have affected the current valuation of financial worth and prices is indicative of system stability. The greater the influence is on current valuations, the greater is the instability (Minsky, 1970). However, assuming that trend-extrapolation appears to be a convention (or heuristic) that is generally followed, it may be hard to identify any over-valuations of expected future cashflows in that way.

3.2.1. The consideration of economic bubbles

As mentioned in chapter I of this thesis, the term bubble is almost never used in the writings of Minsky (Dymski & Shabani, 2017). Again, this may be due to the different understanding of capitalist economies and the emerging bubble processes, where fundamentals do not enter the explanation (Dymski & Shabani, 2017). Euphoric boom phases are used to describe increasing economic instability which, as set out in chapter I section 1, hints towards bubble episodes.

Nevertheless, Minsky's extension of Keynes' analysis of the macroeconomy and the more thorough inclusion and modernization of the financial side of the economy (Minsky, 1992) is a most promising approach. Minsky improved Keynes' analysis by including an explicit theoretical explanation of how changing portfolio and liquidity preferences and with that, changing debt levels, present value calculations and cashflows within a complex financial system can lead to changing levels of stability for the overall economy.

Theoretically, Minsky sees the economy very much as a complex system, similar to explanations offered by Econophysics[35] where developments on the micro-level influence and change the properties of the system on a macro-level, which in turn has effects on the micro-level properties. Minsky succeeds in linking the micro- and macrosphere by employing the balance sheet approach. He convincingly demonstrates how portfolio adjustments, changing liquidity preferences and debt relations on the micro-level lead to changing degrees of system stability on the

[35] Discussed in chapter IV of this thesis.

macro-level over time. The link between the financial and real side of the economy is made via the need to finance first productive, and later, with increasing money supply and decreasing uncertainty, speculative financial investment. The debt that is taken on for such investments and the resulting financial commitments of firms to financial institutions ties those two spheres (real and financial) together. In this way, Minsky is capable of showing how changing system states of the economy emerge consistently through the workings of a complex financial – production economy over time. Hence, no external shocks are needed when attempting to explain economic bubbles as those are part of the various system states and emerge endogenously.

In earlier works, Minsky (Minsky, 1970) hints towards the feasibility of steady states and acknowledges the possibility of multiple equilibria within the economic system. Though Minsky (1970) assures us that there is no global equilibrium indicating that the system overall might not be stable, but only local equilibria, it remains inexplicable why such equilibria should, in a human-made system inhabited by non-rational people, exist. As set out in chapter I, there is no reason to believe that socio-economic systems would tend towards or away from multiple possible equilibrium states, even if those states are only locally stable (unstable). This thesis argues that the only reason Minsky (and for that matter Keynes) employs the equilibrium notion is a mathematical one. When looking at the economic system as an evolutionary system that evolves over time within an ever-changing environment (society), theoretical explanations in favour of possible equilibrium states are not needed. Mathematically however equilibrium models appeared to be the only alternative at the time the FIH emerged and hence influenced Minsky's attempts in quantifying his theory with the help of a mathematical model[36]. In later works (Minsky, 1992, 2008b) possible equilibria are of no interest in the (theoretical) explanations of the FIH and are hence not further mentioned.

Additionally, and for both, Keynes and Minsky, an economic boom starts with an increase in productive investment which will, in Minsky's explanation, eventually lead to speculative finance and end in a crisis. The fact that a boom in financial could trigger a boom in producing markets (as was the case for the Subprime crisis in 2007/2008) is not considered. However, this might be due to the fact that, for example financialisation (Krippner, 2005; Stockhammer, 2010) has only emerged after the FIH was established. Similarly, households are not considered when debt and speculative investment are mentioned. Again, this might possibly be due to the era of Minsky's writings where stricter financial regulation existed and where financialisation had not yet emerged. Nevertheless, overindebted households seem to have been a major contributing factor in the 2007/2008 financial crisis. Additionally, and as pointed out by Dymski (1999) the FIH is aspatial, representing

[36] Minsky attempted (but did not succeed) to formalise his theory employing linear models as well as multiplier-accelerator models, hence the equilibrium notion in such texts (reference to those models is made in Minsky, 1970). However, as will be discussed in chapters III-V, such models are unsatisfactory when attempting to model complex system behaviour and endogenously emerging fluctuations.

a closed economy. However, and to be able to account for specific bubble episodes, the time, the place and the historical circumstances (Dymski & Shabani, 2017) matter and must be included into the analysis. The FIH on its own can only offer a very general framework for a bubble analysis in capitalist economies. Hence, to be able to understand and explain peculiarities of recent bubble episodes, time and space considerations must enter the analysis (Dymski, 2010; Dymski & Shabani, 2017). Going forward, considerations of geographical political economy (Dymski & Shabani, 2017) such as cross border account balances (Dymski, 1999; Dymski & Shabani, 2017), financialistaion as well as region specific institutional setups (to name a few) must be considered and added to the general framework of the FIH if a coherent bubble framework is to be developed with which bubbles can be analysed and understood.

3.3. Post-Keynesian extensions

Building on Keynes and Minsky, the Post-Keynesian perspective especially after the Subprime crisis has been expanded in the area of financialisation[37]. Financialisation has led to a dramatic increase in system instability and has hence contributed to the increase in frequency an magnitude of financial and economic bubbles since the 1980s (for example Stockhammer, 2010).

Financialisation emerged after the deregulations and financial market liberalisations throughout the 1980s, especially in Anglo-Saxon countries. The newly emerging financial system changed the objectives of financial market institutions firstly, from making a profit through interest rate differentials (for deposits and loans) towards fee generating services and secondly, from giving out productive loans to firms towards consumption loans for households (Stockhammer, 2010). With financial market liberalisations and deregulations and with the changed objectives of financial institutions, the financial sector grew explosively when compared to the real sector of the economy (Wolfson, 1990; Stockhammer, 2010). The share of GDP for manufacturing as well as manufacturing profits both have rapidly declined since the 1990s (Krippner, 2005; Driver & Temple, 2013). During the same time, the share of GDP for the service and FIRE (finance, insurance, real estate) industries as well as the profit generated by these two sectors has increased dramatically (Krippner, 2005; Stockhammer, 2010). Stockhammer (2010) argues that one result of the finance sector growing faster than the real sector is the dramatic rise in stock market turnover, that has been an observable trend since the early 1990s.

Furthermore, financialisation has shifted the position and the objectives of producing firms so that the maximization of shareholder value (Stockhammer, 2010) and the increasing level of debt (Wolfson, 1990; Stockhammer, 2010) has limited real investment and led to short-term investment orientation of such firms. At the same time, non-financial firms increasingly depend on their portfolio

[37] It should be noted that Marxian perspectives have also dealt with this phenomenon. However, due to time and space constraints, those can unfortunately not be discussed here.

performance (Krippner, 2005) and hence increasingly rely on the performance of financial markets rather than profits from real output (Krippner, 2005; Stockhammer, 2010). Changes in business and investment objectives from real towards financial investment (Stockhammer, 2010; Driver & Temple, 2013) of non-financial firms in combination with changes made throughout welfare states (Doling & Ronald, 2010) and financial market deregulations have had a huge impact on the behaviour of households, specifically in highly financialised countries such as the UK and US.

With a rapidly decreasing manufacturing sector, employment in manufacturing has decreased accordingly (Krippner, 2005). Though the service and FIRE industries have replaced the GDP share of manufacturing within financialised countries, the number of jobs within the service and FIRE industries has not grown accordingly (Stockhammer, 2010). Hence, fewer people are employed in jobs with decent pay. Additionally, the strong focus of firms on shareholder value has put further pressure on the wages of the remaining manufacturing jobs (Stockhammer, 2010). In combination with a reduction in benefits of welfare states (such as free education and state pension) and easily available consumer credit, household debt has, similar to the debt of firms, grown dramatically (Stockhammer, 2010). Changes in the welfare state (Doling & Ronald, 2010) in combination with financialisation have encouraged that savings of the middle and working class are channelled into private institutions and funds. The exposure of households to financial markets in this way in combination with decreasing real wage, lower credit standards and increasing asset values has additionally contributed to a dramatic deterioration of households' savings rates (Stockhammer, 2010). The falling savings rate of households induces a further reliance of households on credit and financial market performance via perceived wealth effects (through financial market gains) and incurred debt. Hence, household consumption in highly financialised countries is not only driven by the performance of asset prices (Stockhammer, 2010), but also depends on the availability of consumer credit.

Moreover, financial liberalisations have increased the concentration in the financial sector (Stockhammer, 2010). This means that an increasing amount of funds from different parts of society are divided between fewer financial institutions. Additionally, and similar to firms and households, financialisation has also increased the debt levels of the rapidly expanding financial sector (Stockhammer, 2010). The focus within the liberalised and less regulated financial sector (shadow banking) (Stockhammer, 2010) lies on the creation of new financial instruments, aimed at increasing profitability and/or lowering risk. Especially before the 2007/2008 financial crisis, the focus of newly created instruments was on debt securitization via pooling multiple individual loans into composite bonds (Chang, 2014). While it was believed that this type of risk sharing would decrease the risk of system-wide bankruptcies (Crouch, 2009; Stockhammer, 2010; Chang, 2014) and hence increase system stability, the 2007/2008 crisis showed that the risk did not become less, it was simply shifted to someone else in the system.

3.4. Conclusion

This chapter has discussed both, the exogenous and endogenous bubble literature. Various strands of literature within these two approaches were considered. It is argued that the exogenous approach to bubbles consists of orthodox approaches to bubble episodes, where all the literature that has been looked at is deeply rooted in neoclassical assumptions of how capitalist economies work. The classical dichotomy, where financial markets and real markets are looked at separately holds for all the discussed neoclassical propositions, the belief of an attainable equilibrium persists, whereas money is considered to be exogenous and neutral. Within explanations of the Neoclassical Synthesis, the Real Business Cycle theory and the Efficient Market Hypothesis, economic bubbles are not considered at all whereas Monetarism and New Keynesian Macroeconomics provide unsatisfactory explanations for the bubble phenomenon. The biggest issue for all these approaches, however is, the heavy reliance on a stable, self-regulating equilibrium system, within which bubbles cannot emerge. The economic system is believed to be so efficient, that only outside shocks or disturbances could cause bubble behaviour.

The more promising approach is the endogenous approach to bubbles, especially Minsky's FIH (Minsky, 1970, 1982, 1992, 2008b). Through the recognition that money and debt are important and that various economic system stages (such as booms, bubbles, crises, depressions, recessions, and so on) evolve endogenously over time, a more realistic and convincing description of bubble episodes[38] is given. The extension of Minsky's analysis in the form of financialisation by Post-Keynesians brings Minsky's FIH up to date and makes it possible to analyse recent bubble episodes.

The analysis will now move on to mathematical models attempting to portray economic bubbles. In the following chapter III, exogenous bubble models will be analysed. In line with the exogenous bubble literature, exogenous bubble models are deeply rooted in neoclassical assumptions of capitalist economies. Hence, chapter III covers orthodox mathematical approaches to economic bubbles.

[38] Though bubble is not used to describe such an episode. Rather, Minsky (1970) refers to a euphoric boom or considers serious crises or depressions that follow such a boom phase (Minsky, 1982).

Chapter III: Mathematical Models of Exogenous Economic Bubbles

1. Introduction

In line with the distinctions made in chapter I and II, two different approaches to mathematical bubble models can be identified. Within the first type of models, economic bubbles are caused exogenously and are mostly outlier events (in amplitude and frequency). In the second type of model, economic bubbles are endogenous to the (economic) system. Bubbles here are not outlier events (in frequency) and emerge due to the internal workings of the (economic) system and not due to external factors. This chapter will focus on the first type of model (exogenous bubble model), specifically, dynamic general equilibrium models in the tradition of Cass and Shell (1983, 1989) (sunspot models) and Blanchard and Watson (1982) (rational bubble models) will be discussed. For both types of exogenous bubble models, economic bubbles can only be caused by outside (exogenous) disturbances and/or shocks (sunspot models), or through externally created imperfections (rational bubble models). In fact, to create any type of movements within these (static) models, they must rely on continuous external disturbance factors in the form of random variables or stochastic sequences. Otherwise empirically observable persistent swings in the economy would either not be possible at all or die out after the initial shock to the system wears off.

Sunspot and rational bubble models are both deeply rooted in the micro-based analysis of the neoclassical tradition. Here, the strong belief in the fundamental stability of markets with an emphasis on the equilibrium as well as the self-equilibrating tendencies of economies underlie the analysis and are used to explain bubble behaviour that can be observed in capitalist economies. Sunspot models hold on to the neoclassical understanding of macro-models in the Real Business Cycle tradition, where financial markets are ignored. These models try to explain bubble episodes that are solely based in the real side of the economy, rather than bubbles within financial markets. Rational bubble models, on the other hand, are solely concerned with financial markets, while analysing price changes for *one* asset at a time. In these models, it is recognized that the EMH assumption, where an asset price equals that asset's fundamental value, does not empirically hold within financial markets. However, the overall neoclassical paradigm stressing equilibrium, stability and market efficiency is not questioned. In fact, markets are believed to be efficient even during bubble episodes.

Market participants for both types of models are rational and utility maximizing representative agents. The portrayed economies in which bubbles emerge are barter economies, where money, if considered at all, is exogenously given and is nothing more than a veil. Economic bubbles are tied either to a specific market (sunspot models, rational bubble models) or asset (rational bubble models) and are analysed in isolation from other parts of the socio-economic and financial structure. However, ignoring the fact that there are indeed structural factors common to bubble episodes (such as extended growth periods and changing system stability for example) also means, that bubble episodes can only be explained if they are linked to a unique historic or geographical context (Minsky, 1986). In that sense, economic bubbles will remain unpredictable and random outlier events.

Though there are similar underlying concepts that can be attributed to sunspot and rational bubble models, each individual model depends on specifications made by the modeler. Hence, mathematical and at times theoretical generalisations are, unfortunately, not always obvious. For this purpose, a general section will first discuss theoretical underpinnings for sunspot (section 2.1.) and then rational bubble models (section 3.1). This will be followed by a presentation of the main mathematical building blocks which are similar across models of a specific type (sections 2.2. and 3.2. respectively). Often, the mathematics behind those models is more coherent than the theoretical explanations of bubble episodes. Therefore, it is also useful to incorporate basic equations into the analysis which are used to create these economic bubble models. Those model equations have been selected due to their general features representing a certain class of models as well as due to the importance of the accompanying model within that specific field.

The remainder of this chapter is organized as follows. Throughout section 2, sunspot models will be examined and discussed, followed by rational bubble models in section 3. Though both types of models will be considered separately, the subsequent evaluation of the appropriateness of these two types of models in relation to economic bubbles will be discussed for both approaches simultaneously throughout section 4. While there are slight differences within those two different model approaches, the general underlying critique regarding the appropriate treatment of economic bubble episodes within those models can be applied to both. Where relevant, specific reference to either model type will be given. This will be followed by concluding remarks in section 5.

2. Sunspot models

2.1. The theoretical account of sunspot models

While leaning on Jevons' theory of sunspots popularised in the 1880s (Shell, 2007), Cass and Shell (1983) introduced the concept of sunspot equilibrium models in the late 1970s and early 1980s (Shell, 2007). Sunspot models in the tradition of Cass and Shell (1983) are not only an attempt to explain economic fluctuations within the Real Business Cycle framework (Barinci & Chéron, 2001). But it is also a pursuit to justify the repeatedly referred to unpredictable and chaotic changes in financial market prices, the general price level, unemployment rates and market surpluses, which are all empirically observable, while the underlying economic fundamentals[39] are assumed to be stationary and non-fluctuating on a theoretical level (Cass & Shell, 1989; Prescott & Shell, 2002; Shell, 2007; Farmer, 2015). Within this approach, the alleged randomness and volatility of market allocations (Garratt & Keister, 2002) and prices (Azariadis, 1981; Azariadis &

[39] Depending on model specifications, but generally endowments, preferences and technology.

Guesnerie, 1986; Garratt & Keister, 2002) are traced back to external and random shocks (Barinci & Chéron, 2001; Shell, 2007). These external shocks are caused by *extrinsic uncertainty*[40] (Azariadis, 1981; Cass & Shell, 1983; Azariadis & Guesnerie, 1986; Shell, 2007; Farmer, 2015). According to Shell (2007), any volatility in outcomes caused by extrinsic uncertainty resembles excess volatility, which in turn is associated with bubble behaviour. Excess volatility within the sunspot literature means out of the ordinary changes in economic outcomes and is anchored in the model assumptions of general stability and equilibrium. In this Gaussian world, any (standard) deviation that is greater than what would normally be assumed can then be classified as excess volatility or bubble behaviour.

The vaguely defined concept of extrinsic uncertainty is assumed to have no effect on economic fundamentals (Balasko, 1983; Cass & Shell, 1989; Prescott & Shell, 2002; Shell, 2007; Farmer, 2015). Nevertheless, it is the (sole) cause for (supposedly) erratic shifts and movements in the economy (Cass & Shell, 1989; Shell, 2007). Extrinsic uncertainty is believed to be mostly of a psychological nature (Azariadis & Guesnerie, 1986) such as Animal Spirits (Azariadis, 1981; Cass & Shell, 1983), consumer sentiment and beliefs about the future (Azariadis, 1981; Barinci & Chéron, 2001), or market psychology in general (Cass & Shell, 1983; Kraus & Smith, 1998). These different psychological factors constituting extrinsic uncertainty not only affect agents' expectation formation (Prescott & Shell, 2002), but are also summed up under the concept of *sunspots*. Hence, sunspots influence forecasts and actions of economic agents (Azariadis & Guesnerie, 1986), cause waves of optimism and pessimism (Cass & Shell, 1983) and lead to speculation and excess price volatility, even under the assumption of rational economic actors (Cass & Shell, 1983; Kraus & Smith, 1998).

According to Azariadis (1981), any external and unrelated factor that economic agents think might be important for any economic outcome can not only set the business cycle in motion and have real effects on the economy (Cass & Shell, 1983) in the form of changes in consumption (Barinci & Chéron, 2001; Farmer, 2015), prices (Azariadis, 1981) and discount rates (Farmer, 2015), but can also cause economic bubbles (Azariadis, 1981; Garratt & Keister, 2002; Farmer, 2015). Subjective beliefs in the form of external uncertainty, so Azariadis (1981), are capable of inducing random price changes. Evidence of such subjective factors causing unpredictable shifts in the economy, so the author, are past economic bubbles such as the Tulipmania and the Great Depression (Azariadis & Guesnerie, 1986).

Thus within the models, sunspots are extrinsic random variables upon which economic agents base their decisions (Shell, 2007). Mathematically speaking, the sunspot variable is simply a stochastic term that is added to the underlying stable rational expectations equilibrium system. The introduction of this stochastic term

[40] It should be noted that within the mathematical part of sunspot models this distinction is not made. Hence extrinsic uncertainty becomes the sunspot then.

into the models was a necessity in order to create the above mentioned random economic outcomes and fluctuations within the traditional equilibrium models (Prescott & Shell, 2002), while fundamentals stay unchanged.

Though Barinci and Chéron (2001) assert that sunspot equilibria present a theoretical account of Keynes' Animal Spirits, it should be mentioned that within the sunspot literature, Animal Spirits are not specifically defined. They describe extraordinary (not rational) behaviour or simply represent all kinds of psychological factors leading to (economic) misjudgements and bubbles. However, since the overall rational expectation paradigm holds within the models, it is questionable how Animal Spirits can really fit here. Further, uncertainty in the sunspot literature is understood differently from the Keynesian and Post-Keynesian interpretation of uncertainty. Uncertainty in the sunspot literature is closer to the understanding in a neoclassical sense. The overall setting of the economy is stable and economic outcomes are 'certain' and calculable on the basis of probability functions and an attainable equilibrium. In the neoclassical, normative description of the economy, uncertainty is neither always present nor endogenous to the (stable) system. Hence, uncertainty can only be externally created and is linked to specific behaviour of otherwise rational agents or to specific periods and circumstances that cause the equilibrium system to behave abnormally (bubble periods and fluctuations in the mathematical models).

In the following section, sunspot models will be discussed on a more mathematical level as this, rather than theoretical coherence, appears to be at the core of the sunspot literature.

2.2. The mathematical account of sunspot models

Sunspot models are a variant of the Arrow-Debreu model (Prescott & Shell, 2002), portray general equilibrium endowment economies that are inhabited by representative, utility maximizing agents (Azariadis, 1981; Azariadis & Guesnerie, 1986; Cass & Shell, 1989; Farmer, 2015). Hence, these models are rooted in neoclassical, micro - based assumptions about the market structure. Mostly these models are overlapping generation models (Azariadis, 1981; Azariadis & Guesnerie, 1986; Farmer, 2015), since due to the naturally occurring restriction on market participation (economic agents do not live indefinitely) and hence incomplete markets, sunspots can easily be found here (Cass & Shell, 1983; Shell, 2007; Farmer, 2015). With incomplete market participation, the pareto optimality assumption for each competitive equilibrium ceases to exist (Farmer, 2015) and hence, sunspot equilibria are possible.

Generally, sunspot modelers start out by creating a perfect foresight equilibrium base model without uncertainty, meaning that there are no disturbance terms in the initial equations (sunspots do not exist). First, the modelers employ utility optimisation (mostly using the Lagrangean) under defined budget constraints (Azariadis & Guesnerie, 1986), whilst more or less realistic assumptions about the models' building blocks and possible equilibria are made. The aim of this exercise is to approximate the ideal, pareto optimal, perfect foresight equilibrium (or equilibria) that would prevail if uncertainty (sunspots) did not exist. Once a (set of) perfect foresight equilibria has been identified, the second step is to add conditional expectations (conditional on the available information), as well as a disturbance parameter representing a sunspot to either the differential equations, the stationary equilibrium or to the equilibrium path. The goal of the second step is to derive a rational expectations model with sunspot activity. The resulting sunspot model then represents the bubble model. The linearization of dynamic stochastic general equilibrium models (DSGE models) around an undetermined steady state (which represents the first step in 'finding' the perfect foresight equilibrium) and then adding random shocks to the linear system (the second step in creating the sunspot equilibrium models out of the perfect foresight model) generates valid equilibria for the non-linear system (Farmer, 2015).[41] The process of generating a rational expectation equilibrium from the perfect foresight equilibrium and then 'adding' this external random variable is referred to as 'randomisation' in the literature.

To demonstrate how this is done in practice, Farmer's (2015) calibrated, global sunspot model will be used. The author starts out by describing a single steady state solution which represents a saddle point equilibrium with two possible scenarios, in the form of a unique stable and unstable saddle path (also called arm or manifold). Both, the perfect foresight and sunspot equilibrium paths are described through the stable arm, whereas the unstable arm is ignored throughout the paper, with Farmer (2015) stating that "…All feasible bounded trajectories must start on, and remain on, the stable manifold" (Farmer, 2015:19). Any non-stochastic sequence that begins on the stable path will always converge towards (and arrive at) the saddle point equilibrium (Gandolfo, 2009; Farmer, 2015). However, as Farmer (2015) notes for his calibrated and stochastic, two-state sunspot model, it cannot be guaranteed that the system remains on the stable manifold (Farmer, 2015). Hence the author needs to make additional, model – specific assumptions for the system to remain on the stable manifold[42].

The perfect foresight equilibrium base model[43] defining the saddle point equilibrium is represented through non-stochastic sequences satisfying the following equations:

[41] On a side note it should be mentioned that equilibria cannot be identified using non-linear equations. These equations need to be 'linearized' employing the Jacobian to approximate the non-linear equilibria.

[42] In this specific case, Farmer (2015) solves this issue by ensuring that the value for $b'(s_a)$, which resembles future government debt in the positive future forecast scenario, is not chosen independently from $b'(s_b)$, which defines future government debt in the negative future forecast scenario. How this is done in detail is not further explained.

[43] Found in Farmer's (2015) appendix C.

$$p_k{}' = \psi(p_k, b, b') \tag{2.1}$$

$$m' = \phi(p_k, b, b') \tag{2.2}$$

$$b = m'b' + \tau \tag{2.3}$$

Equation (2.1) describes future discounted individual wealth ($p_k{}'$) through the present discounted individual wealth ($p_k,$) and the present (b) and future (b') government debt without uncertainty (sunspot variable). The pricing kernel m' in equation (2.2) represents the future price of an asset as a function of (p_k, b, b') without uncertainty while equation (2.3) defines the government budget equation, where the current value of government debt not only depends on the tax rate τ[44] , but also on the future price of any asset represented by the function of the pricing kernel $\phi(p_k, b, b')$, as well as future government debt b'. The tax rate τ is based on each perishable commodity (apple in the paper), that each agent is endowed with at the beginning of each period as well as on individual wealth p_k.

Having identified the equilibrium for the perfect foresight base model, Farmer (2015) moves on to create sequences of random variables (m, b, p_k)[45] satisfying below equations, which include uncertainty (S'). This uncertainty is also referred to as observable shocks or sunspots by the author. Therefore, the bubble model can be described as follows:

$$p_k{}'(\boldsymbol{S}') = \psi[p_k(\boldsymbol{S}'), b, b'(\boldsymbol{S}')] \tag{2.4}$$

$$b = \tau + E[b'(\boldsymbol{S}')m'(\boldsymbol{S}')] \tag{2.5}$$

$$m'(\boldsymbol{S}') \equiv \phi[p_k(\boldsymbol{S}'), b, b'(\boldsymbol{S}')] \tag{2.6}$$

The future discounted individual wealth within a sunspot environment ($p_k{}'(S')$) is defined through equation (2.4). This equation, so Farmer (2015) explains, links the current and the future discounted individual wealth to current and future government debt via trades in asset markets. That trade in asset markets takes place is simply stated, but how trade takes place is not mentioned. In a closed economy such as in this case, government debt is the liability of private agents (Farmer, 2015). The link of $p_k{}'(S')$ to $b'(S')$ and $p_k(S')$ to b is represented through the function ψ.

The current value of government debt b in equation (2.5) not only depends on the tax rate τ , but also on the expected future price of any asset which is represented by the function of the expected future asset prices $m'(S')$, as well as expected future government debt $b'(S')$. Equation (2.6) depicts the pricing kernel of an Arrow

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44 This tax rate could possibly be an income tax or tax on wealth. Unfortunately, this is not made clear in Farmer's (2015) paper.

45 With $m_i(S')$ being the pricing kernel defined as random variable, p_k as the discounted present value of future endowments and b as the present value of government debt.

Security[46] for the sunspot case. The random (stochastic) variable S' describes uncertainty in $t+1$. It should be mentioned that S is represented through a cycle $S_t^\tau = \{S_t, S_{t+1}, \dots, S_\tau\}$, while all real variables indexed by t are a function of S. To simplify the notation, Farmer (2015) drops the t giving: $x_t(S) = x(S)$ and $x_{t+1} = x(S')$.

Adding the disturbance term to the equations does not change the underlying equilibrium, even during bubble episodes. Only the path on which the equilibrium (sequence) is approached, changes during such bubble (sunspot) periods. Hence, the overall stability of the system does not change even if sunspots are included as the system remains on the stable arm at all times. In an example made by Framer (2015) where he constructs a sunspot equilibrium with two future states, the system starts out and mostly remains in the perfect foresight case. Only in one timestep $T+1$ are there two possible values for the pricing kernel: the perfect foresight value with no sunspot and the value including the sunspot. Though Farmer (2015:23) states that "…at all other dates the economy is in a perfect foresight equilibrium.", it is unclear how and why the economic system moves back towards the perfect equilibrium case (or, for that matter if the system moves back to the perfect foresight case at all). In addition to this, model variables are lacking a precise definition. For example, S and (S') do not only represent uncertainty about current and future variables, they also represent possible future states which are all characterized and influenced by uncertainty of the future. This lack of definition makes it very difficult to identify what is exactly meant in the equations where S and (S') occur. For example, the author assumes that people form their beliefs around observable shocks ($\boldsymbol{S'}$). This would indicate that ($\boldsymbol{S'}$) here means a future sunspot. Unfortunately, it is unclear and not explained how future shocks can be observed today. If, however, ($\boldsymbol{S'}$) means a future state, the argument becomes more plausible when interpreted as uncertainty about future states. But when specified in that way, the variable for the sunspot (uncertainty today about tomorrow) is missing in the equations.

Alongside this model specific criticism, it needs to be pointed out that within the sunspot literature (e.g.Cass & Shell, 1983, 1989; Azariadis, 1981; Azariadis & Guesnerie, 1986; Prescott & Shell, 2002) core concepts are theoretically not precisely defined. The example of Animal Spirits has already been given previously. Similarly, the, to the sunspot theory important concept of uncertainty is also represented vaguely. This vague definition makes it very difficult to differentiate what sunspots really mean. Sunspots could be interpreted as extrinsic uncertainty itself leading directly to economic fluctuations. However, it would also be plausible that sunspots *cause* extrinsic uncertainty which would also lead to fluctuations in the economy. Similarly, it could be the case that extrinsic uncertainty leads to sunspots which would then cause those swings. Mathematically these details do not matter so long as swings away from the equilibrium (path) can be created. However, on a theoretical level this lack of clarification makes it very

[46] An Arrow Security is a (hypothetical) financial instrument where one unit of a commodity or currency is paid if a predefined state of nature occurs at a specific future point in time.

difficult to pinpoint what exactly causes economic fluctuations and bubbles in real economies. Within the models it seems to be more important to create system fluctuations disturbing the otherwise stable equilibrium than to actually understand what causes these fluctuations and bubbles.

Though sunspot models can generate swings away from the perfect foresight equilibrium, it is difficult (or even impossible) to identify when these movements are actual bubble or simple business cycle movements. To be able to make this differentiation, a more coherent approach to the economic system is necessary. Not only is the active role of financial markets in endogenously creating money and supporting the emergence of economic bubbles mostly ignored within the sunspot literature[47], production and investment are both not specifically defined. The emphasis in these models is on simplified exchange economies in combination with strong assumptions about not only market participants but the general workings of capitalist economies. Monetary production economies which can be found in the real world are ignored and hence, a realistic bubble analysis according to the definition set out in chapter I section 1 can, within these model economies not take place. The perseverance with regards to economies that are internally and consistently stable and always move towards an equilibrium that, in reality does not exists, in addition to the hypothesis that a loosely defined and hardly understood uncertainty component, external shock or sunspot is the sole cause for unexpected swings, makes it impossible to not only identify but also understand economic bubbles. However, the entry point of sunspot theorists in explaining bubble episodes is a neoclassical one. Hence, there exists a general agreement that a Walrasian general equilibrium exists (theoretically) (Dymski, 2014). The general equilibrium is the analytical starting (and end) point around which such models are built. In how far reality is portrayed is of secondary importance as long as a logical link to the underlying neoclassical theory can be made.

In the following section, rational bubble models will be discussed.

3. Rational bubble models

3.1. The theoretical account of rational bubble models

Rational bubble models emerged around the same time as sunspot models and, just like sunspot models, try to explain not only general economic fluctuations but also bubble episodes. Whereas sunspot models embed economic bubbles within the economy, rational bubble models mostly concentrate on financial markets and here, only on one asset which contains a bubble (Diba & Grossman, 1987, 1988; LeRoy, 2004; Brunnermeier & Oehmke, 2013)[48]. Bubbles within the macro-economy (aggregate) are of secondary importance. Similar to sunspot models,

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[47] Farmer's (2015) model is slightly different to the pure sunspot models as he tries to combine usual sunspot models with asset pricing models and hence has to specifically consider financial markets and assets.

[48] Martin and Ventura (2012, 2017) differ to most modelers here as they attempt to incorporate the real side of the economy into their model.

rational bubble models hold on to the equilibrium assumption and fall back on psychological factors as explanation for (unexplainable) movements in asset prices. However, these psychological factors are assumed to be always present and hence do always cause the asset price to fluctuate away from the fundamental value.

The initial paper that produced a rich literature surrounding rational bubbles was that of Blanchard and Watson (1982), where the authors showed that bubbles can emerge even under the assumption of rationality and the no-arbitrage condition. The no-arbitrage condition implies that financial markets are efficient and that financial prices are correct at all times. Simply speaking, assets of the same type should be priced the same. The no-arbitrage belief leads to the conviction that no one can ‘beat the market’ continuously and that increasing financial returns of one or more assets above the market average are impossible without taking on more risk.

The rational bubble model is not only an attempt to deal with the dynamic inefficiency problem (Martin & Ventura, 2012) in the sense, that there is too much capital accumulated in the steady state pointing towards bubble behaviour where overproduction and unproductive investments become likely. This literature also stems from the realization of financial economists and financial market participants that asset prices do not solely reflect the fundamental value of an asset as promoted by the EMH (Blanchard & Watson, 1982; Diba & Grossman, 1987, 1988; LeRoy, 2004; Brunnermeier & Oehmke, 2013). As pointed out by Shiller (1990,2005) and Sornette (2003), empirical results in financial markets show that changes in prices for assets are simply not justifiable through changes in market fundamentals only.

Two different types of rational bubble models can be identified. In the first type of model it is possible for bubbles that have burst to *re-occur* in time (Blanchard & Watson, 1982; Martin & Ventura, 2012). Blanchard and Watson (1982) explain the re-occurrence of bubble episodes through a Ponzi game where all that is needed to recreate and sustain a bubble is continued new entries of market participants into the bubble market. The emergence of a bubble is then possible even after trading has started or after a previous bubble has burst. However, this is an impossibility for the second type of models (Diba & Grossman, 1987, 1988; Brunnermeier & Oehmke, 2013). Here, a bubble can *never re-emerge* once it has burst (Brunnermeier & Oehmke, 2013). Hence, under this belief, any rational bubble that exists today must have already existed on the first day of trading and could not have started after that date. Further, if a rational bubble exists, the asset must have been overvalued even before the first day of trading (Diba & Grossman, 1987, 1988).

Common to both types of models is the assumption that a bubble component (Blanchard & Watson, 1982; LeRoy, 2004; Brunnermeier & Oehmke, 2013) is responsible for fluctuations and volatility in asset prices. This bubble element is simply added to the fundamental value of the asset which, in a frictionless environment, is assumed to be equal to the asset's market value. The bubble component itself is believed to be of a psychological nature (Diba & Grossman, 1988), consisting of self-confirming beliefs that the price of a stock depends on variables irrelevant to fundamentals (Blanchard & Watson, 1982; LeRoy, 2004) and is best described as a Ponzi (Martin & Ventura, 2012) or pyramid (Blanchard & Watson, 1982; Martin & Ventura, 2012) scheme, where continuous market entry of new 'bubble buyers' is required to sustain the bubble asset.

Having given a theoretical appreciation of rational bubbles, the underlying mathematical specifications will be presented in the following section.

3.2. The mathematical account of rational bubble models

The mathematical models are generally overlapping generation (Blanchard & Watson, 1982; LeRoy, 2004; Martin & Ventura, 2012) stochastic equilibrium (Diba & Grossman, 1987, 1988; Martin & Ventura, 2017) models portraying simple endowment and pure exchange barter economies with the concept of optimization as a core component. These economies are inhabited by rational and informed agents (Blanchard & Watson, 1982; LeRoy, 2004; Martin & Ventura, 2012) with an infinite planning horizon (Diba & Grossman, 1988). Those representative agents are either risk averse (Diba & Grossman, 1988) or risk neutral (LeRoy, 2004). They are also aware that the bubble security trades at higher prices than is justified by the fundamental value. Due to the rationality assumption, agents will only hold a bubble asset if the price is expected to grow in the future (Blanchard & Watson, 1982; Diba & Grossman, 1987, 1988; Martin & Ventura, 2012; Brunnermeier & Oehmke, 2013) so it can be sold at a profit. Hence, common to all rational bubbles is that they do have to grow rapidly (Diba & Grossman, 1988; LeRoy, 2004; Brunnermeier & Oehmke, 2013) for as long as they last. And in line with the no-arbitrage condition, increasing returns today are justified by the fact that with an increasing bubble the risk of holding that security also increases (LeRoy, 2004).

Moreover, rational bubbles will only occur in infinite horizon settings (Blanchard & Watson, 1982; Diba & Grossman, 1987, 1988; LeRoy, 2004). Further, Brunnermeier and Oehmke (2013) and (Diba & Grossman, 1988) mention that the presence of substitutes could also limit the existence of rational bubbles.

In earlier models utility maximization is specifically addressed and drawn upon (Diba & Grossman, 1987, 1988) whereas in later models utility maximization is not further explored since the prices of bubble assets are not closely related to agents' utilities (LeRoy, 2004). Instead optimal portfolio choice (LeRoy, 2004; Martin & Ventura, 2012; Brunnermeier & Oehmke, 2013) is considered (which nevertheless implies utility maximization by rational agents). All rational bubble models are partial equilibrium models (Martin & Ventura, 2012) holding on to the assumption that markets are not only efficient but that the ideal equilibrium without disturbances always exists (Blanchard & Watson, 1982). However, it is also recognized that this ideal equilibrium, where demand equals supply or, similarly the fundamental value of an asset equals its market value, only exists in theory.

Rational bubble modelers[49] generally start out with the no-arbitrage rate of return on any security or portfolio from time t to time $t+1$

$$r_{t+1} \equiv \frac{(d_{t+1}+p_{t+1})}{p_t} - 1 \tag{3.1}$$

with d_{t+1} being the paid dividend in $t+1$ and p_{t+1} being the price of the security in $t+1$. Hence, the return of an asset in $t+1$ depends on the relation of dividends and prices in $t+1$ to the price of the asset in t. For example, if the price for an asset in t (p_t) increases while the future price and dividend are assumed fixed, the rate of return in $t+1$ (r_{t+1}) will adjust downwards. Taking conditional expectations of (3.1) and rearranging for the price of the security in t yields in

$$p_t \equiv \frac{E_t(d_{t+1}+p_{t+1})}{1+E_t(r_{t+1})} \tag{3.2}$$

with $E_t(r_{t+1})$ being the conditional expectations[50] on returns and $E_t(d_{t+1}+p_{t+1})$ being the conditional expectations of dividends and price in $t+1$.

In what follows, the assumption of symmetric information and fixed expected returns such that

$$E_t(r_{t+1}) = r \tag{3.2a}$$

is made and retained.

Under the necessary assumption of an infinite horizon setting within which a limit for (upper and lower) prices exists, equation (3.2.) and (3.2 a) yield

$$p_t = \sum_{i=1}^{\infty}(1+r)^{-i}\, E_t(d_{t+i}) + \lim_{n\to\infty}(1+r)^{-n}E_t\,(p_{t+n})\,. \tag{3.3}$$

The price of an asset in t (p_t) depends on the sum of its discounted expected future dividends $\sum_{i=1}^{\infty}(1+r)^{-i}\, E_t(d_{t+i})$ as well as on its discounted expected future price $\sum_{i=1}^{\infty} \lim_{n\to\infty}(1+r)^{-n}E_t\,(p_{t+n})$, which approaches zero as time goes towards infinity.

In a frictionless (perfect) equilibrium à la EMH, the price of a security simply equals the fundamental value. However, and as mentioned by Blanchard and Watson (1982), Sornette (2003), LeRoy (2004) and Brunnermeier and Oehmke (2013), this is not the only possible solution to the system equations if the transversality condition does not hold. Hence, the price of a security in t consists not only of the

[49] The equations are taken from LeRoy (2004). However, this is for no particular reason as most other papers (Diba & Grossman, 1987, 1988; Brunnermeier & Oehmke, 2013) draw on the same paper popularized by Blanchard and Watson (1982).
[50] Conditional on today's available information.

fundamental value $\sum_{i=1}^{\infty}(1+r)^{-i}\, E_t(d_{t+i})$, but also of a bubble component $\lim_{n\to\infty}(1+r)^{-n}E_t\,(p_{t+n})$.

It should be noted that, since r is fixed, the only parameter that can drive future prices and hence the bubble component is E_t, the expectations of future prices based on information available in t . Hence, a rational bubble arises once the price for a security today depends positively (and solely) on the expected rate of change of future prices (Sornette, 2003). It should also be mentioned that the assumption of a fixed r appears to be more realistic for short, rather than longer time horizons.

The price of a security p_t in t including a fundamental f_t and a bubble component b_t can be rewritten as:

$$p_t = f_t + b_t \quad . \tag{3.4}$$

As can be seen from the above equation, production is generally ignored within these models while an account of how investment might take place is missing. The same can be said about money, debt and the influence of various economic institutions.

Overall, this analysis does not seek to understand the emerging properties over time that cause bubble behaviour, nor the evolution of a bubble. Modelers are solely interested in adjusting already existing equilibrium models in a way that can accommodate empirical observations. However, the above equations make it clear that financial bubbles cannot be depicted that way in actual markets. For example, increases in asset prices could also be justified through perceived and not actual increases in the fundamental value. This would then not only impact future dividends but also future prices. It would be impossible to distinguish if expected dividends or expected prices drive asset values today. Often the belief in a new era (for example Minsky, 1970) during bubble episodes leads to the conviction that economic fundamentals have changed in a way that would justify an increase in asset prices. Hence the bubble element would not have to be considered to explain changes in asset prices (for example through technological, managerial or financial improvements). This would then lead to the conclusion that financial markets are not experiencing a bubble episode but simply that a new (improved) equilibrium state has been reached. Additionally, the crucial system turning points from stable to unstable behaviour are not touched upon. As Martin and Ventura (2012, 2017) explain, these shifts happen at random without any justifiable logic. Hence when attempting to explain bubbles found in the real world, rational bubble models fail to recognize the underlying characteristics of economic bubbles and are hence incapable of identifying bubble episodes.

Additionally, the belief that economic bubbles cannot reoccur once they have burst is far from what can be observed in real markets. This becomes specifically apparent when bubbles are considered an aggregate phenomenon that not only affect one asset, but the whole financial system as well as the adjunctive economies. When examining bubble episodes of the past it becomes clear that bubbles consistently re-emerge in the same markets and even within the same spatial region (for example Reinhart & Rogoff, 2009). There may be some time between (financial) bubble episodes, nevertheless they are a re-occurring phenomenon, endogenous to the economic and specifically financial system. Admittedly, bubbles are never exactly the same, they may evolve around different (especially new financial) methods, instruments or commodities that lie at the core of the bubble while new and old regions and markets might be involved. Yet, and as set out in chapter I section 1.4, bubbles do have an underlying structure that is 'bubble typical' even across markets, instruments, and regions. However, if bubbles are considered to be attached to only one asset tied to one company as is mostly the case in rational bubble models, the argument of not re-occurring bubbles becomes more realistic though probably also not thoroughly true (specifically for companies and banks that are believed to be too big to fail). But then it should be questioned if 'bubble' for *one* overvalued asset is the correct terminology.

Alongside those theoretical complications, Lux and Sornette (2002) find that the above results and implications of rational bubble models à la Blanchard and Watson (1982) fail to match "…empirical regularities of financial data at a very elementary level." (Lux & Sornette, 2002: 607). Though according to the authors, the empirically observable power-law structure[51] for stock and foreign exchange markets is considered within rational bubble models, the degree of the fat-tailedness of distributions in these models is conflicting what is found empirically. The tails resulting from bubbles are predicted to be much heavier in the models than those that are found in financial data sets. Hence, so Lux and Sornette, (2002) argue, empirical data cannot be matched with the statistical behaviour of asset prices portrayed in rational bubble models.

To conclude this chapter, a general appraisal of the appropriateness of sunspot and rational bubble models in considering and modelling economic bubbles will be given in the following section.

4. The adequacy of exogenous bubble models when explaining empirically observable bubble behaviour

Sunspot models as well as rational bubble models are specifically created to explain observable, but, due to the underlying theory, unpredictable economic outcomes of general equilibrium systems. In general equilibrium models, without either extrinsic uncertainty or a bubble component, no 'random' movements away from the fundamentally defined equilibrium could and should occur, especially since fundamentals do not change in that manner. Not only do these models attempt to explain business cycles (Azariadis, 1981; Azariadis & Guesnerie, 1986; Martin & Ventura, 2012), references to actual economic bubbles such as the

[51] It should be pointed out that there is an ongoing debate of whether power-law structures might also be too simplistic to explain financial returns.

Tulipmania (Azariadis & Guesnerie, 1986), the Great Depression (Azariadis & Guesnerie, 1986; Farmer, 2015) the Japanese asset price bubble (Martin & Ventura, 2012), the dot-com bubble (LeRoy, 2004) and the recent Subprime crisis (Martin & Ventura, 2012; Farmer, 2015) are repeatedly made. Though mathematically exact, these models have become very complex and sophisticated and are capable of creating fluctuations away from the hypothetical equilibrium hinting towards bubble episodes. However, there are several issues surrounding sunspot and rational bubble models predominantly stemming from the underlying theoretical neoclassical and micro-based approach.

In the following subsections, some of these issues will be picked up and evaluated.

4.1. Stationarity, stability and equilibrium

The classical conviction that economic systems are defined through an (attainable) equilibrium determined by non-changing (or very slowly changing) fundamentals which have an intrinsic value is a core component of the stationarity[52] belief and is incorporated into the underlying assumptions of a sunspot. It is presumed that any economic system will always return to its previously calculated equilibrium or equilibrium path after some (external) shock has caused the system to move away from the equilibrium. In other words, it is maintained that economies are self-correcting. This has strong implications for the explanation of observable bubble behaviour. Though bubbles are possible under this conviction (in the short run), the representation of the bubble phenomenon is highly stylized. This becomes apparent when looking at Azariadis, (1981) who notes that there are two possible types of equilibria the economy will inevitably end up in when considering infinite time. Depending on the probability ratio of two defined sunspot variables, the economy could end up in a stable stationary equilibrium, where markets constantly clear, or in an extreme equilibrium of chronic recession or boom-like behaviour. However, since several equilibria are possible in his model (depending on initial conditions), the author states that it is impossible to know which equilibrium will prevail. Further, Cass and Shell (1989) believe that the economic system is best described through a stationary environment (fundamentals are stationary) where non-stationary paths can arise, leading to periodic (business cycle) and a-periodic (bubble) outcomes and movements. In a similar vein, Farmer (2015) designs a saddle point equilibrium, where it is assumed that the system always stays on the stable arm, inevitably ending up in the predefined equilibrium.

Though rational bubble models acknowledge that asset prices do not solely depend on the fundamental (equilibrium) value mostly due to empirical findings in financial markets (see for example Shiller, 1990; LeRoy, 2004), conceptually these models nevertheless hold on to that equilibrium assumption. Diba and Grossman (1988: 746) for example maintain that there exists a 'guaranteed market fundamentals solution' where markets clear. Similarly, Blanchard and Watson

[52] It is maintained that statistical time series are defined by constant statistical properties (variance, autocorrelation etc.) over time.

(1982) define bubbles in equilibrium settings, Martin and Ventura (2012: 3040) characterise ‘equilibrium bubbles’ whereas Brunnermeier and Oehmke (2013) assert that the equilibrium price of an asset can be defined as its fundamental value. LeRoy (2004) implicitly hints towards the equilibrium belief when employing optimal choice for an optimal portfolio. Further and more implicitly, the usage of eigenvalues in Diba and Grossman (1987,1988) implies that there exists one point (equilibrium) around which the approximations of the system equations exists, hinting towards a possible steady state. Moreover, the assumption that the economic system would return close to the fundamental value after the shock has ceased to exist (Martin & Ventura, 2012, 2017) further highlights not only the equilibrium, but also the self-adjustment belief with regards to economies.

However, all of above explanations are far from what can be observed in complex (social) systems evolving in real time. The stationarity assumption limits the understanding of economic bubbles by denying the possibility of ‘abnormal’ system behaviour to occur organically from within. In a stationary environment, bubbles simply cannot arise, similar to business cycles which should not emerge from and through the system itself. Unpredictable exogenous shocks are needed to cause both, business cycles and economic bubbles. But when looking at complex systems such as the economy (as set out in chapter I section 1.2.), it becomes apparent that those systems are capable of creating movements and instabilities from within (for example Sornette, 2003; Keen, 2013). Hence, no external disturbance factors are needed in reality to observe bubbles, hinting towards the possibility that sunspot and rational bubble models are not suited to depict bubble behaviour. Further and on a general note, it cannot be assumed that the economy is a static system fundamentally not changing over time. One example of this is the process of financialisation[53] and the overarching changes it has had not only on financial market behaviour but on the economic system in general. Connected to this are implications for economic bubbles which have increased in frequency and amplitude over the course of financialisation.

Additionally, describing the economy as a system that converges on various paths towards an equilibrium, such as in the sunspot literature, also appears unreasonable. Though there may be multiple paths approaching an indeterminate equilibrium state, theoretically allowing for bubble behaviour under this approach, the concept of a specific (but possibly unknown) steady state or equilibrium path for a complex, evolutionary system over time is too simplistic and not suited to portray economic behaviour including bubble behaviour or social systems in general. Any path could represent a bubble path depending on the definition of the steady equilibrium. This lack of specificity makes it very difficult to falsify the theoretical claim of how to understand bubbles since these types of models are in fact capable of creating swings that can be interpreted as bubble behaviour under the stated theoretical boundaries. However, when neglecting the analysis of

[53] Discussed in chapter II, section 3.3.

various stages of system behaviour and instead focusing on how an economic system can move towards a hypothetical equilibrium, real-life bubbles will remain undetected possibly until they burst.

Further, and more on the mathematical side of Farmer's (2015) model, the slightest change in any of the parameters in a saddle point equilibrium will throw the system off the stable path. This then means that the system can get very close to the perceived equilibrium before it will move away from equilibrium towards infinity (positive and negative). Within the sunspot literature it is believed that observable turning points in the data can only be brought about by unpredictable disturbances to the economy, triggered by (external) sunspots. Under the saddle point approach, this could mean that the economic system slips off the stable arm. The system would, after it passes the stage of approaching the equilibrium, move indefinitely towards positive or negative infinity. This would then indicate that boom phases would never stop (positive infinity) or recessions would become ever deeper (negative infinity). Large outside shocks would be necessary to push the system back onto the stable arm. Moreover, those shocks would have to be 'configured' such that the economic system ends up precisely on the stable path. Though there may be movements in the same direction by economic measures such as in growth, prices, inflation, investment behaviour and consumption for example, the economic system does not appear to 'explode' towards infinity once parameters of economic indicators (such as expected growth rates, consumer sentiment, companies' sentiment, investment figures and current and expected employment for example) change. On the other hand, if it is believed that the economic system consistently moves on the unstable arm (or at least not on the stable arm) then the notion of equilibrium could be abandoned whereas the system would move somewhat aimlessly through time depending on parameter changes. Though fluctuations can be observed in Farmer's model, observable turning points or different stages of the business cycle including rapid growth or decline cannot be explained under the assumption of a fundamentally stable system. This also implies that bubble behaviour as a naturally occurring stage of the business cycle cannot be depicted. Hence it is questionable if saddle point systems can represent actual market, and with that, depict bubble behaviour.

Additionally, the general equilibrium setting implies overall and attainable economic stability. Under the general equilibrium assumption, markets are not only self-regulating but also efficient. In combination with a holding Walras' law[54], over – or underproduction or insufficient demand or supply, all signs of bubble behaviour, bubbles become impossible. Hence, bubble episodes represent not only abnormal system behaviour, are rare, unpredictable, and somewhat isolated events but can also only be caused from outside the system, in the case of sunspots through external uncertainty. Though having recognized that asset prices

[54] Walras' law is only considered in sunspot models. Over- and under-valuations are possible in rational bubble models.

do not merely display the fundamental value of the asset in rational bubble models, it is still unclear how the bubble component becomes so large that it would actually dictate the price of the asset. Martin and Ventura (2012) refer to shocks as consumer sentiment without specifying where these shocks come from, what exactly they are and how they emerged. Again, the typical increase in system instability over the course of a bubble (or a simple business cycle) cannot be depicted that way. Therefore, bubbles will remain undetectable, appear random and with it the sources of bubbles uncontrollable.

Moreover, complex dynamic systems such as the economic system in most real-world economies evolve over time. Each time step then theoretically becomes an initial condition with the potential to re-define the previous path or pattern. Hence it is questionable if the system even moves towards (or away from) a hypothetical equilibrium as consistently as propagated by neoclassical models. The better approach would be to leave this conviction behind and look at the dynamic system behaviour over time to uncover the system conditions of bubble episodes. Whereas this was nearly impossible (mathematically and data wise) some hundred years ago, it can be done with relative ease now due to increased computer capacity and available data. Hence, there is no need for the simplifying assumption of an equilibrium system anymore.

4.2. Exchange economies without production or money and the issue of partial analysis

Within the sunspot and rational bubble literature it is assumed that simple barter and endowment economies without money can represent actual capitalist market behaviour (Azariadis, 1981; Blanchard & Watson, 1982; Cass & Shell, 1983, 1989; Azariadis & Guesnerie, 1986; Diba & Grossman, 1987, 1988; Martin & Ventura, 2012; Farmer, 2015). Production generally plays no specific role and the supply of goods is simply accepted as given. Similarly, the labour market and wage formation are assumed away. Generally, the young work and are endowed with divisible leisure (Azariadis, 1981; Azariadis & Guesnerie, 1986) or perishable consumption goods (Diba & Grossman, 1988), while the old consume (Farmer, 2015). Endowments are constant and unrelated to employment whereas money is believed to be simply a social norm (Cass & Shell, 1983) with no intrinsic value (Azariadis, 1981) and hence, consumers are indifferent in holding money or securities (Cass & Shell, 1983). Azariadis (1981) ascertains that business cycles and economic bubbles are possible even if money is ignored in that way. In a similar vein, though prices for assets in rational bubble models are discussed, money does not enter the equation, neither does credit.

Further, both types of models do not look at the economy as a whole, instead only specific markets such as security markets (Cass & Shell, 1989; Farmer, 2015) or the housing market (LeRoy, 2004) are looked at in isolation from other interconnected parts of the economy. The abstraction of these models is so high that many times presented results, in the case of sunspot and rational bubble models created bubble behaviour, can hardly be applied to the real world.

It is unexplained why financial markets would exist if production and investment is not accounted for. The sole reason for the emergence and existence of financial markets is the financing of investment, productive and financial. There is no reason or possibility for financial markets to prevail without a producing side of the economy. The repeated reference to a fundamental value generally is associated with something of 'real' value, even in this literature. However, if the producing side is ignored, it is very difficult to see how business cycle swings and bubbles could even emerge. Though the financial sector plays a crucial role in supporting business cycle movements, and with that bubble behaviour, it is not able to do so without the other sectors. Hence, even though these models create bubble behaviour or movements away from the equilibrium (path), this can only be done through very stringent model assumptions. However, in reality, economic bubbles do not emerge in that way. As pointed out in chapter I section 1, bubble episodes are an inherent part of the business cycle, closely attached to the growth, investment and lending situation, which in turn depends on where in the business cycle the economy is.

Similarly, the underestimation of the importance of money to the point that it simply represents a veil leaves no room for the bubble behaviour that is observable today. Though bubbles could emerge locally and be restricted to a specific market (for example seashells, salt, or fur in primitive exchange economies) under this belief, it would not be possible for economic bubbles to emerge simultaneously in different regions and different markets affecting different social groups. This phenomenon only becomes possible through money flows interconnecting different markets, regions, and groups. Not only is the importance of money neglected in these models, the endogenous creation of money or purchasing power is also not considered. Money supply, if considered at all, is exogenously determined ignoring the creation of additional purchasing power through loans within the economy. In fact, bubbles can emerge even without the availability of loans (Martin & Ventura, 2012) which is contradicting empirical observations during expansionary and specifically bubble episodes. To understand how economic bubbles emerge it is important to comprehend exactly that, how additional purchasing power is created from within the system. The creation of additional purchasing power is not only a crucial part to any boom phase in the business cycle and indicative of the system stage, it is also one of the main drivers of economic bubble episodes.

Disregarding this analysis throughout the discussed models creates the impression that business cycles and economic bubbles are unpredictable, random events solely driven by loosely defined and hardly understood psychological factors. Again, while psychological factors do play a role, they are very hard to identify in real time. Further it would be too simplistic to think that in a complex system one element is sufficient to explain specific system behaviour. When looking at economic bubbles, there generally is not one single event or parameter causing them. Economic bubbles cannot be identified or understood when the underlying analysis only considers parts of the economy with unrealistic assumptions about loan creation and money while neglecting production, investment, and labour markets.

4.3. The micro-approach and rational agents

Bubbles in the rational bubble literature are by no means an aggregate phenomenon affecting the aggregate financial market and hence the economy as a whole. Rather, bubbles are attached to *one specific asset* in the form of the previously mentioned bubble component (Diba & Grossman, 1987, 1988; LeRoy, 2004; Brunnermeier & Oehmke, 2013). And here, only price changes of this one specific asset in the financial market are of interest. Hence, bubble assets are those, where the price of the asset is greater than that of possible substitutes or what would be considered the average price in that specific market. Systemic features of bubble episodes are ignored within this approach. Diba's and Grossman's (1988) and Brunnermeier's and Oehmke's (2013) reference to substitutes that could potentially limit the emergence of bubbles further points towards a micro-based problem rather than a problem on an aggregate scale. In some models such as Blanchard and Watson (1982) the link to the aggregate economy is made by assuming that a bubble asset can theoretically affect other asset prices, portfolio compositions and the overall wealth. This, so the authors argue, will have real effects on the economy such as increases in demand for goods and money. In later papers, though also starting out by considering only one asset, Martin and Ventura (2012, 2017) find that the economy on a macroeconomic level fluctuates between bubble episodes and the fundamental (equilibrium) state. Hence, an attempt to link bubbles to the whole (aggregate) economy is made. Bubbles, so the authors argue, are then responsible for the dynamics in the system. It is assumed that the capital stock converges towards an interval consisting of fundamental and bubble state. Once the economy has reached this interval (steady state distribution), it will fluctuate between these two states forever (Martin & Ventura, 2017). However, the authors are unable to identify why the system would change from one state to the other arguing that bubble episodes start and end for no good reason (Martin & Ventura, 2012, 2017).

Further, rational bubble models explicitly consider utility maximization, especially in earlier models such as in Diba and Grossman (1987,1988). Later, more finance-based models only implicitly assume utility maximization through optimal portfolio choice. Finding the hypothetical equilibrium in these models is not as important as it is in sunspot models. It is of greater usefulness to define the bubble component as it is believed that only the bubble component can drive asset prices to fundamentally unjustifiable highs and lows. The fundamental value is based on the assumption that every financial asset has an intrinsic value, which can be described through discounted future dividends. It is also asserted that the fundamental value does not change quickly and dramatically as the bubble component would. This leads to the conclusion that the fundamental value is equal to the equilibrium value of any asset.

Similarly, sunspot models are deeply rooted in micro-based assumptions about the economy. This becomes apparent when looking at the importance of finding the optimal consumption bundle at the optimal utility given a specific budget constraint for the representative agent. The optimizing condition for these equations is a corner stone of sunspot models. Agents' probability beliefs, preferences and substitution effects are equally important. Findings made for a representative agent are believed to be transferable to the aggregate without further adjustments. Additionally, these representative agents are assumed to be rational and fully informed. Hence knowledge and information are distributed evenly between market participants. These assumptions imply that economic bubbles are a theoretical impossibility. If all agents in the market have access to the same knowledge, act rationally and maximize their utility according to specified budget constraints, bubbles cannot be generated from the workings of the markets alone. Hence, and again, it is necessary to introduce a disturbance term to create movements away from the equilibrium path and possibly bubble behaviour.

Nevertheless, the assumption that a representative, utility maximizing agent approach can in fact yield credible aggregate results has to be questioned. As Shaikh (2012, 2016) points out empirical, analytical and historical evidence is not in favour of this belief. It has been demonstrated, so the author argues, that aggregate results are detached from microeconomic results since the structures underlying aggregation are different from those on the micro-level. The economic structure on an aggregate level cannot be depicted using a micro-based approach. Hence, economic bubbles as an aggregate phenomenon can also not be explained that way.

Additionally, as discussed in chapter II section 2.4.2., behavioural decision research emerged as a critique of the rational, fully informed market participant paradigm. The conviction that the overall rational agent is influenced by unexplainable and random psychological factors, causing changes in uncertainty and leading to bubble behaviour simply is not true in theory and reality (for example Kahneman & Tversky, 1979). Though psychological factors do influence market participants, they do so routinely and all the time. People consistently use heuristics (mental shortcuts) and not calculus to make decisions, especially when faced with complex problems and uncertain outcomes. The resulting biases can create systemic misevaluations of economic parameters leading to bubble behaviour (Tversky & Kahneman, 1974; Johnson & Tellis, 2005) which, under the assumption of rationality, cannot be accounted for.

As indicated in section 2.2. and 4.1. of this chapter, sunspot and rational bubble models are models in the neoclassical tradition. As such, theorists explain occurrences such as bubble episodes in 'real' markets on the back of models that employ optimisation calculations and rational choice while a general equilibrium setting is a legitimate reference point towards which a system always tends (Dymski, 2014). Hence, and in line with Dymski's (2014) argumentation, any system behaviour will be explained with reference to this equilibrium. Under the assumption of perfectly coordinated, efficient markets that are inhabited by rational and perfectly informed agents who, through utility (or profit) maximisation on an individual level are able to achieve welfare improvements on the macro-level (Dymski, 2014), the structural and institutional setup does not have to be considered if the behaviour of the economy is to be explained. Therefore, within the neoclassical framework it is acceptable for the theorists of sunspot and rational bubble models to only look at one asset, one market or one economic agent at a time as those are representative for the overall economy. Similarly, within this theory it is legitimate to ignore governments, banks, money and credit since markets function perfectly well without governments, banks or money. Nevertheless, as pointed out by Dymski (2014) and Dymski and Shabani (2017) and as stressed throughout this thesis, a theory and its accompanying models that evolve around an idealistic description of the economy which neglects core parts of the institutional setup and structure, clarifies nothing. Models of that type are solely interpretations of a theory that, as argued throughout chapter II, is incapable to realistically account for and explain bubble episodes.

5. Conclusion

All models are an abstraction from reality. Any model's aim is to explain complex phenomena in a more accessible way by concentrating on stylized facts and simplifications. According to Varoufakis (2013) in sciences other than economics initial model (over-) simplifications are eventually adjusted in order for the model to result in a more realistic explanation of behaviour or outcomes. However, within the economics discipline and especially for models rooted in neoclassical economics, these necessary adjustments have not taken place. As Sornette (2014) notes using the example of financial markets, though observed empirical findings do not match the results of the respective neoclassical mathematical models, the underlying neoclassical theory is not falsified and rejected as would be the case in other sciences. Rather, it is believed that either a new 'puzzle' or market imperfection has been found, or that other hidden effects within real economies have not been accounted for in the mathematical model. In this way, economic theory and the associated models are assigned a normative role. This means that it is not explained how the economic system works in reality, but rather how economies should behave in order to comply with the theoretical and mathematical models. However, ascribing economic theory and the associated mathematical models a normative role leads to great disparities of model predictions when compared to empirical evidence (Sornette, 2014). The divergence of normative model predictions and empirical facts becomes especially apparent when looking at economic bubbles which, considering the underlying model assumptions of efficiency and stability, should not occur. To address the discrepancy between empirical observations and model predictions, since the 1980s, mathematical models have evolved that specifically consider economic bubbles (or business cycle fluctuations in general). However, as shown above, these models do not stray too much from the overall theoretical assumptions or mathematical building blocks of standard neoclassical mathematical models of the economy.

And although sunspot and rational bubble models are very accomplished on a mathematical level, the results can only be as good as the underlying approach when attempting to describe economic relations (Minsky, 2008a). The lack of definition of key concepts (such as uncertainty or psychological factors) in combination with the theoretical impossibility of economic bubbles makes the link of mathematical results to theory very difficult. Specifically, when trying to relate mathematically reproduced empirical observations (economic bubbles) to the underlying neoclassical theory, it becomes clear that a theory stressing equilibrium and rationality is not suitable for the explanation of economic bubbles. The inadequacy of the underlying theory also leads to the issue that the models used to describe economic bubbles are not appropriate mathematically when attempting to portray bubble behaviour in a complex world. Though both, sunspot and rational bubble models are capable of creating dynamics within a simple system setting, often it is not understood where bubble movements come from, why bubbles ‘suddenly’ burst and how bubbles could be identified in real markets. The evolution of the complex, economic system, turning points (critical points) in system behaviour as well as changing system stability are all ignored. This major shortcoming within the discussed models further highlights their incompatibility when compared to empirically observable bubble (or general system) behaviour.

The Econophysics approach, although similar to rational bubbles in that it concentrates solely on financial markets, differs mathematically. This approach builds on the complex system literature popularized in the natural sciences, specifically (mechanical) physics. Here, an equilibrium setting is not needed to create dynamic system behaviour, including bubbles. Though it is unlikely to have an exact solution to the system equations which would be attainable in above models, it is possible to observe the evolution of the system over time, specifically the varying levels of stability. What is appealing in this is that these dynamics emerge endogenously and are built into the system. Hence bubble behaviour would also emerge endogenously which, at least from a Minskian perspective, appears to be the more reasonable explanation. Further, while looking at changing system stability, it would indeed be possible to identify a situation in which the economy enters (or leaves) a bubble phase

In the following chapter this approach will be looked at in detail with a focus on the suitability in explaining economic bubbles.

Chapter IV: Mathematical Models of Endogenous Economic Bubbles

1. Introduction

In line with the discussion on chapters I and II, there exists an alternate mathematical approach to the one discussed in chapter III. Theoretically, the belief, that the economy as part of a social system cannot be described as an equilibrium system and that in fact, bubbles occur regularly and emerge endogenously, has existed longer than the mathematical elaborations of this idea (for example Schumpeter, 1927, 1928; Fisher, 1933; Minsky, 1982, 1992, 2008b). The reason for this is clear; not only were the (statistical) tools and methods missing to deal with large data sets (Jovanovic & Schinckus, 2013), the amount of reliable data needed was also not available. Only the increased processing power of computers in combination with improved data collection since the 1980s have made this possible. With this, Econophysics was able to refute theoretical claims of Gaussian return distributions within financial markets under which bubble episodes were theoretically not possible and hence, practically not accounted for.

Econophysics emerged during the mid-1990s with its founding father being Eugene Stanley who coined the term (Suavoiu & Iorga–Simuan, 2008; Rickles, 2011; Jovanovic & Schinckus, 2013; de Area Leão Pereira et al., 2017). Econophysics arose in opposition to the prominent EMH (Sornette, 2003, 2014; McCauley, 2006; Rickles, 2011; Jovanovic & Schinckus, 2013; de Area Leão Pereira et al., 2017), with the aim to replace the neoclassical paradigm based on Gaussian return distributions, while exclusively considering financial markets (McCauley, 2006; Suavoiu & Iorga–Simuan, 2008; Jovanovic & Schinckus, 2013). In addition to financial economics and mathematical finance, Econophysics has since become the third element of modern finance theory (Jovanovic & Schinckus, 2013).

Econophysics is an extension of physics attempting to study financial market phenomena (Jovanovic & Schinckus, 2013). Hence, it is not surprising that the ideas, concepts and methods of this approach are rooted in statistical physics (and statistical mechanics) (Sornette, 2003; Suavoiu & Iorga–Simuan, 2008; Rickles, 2011; Scheffer et al., 2012; Jovanovic & Schinckus, 2013). Mathematical methods of statistical physics such as power laws, correlation and scaling as well as chaos theoretical approaches and network pattern recognition, are all applied to describe financial market features such as return distributions, price dynamics and bubble episodes (Suavoiu & Iorga–Simuan, 2008). When explaining stock market fluctuations, but especially when analysing extreme events such as crash episodes in financial time series data (de Area Leão Pereira et al., 2017), Econophysics draws on theories of turbulence (based in thermodynamics), earthquakes, sand piles, and radioactivity (Sornette, 2003; Suavoiu & Iorga–Simuan, 2008; Jovanovic & Schinckus, 2013).

Contrary to neoclassical theories, in Econophysics, empirical observations as opposed to theoretical models rooted in economic theory are the starting point when analysing financial market behaviour (McCauley, 2006; Suavoiu & Iorga–Simuan, 2008; Rickles, 2011; Jovanovic & Schinckus, 2013). This development outside of an economic theory that cannot explain empirical findings in time series data such as, for example fat tails, is understood to be the main advantage of Econophysics (Jovanovic & Schinckus, 2013). McCauley (2006) believes that (orthodox) economic theory is best ignored by Econophysics while all its assumptions should be abandoned unless they are backed up empirically. According to Suavoiu and Iorga–Simuan citing Mantegna and Stanley (2000, cited in Suavoiu & Iorga–Simuan, 2008: 33), no economic theory is needed to understand financial markets as the observed behaviour is very similar to systems found in physics. This emphasis on empirical data rather than economic theory is, when compared to neoclassical theory, ground breaking and the main added value that Econophysics is believed to bring to the table (Rickles, 2011).

In the following section 2, the Econophysics approach in relation to financial markets will be looked at in more detail. Section 3 will concentrate on the attempt of Econophysics to explain financial bubble episodes. This will be followed by an evaluation of the appropriateness of the Econophysics approach to economic bubbles in section 4. Section 5 will highlight advancements made by Econophysics when compared to neoclassical theory and conclude.

2. The Econophysics approach to financial markets

Econophysics leans heavily on the concept of complex systems when attempting to interpret their statistical findings (for example fat tails in returns and criticality) within financial market data and when trying to explain observable bubble behaviour within such markets. Complex systems are systems that consist of many heterogenous subsystems (Rickles, 2011), where the aggregate (macroscopic) properties of the system emerge through mostly non-linear interactions of many different (heterogenous) particles and subunits on the microscopic level (Suavoiu & Iorga–Simuan, 2008; Rickles, 2011). Hence macroscopic systems are defined by interactions within the microscopic structure. Since the properties and the behaviour of the complex system depend on the interactions and properties of the system's particles and subunits, it follows that the overall system behaviour of a complex system emerges endogenously. This characteristic feature of complex systems is also known as self-organization. It is recognized that the aggregate properties of the system are different from those on a microscopic level (Suavoiu & Iorga–Simuan, 2008; Rickles, 2011). It is further understood that changing macroscopic properties themselves will induce changes on a microscopic level, which in turn will lead to further changes on the macroscopic level (Sornette, 2003, 2014). Hence, the approach here is not only bottom up, but also top down.

Translated to financial markets, the complexity approach means that aggregate phenomena and differing levels of system stability (such as bubble episodes hinting towards increasing system instability and ending in a market crash) emerge endogenously due to the complex interactions of many different (heterogenous) market participants. And since socio-economic systems fall under the notion of self-organized adaptive (complex) systems (Sornette, 2003; Suavoiu & Iorga–Simuan, 2008; Rickles, 2011; Kirman, 2018), Sornette (2003, 2014) argues that financial markets are then best understood as self-organizing systems with a hierarchical structure of traders. The co-operative and imitative behaviour of traders of different hierarchical levels, leads to a self-organizing system that can generate differing system properties indicative of varying levels of system stability on the aggregate level (system states like booms and bubbles and properties of system states such as crashes indicating the end of a bubble episode). However, these aggregate properties do not only differ from those on the microlevel (interactions of traders) but can also cause interactions and properties on the microlevel to change. Overall this feature of complex systems then implies that aggregate changes in the system tied to varying levels of system stability are not only generated from within but that they will induce changes in the microstructure of the system which, again, will affect and change the properties on the aggregate level. Therefore, no external disturbance factors are needed to create changing system stability and, as in the case of financial market crashes, dramatic shifts and transitions in the system states[55]. What is interesting from a bubble point of view when accepting the complex system notion is criticality and, in that context, the occurrence of critical points within a complex system. Extreme events in physical complex systems are defined by critical points which induce a regime shift in system behaviour. This indicates that the system, after it has bypassed the critical point, will behave differently, and produce different system properties. For Econophysics, crashes in financial markets are indicative of regime shifts and are hence closely looked at. More on this will be in section 3.

Empirical findings made by Econophysics are now accepted as stylized facts of financial markets (Gallegati et al., 2006; McCauley, 2006; de Area Leão Pereira et al., 2017). These stylized facts include, among others, fat tailed returns, volatility clustering and volatility persistence (also called long memory) of stock market returns (Sornette, 2003, 2014; Gallegati et al., 2006; Rickles, 2011; de Area Leão Pereira et al., 2017). Those stylized facts find their application in, among others, agent based modelling and in the complex network research (de Area Leão Pereira et al., 2017).

It should be noted that these empirically grounded financial market observations negate not only to what has been theoretically defined by the EMH, but also to much (if not all) of the assumptions which financial calculations within the modern

[55] From a complex system point of view there are stable and unstable system states and those system states that exist in-between. In the Minskian version of this, one finds three types of finance (hedge, speculative and Ponzi), all defining different levels of system stability (here from stable to unstable) (for example in Kindleberger & Aliber, 2005 and Minsky, 2008b).

portfolio theory are based on such as the Black and Scholes formula of option pricing (Rickles, 2011; Jovanovic & Schinckus, 2013; Sornette, 2014), the capital asset pricing model (CAPM) and the value at risk model (VaR) (Jovanovic & Schinckus, 2013). All these approaches base their calculations on the assumption of Gaussian return distributions and hence, ever-lasting stability. However, one of the main criticisms regarding the EMH on an empirical level is the assumption of normally distributed (Gaussian) returns as well as the random walk assumption of financial market prices (Sornette, 2003, 2014; Rickles, 2011). Under the EMH assumption of Gaussian returns, and due to the mathematical definition of this distribution, only mild fluctuations of returns can be considered. Larger fluctuations of returns observable during bubble episodes cannot be dealt with when the underlying return distribution is Gaussian (Rickles, 2011; Sornette, 2014). While the fat tails of returns that are observable specifically for high frequency assets (one month or less) (Cont, 2001; Rickles, 2011) cannot be explained using the Gaussian distribution, in reality, these fat tails also point to the fact that large fluctuations in financial returns are more common than considered under the EMH. Hence, large fluctuations in financial market prices that can be observed during bubble episodes cannot be accounted for. And though (log) normal return distributions (assumed in the Black and Scholes formula of option pricing) appear to be a good fit during times of system stability where fluctuations are mild (Sornette, 2003; Rickles, 2011), these assumed distributions do not consider and are incapable of determining larger fluctuations that occur during times of increasing system instability (bubble episodes).

3. Econophysics and its explanations for bubbles

Econophysics utilises the complex system approach discussed in section 2 of this chapter to not only account for the complex structure of financial markets (Sornette, 2003, 2014), but to also explain the non-equilibrium nature of these markets (Sornette, 2014). Hence, econophysicists are especially interested in extreme events in financial time series (de Area Leão Pereira et al., 2017). Scheffer et al. (2009, 2012) find, that specifically in complex systems, abrupt changes from one state to another (financial market crashes) are common and happen regularly. Sharp regime shifts, so Scheffer et al. (2012) argue, represent a critical transition which occurs endogenously. Applied to financial markets, extreme events are considered to be market crashes that are presumed to be precipitated by financial market bubbles. Hence, to explain extreme events in the financial system in more detail, the Econophysics literature draws heavily on catastrophe theory (for example Sornette, 2003; Rickles, 2011), with the focus of Econophysics being on the emergence of critical points through endogenously created system instabilities (Scheffer et al., 2009, 2012). Since the critical point is an indicator for a change in system properties hinting towards a regime change of the system as a whole (from stable to unstable and vice versa), it is not surprising that particularly the time and the changing properties of a complex system just before a regime change (from boom to financial market crash) has attracted a lot of research (Sornette, 2003, 2014; Sornette & Woodard, 2010; Scheffer et al., 2009, 2012; de S. Cavalcante et al., 2013).

The most comprehensive attempt to explain financial markets and the reoccurring bubbles in them is made by Sornette (2003). The author is convinced that stock market crashes are comparable to the above-mentioned critical point phenomenon. Due to the cooperative and imitative behaviour of traders which are organized in a hierarchical network, self-organization within financial markets occurs (Sornette, 2003; Sornette & Woodard, 2010; Filimonov & Sornette, 2011; Sornette, 2014). This ever-changing self-organized behaviour on a micro-level leads to peculiar structures and varying characteristics of the overall system on a macro-level, reflected in changing system stability. The changing nature of the self-organized behaviour can be traced back to the different strengths of imitation among market participants (Sornette, 2003; Filimonov & Sornette, 2011; Sornette, 2014). Hence, self-organized behaviour is at the core of bubble formation (Rickles, 2011). When traders are lacking information, it is optimal for them to imitate their neighbours within the network. This imitation leads to local herding and creates order within the system. On the other hand, there exist perceptions on information that are different from individual to individual. If these personal perceptions (biases) are stronger than possible imitating forces or if personal information is believed to be more accurate, individuals within that network will most likely not mimic the actions of their neighbours. Hence disorder ensues.

It must be pointed out that disorder here is not indicative of panic in financial markets, quite the opposite. It suggests that herding does not occur without which a panic cannot emerge. More specifically and applied to financial markets disorder means that many different heterogenous market participants have many different investment strategies and objectives. Hence, actions within such a market are not coordinated in a way that could lead to bubble behaviour. Therefore, disorder within such a complex system is indicative of system stability. On the other hand, it is maintained that, the greater the order is within financial markets, the more traders imitate other traders. Trading and investment strategies are then very similar (or the same) and a certain number of traders have the same (or a very similar) opinion about the market and possible future prospects. A sign of order in financial markets are financial market prices that move together in the same direction. Bubble episodes are then indicative of (rapidly) increasing order within complex financial system.

It should be noted that there are different degrees of order within complex systems. The higher the degree of order, the higher is the level of imitation among traders with respect to investment strategies and opinions about the market and the higher is system instability. Therefore, the higher the degree of order in the system, the more likely it becomes that a bubble emerges. A bubble enforces order and hence instability within the financial system to a point, where a small disturbance to the system (loans are not payed back on time at a local bank) can cause the system to enter a different system state (recession or depression) via a market crash. The changing strength of imitation leads to constantly changing levels of order and disorder, which in turn is indicative of diverse levels of system stability. A high degree of order then corresponds to an increased level of system instability (Sornette, 2003, 2014).

The Ising model of cooperative behaviour, so Sornette (2003, 2014) argues, can describe the interactions of agents, and with that, the struggle between order and disorder. In this physics model, which was initially designed to account for ferromagnetism, the critical point determines the system properties (Sornette, 2014). The stronger the imitation (or ordering) force, the closer will the system be to the critical point. The closer the system is to the critical point, the higher is the system instability and the higher is the likelihood that small disturbances can cause dramatic shifts in system behaviour, such as financial market crashes (Sornette, 2014). Sornette and Woodard (2010) and Sornette (2014) emphasise that the specific cause of a crash is of secondary interest. The crash has an endogenous origin tied to increasing instabilities of the overall system when close to a critical point. Imitation, herding, self-organized behaviour and feedback all lead to increasing instabilities (Sornette, 2014). Specifically, the unsustainable increases in stock market prices based on overoptimistic future expectations of most of the public and of most financial market actors, strengthened by (positive) feedback mechanisms is, according to Sornette and Woodard (2010) and Sornette (2014), the true origin of financial market bubbles. Any small disturbance, such as new regulations or interest rate changes, could cause a system crash on a global scale once the system has entered an unstable phase and is close to a critical point. (Sornette, 2014). As discussed in chapter I and chapter II section 3.2., Minsky has a similar theoretical understanding of differing levels of stability emerging within capitalist economies. Unfortunately, this link is not made by Econophysics.

Similar to Sornette (2003), Scheffer et al. (2012) assert that the likelihood of a system transition increases, the closer the system gets to the critical point. Scheffer et al. (2012) maintain that the overall changing behaviour of a system (stable to unstable) depends on the degree of heterogeneity of the components (agents) as well as the degree of connectivity within that system. Hence, the network structure of a system is crucial in determining the overall susceptibility to disturbances[56] arising not only exogenously, but especially endogenously. The higher the degree of connectivity among the network nods (representing agents, banks and other institutions for financial markets), and the higher the homogeneity between those nods (agents, banks, other institutions are similar in, for example, their investment and financing strategies), the greater will be the probability of sudden and severe system changes (Scheffer et al., 2012). In other words, the greater the

[56] Since this approach is heavily rooted in naturally occurring systems, exogenous disturbances could be changes in the environment such as changes in temperature or magnetic fields. Endogenous disturbances are changing levels of stability within the system like increasing fragility of a rabbit population due to too many rabbits being born. Though the general approach seems reasonable, Econophysics have struggled to apply this in detail to the financial market. More on this in section 4.

heterogeneity and connectivity in financial markets, the higher is not only the system instability but also the possibility that bubbles and crashes occur. Hence, with the observable increase in connectivity, but especially homogeneity during bubble episodes, these highly connected and homogenous systems will approach a tipping point (critical point), where small disturbances (customers in a local branch cannot meet their debt) can lead to system wide distress inducing a transition to a new system state (a financial market crash with deflating prices) (Scheffer et al., 2012)[57].

The hallmark of such critical behaviour are power laws. Power law distributions, Sornette (2003) suggests, appear to be a good approximation of the actual price and return distributions of assets, mainly because power laws are fat tailed distributions. However, due to the imitative behaviour in a hierarchical system, log-periodicity has to be expected within simple power law structures (Sornette, 2003, 2014). As the critical point is approached, oscillations of that power law representing rapidly increasing asset prices, intensify. Simply speaking, financial market prices rise at a faster rate the closer the systems gets to the critical point, with the frequency of price oscillations increasing. However, since the acceleration in asset prices (and returns) are oscillatory, phases of acceleration will always be interrupted by quiet phases (Sornette, 2003).

Sornette (2003, 2014) argues that the log-periodic power law structures in asset prices observable before a critical point (or for that matter before a crash) can be used to identify possible future financial crashes. To show this, the author uses a log-periodic correction of a power law to test for past financial crashes. Among those are the Black Monday in the US in 1987, the financial crash of 1929, various crashes of the Hong Kong stock exchange in 1987, 1994 and 1997 and the NASDAQ crash in 2000. For all those past financial crashes, Sornette (2003) is able to fit the data to the log-periodic power law structure surprisingly well. However, when attempting to predict future market crashes using the log-periodic power law by extending current price trends, results are mixed. Sornette (2003) explains the great difficulty in predicting market crashes with the fact that the fitting procedure of the log-periodic power law to actual market data yields several possible crash dates. However, in reality, only one of those possibilities will occur. Similarly, Sornette and Woodard (2010), maintain that the prediction of a specific crash scenario is due to the (time and space specific) randomness of actual crashes impossible. There will always be unforeseeable occurrences that can induce or prolong a crash. Hence, only a general indication of a possible impending crash is possible.

Following a similar argument, Scheffer et al. (2009) maintain that there are empirical (statistical) patterns that are indicative of system fragility which precede large and endogenously emerging system changes (such as a financial market

[57] How this can be applied to financial markets is not explained by the authors. This connection was attempted by Sornette (2003) and this author.

crash). Hence, from a critical transition point of view, generic (statistically observable) system properties arise especially when the system gets closer to a critical point (Scheffer et al., 2009). Those system properties include increased autocorrelation and increased variance (in asset prices or returns for example). Increased variance and autocorrelation can also be indicative of critical slowing down (Scheffer et al., 2009, 2012). Critical slowing down describes the rate at which the system can recover from small perturbations. According to Scheffer et al. (2009, 2012), the recovery rate becomes increasingly slow the closer the system is to a critical point. Hence, small disturbances (such as defaults on loans in a local bank) within the system can then cause abrupt changes towards a new system state (from boom to depression through a financial market crash for example).

However, Scheffer et al. (2012) warn that specific patterns are difficult to identify in real-time data due to the lack of appropriate models (Scheffer et al., 2009). Hence, critical slowing down should be used as a general indicator for a possible change of the current regime (Scheffer et al., 2012). On top of that, and contrary to what Sornette (2003) attempts, Scheffer et al. (2012) state that it is impossible to know, how close the system is to a critical point in real time. This then makes it very hard (if not impossible) to identify the degree of system instability and with that, the approximate time the system might flip to a new system state (from bubble through a crash to recession or even depression).

Though generally the Econophysics approach to financial markets seems reasonable, there are major shortcomings when attempting to explain in *detail* how findings made in statistical physics and in the field of complex systems can be applied to financial markets, and here especially to economic bubbles. Those issues, among other things, will be picked up and explored in the following section.

4. The adequacy of Econophysics in explaining economic bubbles and other issues

As shown above, one of the main aims of Econophysics is to explain bubble phenomena in financial markets. Although the complex system approach yielding endogenous bubble creation tied to changing system stability is a promising approach, there are multiple issues surrounding this research field. While some of the problems stem from the ignorance regarding economic research and economic theory, especially from heterodox economics, part of the issues that arise derive from the impossibility to match findings in natural complex systems (where the properties of particles always behave in the same way) and findings made in statistical physics, to the socio-economic sphere.

It should be pointed out that a unified and/or formal model description of bubbles is still missing. One reason for this might be the relatively loose collective of researchers working in that area. Another reason could be that the research that is being done does not only concern financial market bubbles and crashes, but all types of different extreme events such as earthquakes, erupting volcanoes, and tipping points of biospheres to name a few. It is believed that all these extreme events in complex systems do have a similar underlying signature when the critical point (also bifurcation point or tipping point) is approached. These typical signatures hold over many different classes of complex systems. Since financial markets are considered complex systems themselves, findings in these other fields are then matched to financial market data. However, the sole reliance on empirical data and theories rooted in physics in combination with the belief that statistical findings alone can explain financial market crashes has led to great difficulties within Econophysics when attempting to relate statistical observations to socio-economic systems on a theoretical level (McCauley, 2006; Suavoiu & Iorga–Simuan, 2008; Jovanovic & Schinckus, 2013). Kirman (2018) argues that Econophysics has not been successful in its attempt to create a new theory based on empirical observations. McCauley (2006) stresses that statistical physics alone cannot explain financial market bubbles while Jovanovic and Schinckus (2013) believe that Econophysics is not only less concerned with theoretical explanations, but that Econophysics has, despite the mathematically more robust explanations of financial market crashes, very rarely contributed to new theoretical appraisals of the data observations.

These, and other issues relating to economic bubbles will be picked up and discussed in the following subsections.

4.1. Missing economic theory and neoclassical explanations of financial markets

Although claiming that a (bubble) theory is developed through empirical observations in financial market data alone (Rickles, 2011), Econophysics is nevertheless based on theoretical assumptions. Though these assumptions are not rooted in economic theory but in the theory of (naturally occurring) complex systems and (statistical) physics, they are omnipresent. One of those assumptions is the existence of one (or more) stable equilibria (Sornette, 2003; de S. Cavalcante et al., 2013). Jovanovic and Schinckus (2013) argue that though Econophysics generally does not reject the notion of equilibrium, the equilibrium assumption itself does not play a key role in their analysis. Hence it is understood that the economic system does (theoretically) not necessarily converge towards an (existing) equilibrium (Jovanovic & Schinckus, 2013).

Additionally, Suavoiu and Iorga–Simuan (2008) indicate that due to the non-stationarity of markets, general stability (hinting towards equilibrium) cannot be assumed. McCauley (2006) rejects the notion of an equilibrium on the same non-stationarity claim arguing that financial time series never approach any constants and that hence financial markets do not have an equilibrium state. On the other hand, Scheffer et al. (2012) state that complex systems are more often than not found close to attractors (equilibria). Cavalcante et al. (2013) argue that in complex systems there exists an equilibrium around which the system normally evolves. If another equilibrium is present, then the system will flip between these equilibria (or basins of attraction). The transition between those two states via the bifurcation (tipping) point so the authors argue, causes extreme events (bubbles and crashes). However, the system will always be pulled back towards that equilibrium it should normally be in. While this may seem obvious for temperature fluctuations, it is highly questionable for periods of financial and economic bubbles. The assumption of a natural ruler which controls system behaviour ensuring some kind of equilibrium, while possibly a good representation for natural systems, appears to be questionable for human-made socio-economic systems. And although Sornette (2003, 2014) clearly mentions his intention to explain out of equilibrium fluctuations (bubbles), the term itself hints towards the existence of a possible equilibrium. This suspicion is supported by the notion that negative feedback in financial markets regulates growth back towards the equilibrium and that mathematically, financial market models consisting of multiple equilibria, are adequate (Sornette, 2003). However, at the same time the equilibrium assumption based in economic theory is criticised as being too harsh (Sornette, 2003). Hence, theoretically it is unclear where Econophysics stands with regards to the equilibrium assumption. Mathematically however it appears that the calculations are based on natural systems that are generally stable and exhibit equilibria. This can be seen by the consistent reference to the α– stable Lévy distribution (Sornette, 2003; Jovanovic & Schinckus, 2013; de Area Leão Pereira et al., 2017) as a variation of the Gaussian distribution to depict price behaviour in financial markets. Under the assumption of a calculatable variance, it appears that implicitly an underlying value, fundamental or equilibrium price is tied to this (and other) stable distribution(s). However, and as it is argued within this thesis, perceived underlying fundamental values or observable price trends within financial markets are a sign of high order (e.g. high connectivity and homogeneity) in financial markets as well as an indicator for the prevailing convention within such markets. Hence, the claim of scaling and universality tied to such stable distributions seems theoretically not plausible as the degree of order and the underlying convention especially within bubble episodes may change quicker than the distribution permits (more on this in section 4.2. of this chapter). And although fat-tailed distributions allow for more extreme fluctuations in price than the Gaussian distribution, global system stability and an underlying fundamental value prevail[58]. However, and as argued throughout chapters II and III, equilibrium systems are not an acceptable representation of social systems such as the economy, specifically when attempting to understand bubble phenomena.

The attempt to explain the (price) behaviour in financial markets merely based on observable data and to derive realistic measures or possibly models based on those observations is appealing at first glance (Gallegati et al., 2006; Rickles, 2011). The same can be said about the attempts of Econophysics to find the underlying mechanisms responsible for financial markets' stylized facts, and here

[58] On a side note it appears that difficulties and unclarities of this type may contribute to the fact that to date Econophysics has yet to produce a coherent bubble model. It seems as if empirical regularities needed for such a model are still not quite agreed upon.

especially for bubble behaviour. However, the single use of physics models to explain socio-economic phenomena is inappropriate. For example, the Ising model which was initially developed to account for magnetic polarisation (Sornette, 2014), is uncritically used to explain social influence on humans, individual decisions and interactions within a social network (Sornette, 2003, 2014; Sornette & Woodard, 2010). The attempt to explain how communication takes place goes back to the complex system approach discussed in section 2 of this chapter, where microstructures generate different macrostructures. While throughout most of the literature the behaviour of agents is ignored (Rickles, 2011), an explanation of how people behave becomes inevitable if the Ising model is employed. Assumptions made about the behaviour of agents then range from rational (Sornette, 2003), to boundedly rational (Sornette, 2014) to behavioural (non-rational), where biases and heuristics take over (Sornette & Woodard, 2010). However, it remains unclear how exactly these different types of behaviour (Rickles, 2011) can generate especially financial market crashes (which are preceded by bubble episodes), even when the network approach to markets is added (for example Sornette, 2003).

According to Sornette (2003), the risk of a crash increases dramatically when the interaction between traders becomes strong enough. Similarly, a bubble occurs due to an increase in effective interactions of investors leading to increases in market prices (Sornette & Woodard, 2010). What this means for real markets, how this could be measured and, how this could be included into a model representation of financial bubble episodes remains a mystery. While possibly valid for ferromagnetism, it appears to be too simplistic to assume increased (effective) communication between particles (agents) will lead to increased system instabilities and crashes. Human communication is too complex to be captured in this way. It cannot simply be assumed that socio-economic systems behave in the same way as electrons or water molecules when interacting with each other (Suavoiu & Iorga–Simuan, 2008). Further, the fall-back on behavioural economics and New Keynesian assumptions about agents' psychology such as bounded rationality or biased behaviour as well as the notion of Animal Spirits (Sornette, 2003, 2014; Sornette & Woodard, 2010) leading to economic bubbles has to be questioned[59]. Not only are these varying types of agents' behaviour vaguely defined so that anything could trigger a bubble episode due to the multitude of possible biases and heuristics, but the varying behaviour of agents will always be case (bubble) specific and cannot be used to derive stylized facts for bubbles. Additionally, when employing the complex system approach, the overall direction of the system (stable to unstable) should be the focus. Hence, it should be sufficient to acknowledge that agents' behaviour is never fully rational in the Muth, (1961) sense. What could be useful to depict changing system stability is the consideration of the (endogenous) creation of money and availability of credit within the economic system over the course of a boom turning into a bubble (Keen,

[59] A more detailed discussion on this can be found in chapter II section 2.4.3.2.

1995, 2011, 2013, 2017; Leijonhufvud, 2009a). While Minsky (2008b) did consider such an analysis, unfortunately, within Econophysics, this is not touched upon. A more detailed discussion regarding this issue will follow in 4.3.

The fall-back on more traditional theoretical explanations of not only financial markets, but also bubble episodes stems from the fact that Econophysicists are unaware of the richness of economic theory (especially in the heterodox tradition) (Gallegati et al., 2006). For example, Sornette (2003) attempts to explain the increased volatility of financial market prices since the 1980s by linking it to hedging strategies of investors. Financialisation or, for that matter changes within financial markets towards a more liberalised approach, are not considered. Overall, Econophysics' attempts to explain economic bubbles are very vague and not capable of offering a clear understanding of what bubbles really are. It is very disappointing that even with the complex system knowledge at hand, very general, theoretically unsatisfactory explanations for economic bubbles are employed (for example in Sornette, 2003, 2014). Not surprisingly, Sornette (2003) comes to believe that bubbles do not always crash but deflate smoothly, depending on agents' behaviour. A statement in strong opposition to what, for example Minsky (2008b) or Galbraith (1993) maintain and to what is argued throughout this thesis.

Similarly, Sornette (2003, 2014) believes that the EMH is a good approximation for financial markets as assumptions made there hold during 'normal' (stable) times. However, the author then struggles to theoretically explain bubble episodes. Sornette (2003) can only explain bubbles by adding the behaviour of traders. According to Sornette (2003), not all traders have yet learned to use the information included in financial market prices correctly. That in combination with changing confidence, market psychology and future beliefs leads to self-fulfilling bubbles and crashes. In a similar vein, Sornette and Woodard (2010) attempt to explain the 2007/2008 Subprime crisis. According to the authors, the then new financial instruments (CDO's – collateralized debt obligation) would theoretically cause no harm during stable times. Sornette and Woodard (2010) fall back on the specific-historical-context argument where new financial instruments simply happened to be available. Again, one must point to Galbraith (1993) who argues that every major financial crisis is clearly connected to financial innovation and hence to newly available financial instruments. And according to the author, all financial innovation is clearly connected to the creation of debt.

Again, the complex system approach, though tied to natural phenomena, would have so much more explanatory power if neoclassical explanations were left aside. The complex systems approach could be linked to heterodox theory relatively easily (specifically to the literature in the Minskian tradition discussed in chapter II section 3.2. and throughout chapter V). However, and as stated earlier, a lot of the literature appears to be unknown to econophysicists. Hence, the most prominent paradigm (neoclassical economics) is fitted to the complex system approach. This lack of theoretical grounding in the rich economic literature makes it impossible for Econophysics to explain their empirical findings theoretically and hence link relevant discoveries made in the field of complex systems and criticality meaningful to socio-economic systems. A relevant bubble explanation cannot occur if the only economic theory employed is in a neoclassical tradition, no matter how ground-breaking the empirical discoveries in financial markets tied to (statistical) physics are.

Another issue that partially emerges out of the heavy reliance on neoclassical theory when attempting to explain economic bubbles (statistical physics tools aside), and partially out of the importance placed on critical phenomena and the before mentioned implicit assumption of equilibrium states, is the theoretical non-inclusive approach to economic bubbles. This means that macroscopic properties of the system can clearly be divided into normal (stable) and bubble (unstable) times. While this classification might be obvious with regards to statistical properties in financial time series (Sornette, 2003), the assumption that there exists two (or more) different system states between which the economy switches is too simplistic and does not move much from the neoclassical assumption of normal times versus bubble times. Theoretically this might have the consequence that economic bubbles easily become outliers, situations that usually do not happen, confined to specific markets, regions and times; even if the recognized fat-tailed return distributions and self-organization within a complex system tell a different story mathematically. When the economy is theoretically approached this way, the explanation for bubble behaviour will always yield a neoclassical interpretation. Then it is enough to look at bubble periods in isolation. This isolated approach has been adopted by Econophysics (Sornette, 2003, 2014, Scheffer et al., 2009, 2012; Sornette & Woodard, 2010; de S. Cavalcante et al., 2013). The mathematical analysis usually starts out during the bubble episode, and here close to the possible crash (tipping point). If the biggest concern lies in when the system will pass a bifurcation point, economic bubbles cannot be explained. Without explicitly considering the evolution of the (complex) system over time, it is impossible to understand economic bubbles[60]. If the broader system evolution over time is considered, it becomes clear that bubbles are not a system state independent to what is usually observed. It is a naturally occurring part of what can be observed in a complex system, even if the statistical properties change during that specific period. As previously mentioned, the evolution from stable to unstable economic system states (linked to the creation of credit and the types of investment) is an important indicator for system stability. However, and again, this is not clearly formulated. Econophysics runs into great difficulties when attempting to relate the theoretical insights of the Ising model to financial market behaviour. Though theoretically the model is very plausible, Econophysics cannot link the explanations of changing order and disorder meaningfully to financial markets.

A final issue regarding the theoretical approach of Econophysics to economic bubbles is the assumption that, simply because financial markets display

[60] An issue tied to this is the isolated approach to financial markets. A point that will be picked up in 4.3.

characteristics of complex systems found in the natural sciences (Sornette, 2003; Rickles, 2011; Scheffer et al., 2012), findings made there can universally be applied to different markets, regions and times[61]. Though financial market time series display statistical properties found in other complex systems (Rickles, 2011), economic and financial systems are not natural systems that evolve at a constant rate over time. Socio-economic systems not only change at a much faster rate over time, they also change at a more varying rate than natural systems. The environment in which financial markets are embedded cannot be compared to natural systems when looking at the rate at which underlying structures have changed in the past (e.g. policy regimes, technological changes etc.).

Suavoiu and Iorga–Simuan (2008) point out, that the discovered distributions in time series are by no means conclusive and stable. These distributions change with the agents' collective behaviour. McCauley (2006), states that universalities should not be expected in socio-economic systems. Therefore, it is highly questionable if statistical properties found in specific financial markets of certain countries can really be universally applied to all other financial markets. It appears more likely that those structures are similar across countries with a similar economic model, similar organisation of financial markets and a similar policy regime. Hence, statistical regularities are not universal but specific to a certain (similar) group of countries. Again, it needs to be pointed out that socio-economic systems of interacting people cannot be compared to particles that will always yield the same outcome. Comparable to above argument, the changing institutional setup as well as the alternating nature of the economy itself change and define the behaviour of agents and of the (economic) system as a whole. Hence, universal regularities found in natural complex systems can most likely not be applied over regions, time and markets as is claimed by Econophysics.

Besides these theoretical complications when attempting to relate empirical findings in financial time series data to the workings of socio-economic systems, there are also unresolved issues with regards to mathematical tools, statistical testing and the appropriateness of specific distributions. These issues will be picked up and evaluated in the following section.

4.2. Unsolved problems regarding the mathematical methodology

Possibly due to a missing theoretical socio-economic grounding, the research field of Econophysics is very diverse when attempting to explain economic bubbles. Explanations for economic bubbles range from attractor bubbling in chaotic systems (de S. Cavalcante et al., 2013) to the critical point analogy in highly organised systems (for example Sornette, 2003) to self-excited multi fractal dynamics (SEMF process) (Filimonov & Sornette, 2011) to account for chaotic dynamics in financial markets.

[61] The universality claim can be traced back to the underlying power-law distributions. These fat-tailed distributions are assumed to represent (financial) market behaviour well. A point that will be picked up in 4.2.

Cavalcante et al. (2013) believe that during bubble episodes, the system jumps from the stable equilibrium orbit it is usually in, onto the orbit of a strange attractor in neighbouring regions. Strange attractors only emerge in chaotic systems. Hence, if the financial system during bubble episodes would in fact follow the orbit of a strange attractor, it would be impossible to depict where the system as a whole will be in the next time step. It could be really close to the present location in phase space, however it could also be really far from the present location. It would be simply impossible to know where exactly the system could be next. Translated to financial market prices this would mean that prices could be very high today, extremely low tomorrow and very high again the next day. Though not mentioned in Cavalcante et al. (2013), a resemblance to the EMH, where prices evolve independently in each time step, appears obvious. However, when looking at financial market data, the belief that the financial system could in fact follow the orbit of a strange attractor is falsified through the empirical observation of volatility clustering, where price increases are followed by price increases (increasing buy orders) and price decreases are followed by price decreases (increasing sell orders), especially during bubble episodes. Additionally, and as argued above, it must be questioned if financial markets really resemble chaotic systems (in the sense of non-coordination) and if a stable equilibrium, even if dynamic, exists.

Filimonov and Sornette (2011) attempt to explain the self-organized behaviour of financial markets, quantify complex fluctuations in financial systems and account for critical events (market crashes) via the SEMF process. Their emphasis lies on the non-stationarity of increments, especially that of financial market prices and returns. Non-stationarity here means that price increases (or decreases) can differ substantially in each time step and do not grow at a similar pace at all times (as would be the case for a geometric Brownian motion in combination with Gaussian return distributions underlying most finance models). The non-stationarity of returns, the authors explain, is responsible for transitory and permanent regime shifts of the system. At the root of non-stationarity within the SEMF process is the rare occurrence of extreme events such as financial market crashes (Filimonov & Sornette, 2011). According to the authors, those rare and extensive outbreaks of volatility within a system, are responsible for the heavy (fat) tails that can be observed for financial market return distributions. Return distributions that range within 1% - 20% can easily be explained by power law structures(Filimonov & Sornette, 2011:4). However, for return distributions that go beyond this range, the SEMF process with its quasi-stationary regimes that are infrequently interrupted by bubbles and crashes, is a better representation (Filimonov & Sornette, 2011). Filimonov and Sornette (2011) then name the, for financial markets observable self-organization and times of instabilities, to be stylized facts of chaotic dynamics found in financial markets. However, the authors' attempt to explain financial market crashes solely based on the created SEMF process is, unfortunately disappointing and cannot be used to identify economic bubbles. It also appears to be a step back for Sornette who had a much better interpretation for the emergence of system instabilities in his 2003 book. It is a very vague attempt when theorising that system fragility is due to changing market prices. Arguably, changing market prices can also be seen as the result of changing system fragility (see for example Sornette, 2003; Minsky, 2008b) and not as the cause.

Overall within the literature, more attention has been given to the critical point analogy and criticality, where system properties can change dramatically after the tipping point (bifurcation point, critical point) is passed. In financial markets, such dramatic regime shifts are associated with financial market crashes which are believed to be preceded by bubble episodes (Sornette 2003, 2014; Scheffer et al. 2009, 2012). The hallmark of such criticality are power law distributions (Sornette, 2003; Rickles, 2011) which found a wide application within Econophysics (Jovanovic & Schinckus, 2013; de Area Leão Pereira et al., 2017).

However, it has been questioned if power laws are in fact an appropriate distribution that can be used to describe financial market behaviour (Jovanovic & Schinckus, 2013). In 2014, Sornette points out that power law structures are only valid over a very limited range and might overall be too simplistic to determine financial market returns and prices. Similarly, Gallegati et al. (2006) argue that there is no reason to believe that simple power law structures can actually be found in differing socio-economic data sets. Rickles (2011), while leaning on Pisarenko and Sornette (2006, cited in Rickles, 2011: 558) maintains that power laws can at best be a vague approximation of financial return behaviour. Further so the author argues, there are several other fat tailed distributions that would offer similar approximations to data sets found in finance. Employing a variant of the simple power law[62], Sornette (2003) admits that there are significant issues when attempting to prove that log-periodic power laws are associated with specific market mechanisms (such as bubbles and crashes). The author even goes so far than to say that a proof may be indeed impossible.

Cavalcante et al. (2013) argue that extreme events such as financial market crashes cannot be predicted when power laws are used. This is because power laws are scale free (also called scale invariant or scale free symmetry) distributions. In statistical physics, scaling laws emerge as system properties due to interactions on the microscopic level (Rickles, 2011). For economics this would mean that the interactions of traders result in specific (aggregate) market behaviour. Scale free symmetry not only points to the underlying idea of overall system stability with Sornette (2003: 191) highlighting the fact that precisely at the critical point, the scale invariance symmetry of a system is exact[63]. Scale invariance also describes the properties of a system that remain invariant under certain transformations such as rotation or inversion (Sornette, 2003) and transformations of scale (Rickles, 2011). In other words, the probability of observing (bubbles and)

[62] The afore mentioned log-periodic power law.

[63] This indicates a balanced system. For neoclassical economics this translates into a stable equilibrium. A critique of the stability and equilibrium assumption can be found throughout chapter II, in chapter III section 4.1. and throughout this chapter.

crashes of different magnitudes does not depend on the size of the event itself (Rickles, 2011). Small and extremely large crashes have the same probability of occurrence and are caused by the same underlying structures and behaviour of market participants. Scale invariance also indicates that properties of the system can be reproduced on different time and space scales (Sornette, 2003). For financial returns and financial market crashes this means that their underlying features do not change over instruments, regions and times, for example. Financial market crashes are therefore assumed to have universal features and underlying mechanisms that are identifiable for any bubble and crash scenario. Hence, scale invariance represents universality (Sornette, 2003).

In addition to the theoretical critique regarding universality expressed in 4.1., it is unclear if the use of scaling laws signalling universality is mathematically appropriate (Rickles, 2011). Similar to Cavalcante et al. (2013), Brooks (1999, cited in Rickles, 2011: 558) maintains that stochastic processes (which arguably can be observed within financial markets) are underrepresented when scaling laws are used. Further, one scaling law could compare with different distributions (other than power laws), hence the issue of identification arises. Rickles (2011) indicates that the isolation of a specific scaling law within financial market data is not enough to identify the underlying mechanism (distribution) that generated the data. Therefore, so the author discusses, it must be accepted that scaling laws can falsify (e.g. the Gaussian distribution, which is not scale free) but not confirm which underlying distribution is at work. According to McCauley (2006), the emphasis of statistical physics on universality, and with that on universal exponents is, for financial markets, unjustified. Scaling exponents in financial markets, so the author explains, range from 2-7 and are market dependent (McCauley, 2006: 604).

Additionally Gallegati et al. (2006) argue that a more robust statistical analysis is needed within Econophysics. The authors even believe that there exists a resistance towards more rigorous statistical testing. For example, Sornette (2003) is able to create good visual fits for past bubble episodes and their crashes. However, market crashes cannot be predicted through visual fits and the accompanying data mining procedures. This, so the authors maintain, would have been obvious had a more precise statistical analysis in combination with explicit tests taken place. Additionally, needed observables for the fitting procedure employed by Sornette (2003), such as the lowest value of an index before the start of a bubble and the highest value of an index just before the crash, can in real time not be determined or cannot be precisely predicted. The visual identification of a critical point in past time series might be obvious, in real time however it is impossible to know how close a system is to the critical point (Scheffer et al., 2012). Considering how important the critical point is when trying to identify financial market crashes within the literature, this statement is rather disappointing. Further, Scheffer et al. (2012) highlight the fact that there exist considerable obstacles in developing accurate procedures for the identification of, for example, critical points. Empirical indicators such as flickering, increases in volatility or slowing down cannot be used to predict regime shifts (financial market crashes). Unpredictable, stochastic shocks, so the authors argue, will always play a role due to the unknown future as well as due to the complexity of the system itself. Additionally, Scheffer et al. (2012) point out that real values of above-mentioned empirical indicators can, as of yet, not be used to depict differing levels of system fragility. Gaps in the understanding of how exactly complex systems work remain. Therefore, the authors are convinced that Econophysics is far from being able to construct robust and accurate predictive models of financial market crashes.

In addition to these complications, it is also questionable if market bubbles and crashes can really be understood if financial markets are looked at in separation from the rest of the economy. Similar arguments that have already been brought forward in chapter III, section 4.2. can be made. Hence the following section will briefly discuss how points made previously can be critically applied to Econophysics.

4.3. The issue of partial analysis, no money and no production

Like the sunspot and rational bubble models discussed in chapter III, Econophysics mostly looks at one market (financial market) only and in isolation to the rest of the economy (McCauley, 2006; Suavoiu & Iorga–Simuan, 2008; Jovanovic & Schinckus, 2013). And here, mostly the time around the critical point indicating a possible crash is of interest. (Sornette, 2003, 2014; Gallegati et al., 2006; Scheffer et al., 2009; Sornette & Woodard, 2010; Filimonov & Sornette, 2011; Rickles, 2011). The justification to do this, appears to be the amount of available and reliable data (which needs to be considerably high so that statistical physics methods can be applied), as well as the conviction that financial markets dominate all other sectors of the economy (McCauley, 2006; Suavoiu & Iorga–Simuan, 2008; Sornette & Woodard, 2010). However, and as mentioned above, a connection to financialisation is not made. Production, investment, endogenous money creation via credit, as well as institutions and the institutional setup of the economy are all ignored which, according to the bubble definition set out in chapter I section 1, must be considered in any benchmark model. As Gallegati et al. (2006) infer, when ignoring changes in key economic relationships over time, findings made cannot be a valid explanation for capitalist economies, especially when production is neglected. Similarly, McCauley (2006) asserts that such barter economies are neither empirically nor theoretically relevant. Suavoiu and Iorga–Simuan (2008) rightly note that financial markets are only part of the bigger economic system. Questionable empirical regularities (scaling and universalities) found through an isolated analysis, if they indeed existed, could then certainly not just be applied to the whole system (Suavoiu & Iorga–Simuan, 2008). And as already mentioned in chapter III section 4.2, it is unclear why a financial market should exist if there is no production, investments, or loans. There simply is no meaningful justification.

Especially the neglect of loan creation tied to investment leads the promising complex system approach to the economy ad absurdum. Explanations for financial crashes are then tied to the increased, effective communication of investors alone (Sornette, 2014). How this could be measured and used to depict changing levels of system fragility is unclear. Additionally, money does not play a role within Econophysics. Though prices of assets are of concern, it is unclear why exactly these prices change (other than due to psychological factors, see for example Sornette (2003)). Bubbles that have emerged out of consumption booms that were stipulated by liberalisations in the financial sector (easy availability of credit) and are tied to (suddenly) increasing purchasing power such as in Sweden in the 1980s and Japan in the early 1990s (Glyn, 2006), cannot be explained if money and with that, money creation is ignored. Would endogenous money creation, the changing type of investment, as well the changing type of loans over the course of an economic cycle be considered, changing levels of system fragility over time, and with that economic bubbles, could not only be measured and described in real time, theoretical explanations of system instabilities would also be less vague.

Without considering the whole economy, its institutions and with that money creation, investment and production, a realistic endogenous bubble analysis cannot take place. It is not enough to simply confine the analysis to one specific market and here, only to one specific phase of the bubble (crash) to meaningfully explain economic bubbles. By only observing the outcome within an already restricted analysis, it will not be possible to understand what exactly constitutes bubbles. Unfortunately, and due to a missing socio-economic theory underlying the Econophysics approach, Econophysics employs the heavily criticised neoclassical theory; implicitly by considering a 'natural' stable state and explicitly by using psychological factors to explain 'rare' events such as economic crashes, while emphasising barter economies by ignoring production, investment, credit and money.

However, the complex system approach popularised by Econophysics is promising. Similarly, findings made by Econophysics within financial market data such as fat-tails of returns have to be appreciated as these findings have not only (mathematically) falsified assumptions made by the EMH (such as Gaussian return distributions), these findings have also made it clear that financial bubbles are by no means a rare and exogenously created phenomena, that should never occur. To end on a positive note and to highlight possible future applications, especially in a Minskian view of economic bubbles, a brief summary of valuable Econophysics findings will be presented before this chapter is concluded.

5. Improvements to the exogenous bubble approach and conclusion

The main contributions made by Econophysics to financial market theory and the theory of bubbles is based on their analysis of time series data (Gallegati et al., 2006). The revelation, that return distributions are by no means Gaussian but indeed fat-tailed and that there exists volatility clustering in financial market data can, among other things, be attributed to Econophysics (Gallegati et al., 2006;

Rickles, 2011). The importance of these findings cannot be overstated. Based on empirical financial market data, it could be shown mathematically that economic bubbles and crashes do occur more often and at greater amplitude than assumed by the neoclassical paradigm, especially the EMH. Fat tails and other stylized facts of financial markets (for example volatility clustering and long memory) are also signatures of complexity (Rickles, 2011). Based on these (and other) statistical regularities and based on the fact that financial markets consist of many different interacting agents, an analogy to the complex system approach can be made (Sornette, 2003, 2014; Gallegati et al., 2006; Scheffer et al., 2009; Sornette & Woodard, 2010; Rickles, 2011; de S. Cavalcante et al., 2013).

Appealing in the complex system approach to the economy is not only the fact that interactions on a microscale lead to macroscopic properties that are different from those on the microscale, but that also influence the interactions on the macroscopic level (Rickles, 2011). When economies are looked at in this light, it becomes apparent that properties of the system are emergent. This means that through changing interactions on the microscopic level, aggregate properties of the economy such as stability (or fragility) levels are not only created from within but do themselves change (and cause change). Financial bubbles are then an endogenous part of an evolving complex system, tied to the level of system instability (Sornette & Woodard, 2010; Sornette, 2014). No exogenous factors are needed to create a bubble, though they could induce the bubble to burst (and crashes to occur).

A theoretical account for changing system instabilities based on economic theory can be found in Minsky (1970, 1982, 1992, 2008b) and, in combination with the complex system approach, appears worth pursuing. Endogenously emerging changing stability levels in Minsky's analysis, and with that, bubble episodes, are explained via the changing quantity and quality of debt over the course of a boom. Links between the real and financial side of the economy are made via debt and income streams connecting firms, investors, banks and other financial institutions and households, which enables an integrated analysis of the economy over time. The changing debt levels in combination with the financial links between above mentioned market participants could then be used to explain emerging complex system behaviour leaning on theoretical accounts of complex systems found in Econophysics.

In the following chapter, a first attempt to include the complex system approach into a Minskian inspired mathematical model, with production, investment and the evolution of debt at its core, will be presented.

Chapter V: Keen's Minsky Inspired Monetary Model of the Economy

1. Introduction

As discussed in chapter IV, the complexity approach to economic models offers a promising way to explain emergent and aggregate economic behaviour including bubble episodes. Not only can changing microscopic behaviour account for macroscopic system properties and vice versa, but also, the changing level of system fragility over time can be explained. What is interesting from a modelling point of view is that, when utilising this approach, relatively simple model equations can lead to (very) complex system behaviour through the interaction of the different system equations. As argued in chapter IV however, the missing coherent (economic) theory underlying the Econophysics (and to some extent the complex system) approach is a major shortcoming.

As argued in chapters I, II and IV, Minsky's analysis is an analysis of a complex system evolving over time. Hence, combining insights from the complex system approach discussed in chapter IV section 2 with Minsky's FIH appears to be the next step in understanding bubble episodes specifically, and the evolution of a capitalist economy in general. Keen's knowledge of not only the FIH but also his familiarity with the mathematical side of complex model approaches (such as Econophysics) has made his attempts to model Minsky's theory the most convincing to date. Keen's (1995, 2011, 2013) aim is to generate an endogenous business cycle model consisting of households, an active real and an active financial sector of the economy where the importance of money is recognized and where endogenous money creation is explicitly considered. Specifically, endogenous money creation via the creation of debt is theoretically recognized to have direct implications for the evolution of the economic system over time, possibly leading to economic crisis.

Keen's first attempts to express the FIH through a mathematical model culminated in 1995, with the altered Goodwin growth cycle model. The inclusion of debt into that model, led, so Keen (1995) argues, to qualitatively promising results. A debt induced breakdown within the model, where investment and employment fall while debt rises, occurs (Keen, 1995). This altered growth model has since become the base model for Keen's attempts to model the FIH. In later works (Keen, 2011, 2013), the author links this base model, which only considers the real (producing) side of the economy, to the financial side of the economy, where endogenous money creation (via bank credit) becomes possible. Keen (2011, 2013, 2017) argues that his Minsky inspired complexity model can not only create (complex) endogenous cycles, including economic boom and bust episodes, but that the model is also capable of (qualitatively) explaining the economic development of the past five decades, including the Great Moderation and the global financial crisis that commenced in 2007/2008.

In the following section 2, Keen's model will be discussed. For this purpose, the (altered) Goodwin growth cycle will be looked at in section 2.1. which is followed by a brief explanation of stock flow consistent modelling, specifically the equations stemming from the Goodley table in section 2.2. Section 2.3. concludes by bringing both, the Goodwin growth cycle and the Godley table together, leading to the final Keen model. Section 3 consists of a critical appraisal of the model, specifically with regards to economic bubbles. Though the model is capable of mathematically generating endogenous bubble episodes, unfortunately the level of abstraction and schematization is so high, that findings of that model cannot be applied to specific economic episodes of the past (or the future), which is in contrast to what Keen (2013) believes. Section 4 concludes this chapter.

2. The model

The presentation of the Keen model in this section predominantly leans on Keen's 2013 paper as this is the most complete and coherent representation of the model by the author to date. To retain coherence, symbols used are different from those used by Goodwin (1967) and correspond to Blatt (1983) and Keen (2013). Keen's model is developed in three steps. As mentioned previously, the Goodwin growth cycle can be seen as Keen's model foundation. This can be traced back to the capability of the growth cycle model to generate continuous, endogenous cycles. Hence, step one is to understand Goodwin's growth cycle. However, as Keen (1995, 2011, 2013) infers, adjustments to some of the equations (investment and Phillips curve) need to be made for a more realistic model. Therefore, step two in the modelling process involves the alteration of the Goodwin growth cycle and the introduction of debt. Finally, in step three, Keen (2011, 2013) introduces the financial sector into the model via the Godley table. The Godley table is taken from the stock flow consistent approach to economic dynamics and describes the financial identities in that approach. In the following subsections, these three steps will be looked at in detail.

2.1. The Goodwin growth cycle

Goodwin was not only one of the first proponents for the usage of a non-linear analysis in economics, his growth cycle is also understood to be the first application of the Lotka-Volterra (predator – prey) equations (Harvie, 2000; Gandolfo, 2009; Sordi & Vercelli, 2014). The Goodwin model is a highly schematized model of cycles in growth rates (Goodwin, 1967; Blatt, 1983; Gandolfo, 2009; Sordi & Vercelli, 2014), which are caused by the interplay of the level of employment and the wage share of output (Harvie, 2000; Gandolfo, 2009; Keen, 2013; Sordi & Vercelli, 2014). The solution to the two differential equations of the system (the level of employment and the wage share of output) is a family of closed orbits that all share the same equilibrium[64] at the centre of the cycle(s) (Goodwin, 1967; Blatt, 1983; Harvie, 2000; Gandolfo, 2009; Keen, 2013; Sordi & Vercelli, 2014). The initial

[64] The equilibrium consists of the average values of the workers' share of output (measured in GDP) and the average level of employment over time (Goodwin, 1967; Harvie, 2000).

conditions of the system not only determine on which orbit the system (representative point) moves around on, but they also determine the direction of the movement (Goodwin, 1967; Blatt, 1983; Harvie, 2000). And as long as there are no external changes, the movement on that specific orbit is never ending (Goodwin, 1967; Blatt, 1983). In the very long run, the equilibrium that is shared among the family of closed cycles, is not only independent of initial conditions, but also of external disturbances (Gandolfo, 2009). External shocks will furthermore not change the behaviour of the cycles. The representative point (the system) will simply move to another orbit of the same family (Gandolfo, 2009). Since the equilibrium point is neutral (neither stable nor unstable) (Blatt, 1983), there are no forces that could push the representative point further away, or pull closer to the original cycle in the aftermath of an external shock (Blatt, 1983; Harvie, 2000).

Goodwin made seven assumptions before defining the model's equations: there exists only two factors of production, capital (plant and equipment) and labour; all quantities are in real terms and the capital output ratio is fixed[65]; the labour force as well as productivity are considered to grow at a constant rate whereas the constant productivity growth is justified via technological progress. All profits are presumed to be saved or reinvested, while all wages are consumed. Moreover, wages of workers are believed to rise in the region of full employment (and fall with decreasing employment level). This relationship is represented by the linear Phillips curve relation (Goodwin, 1967; Blatt, 1983; Harvie, 2000; Gandolfo, 2009; Sordi & Vercelli, 2014).

The model equations taken from Keen (2013)[66] are as follows:

The level of output Y is determined by the capital stock K and the fixed accelerator v such that

$$Y = \frac{K}{v} \tag{1.1}$$

Since the accelerator is fixed, output will only change when the capital stock (plant and machinery) changes.

The level of employment L is determined via the fraction of output Y and labour productivity a

$$L = \frac{Y}{a} \tag{1.2}$$

For the employment level to increase, output has to grow faster than labour productivity.

[65] A fixed capital output ratio was specifically considered in Keen (1995). This fixed relation was, while the equation remained unchanged, not explicitly mentioned in Keen (2011, 2013). However, for the simulations, the capital to output ratio $v = \frac{K}{Y}$ is fixed at the value 3.

[66] Keen (1995, 2011, 2013) employs the notation used in Blatt (1983: 204-216).

Since full employment is not presumed in the Goodwin model, the employment rate needs to be defined. The employment rate λ can be derived via the ratio of the level of employment L to population N. Hence

$$\lambda = \frac{L}{N} \tag{1.3}$$

Full employment, though never reached in this model, corresponds to $\lambda = 1$ (Blatt, 1983).

Wages are tied to the employment rate so that an increase in employment (λ approaching 1) will lead to increasing wages (Blatt, 1983). Hence, the Phillips curve relation, which accounts for changes in real wages w via the employment rate λ, can be written as:

$$\frac{1}{w}\frac{dw}{dt} = (-c + d \cdot \lambda), \text{ which is re-written as } P_h(\lambda) = (-c + d \cdot \lambda) \tag{1.4}$$

The level of profit Π, representing the capitalists' share of output, is determined by subtracting the wage rate w times labour L from output Y

$$\Pi = Y - w \cdot L \tag{1.5}$$

Investment solely depends on profit such that, according to above assumptions, all profits Π are used for investment I

$$\Pi = I \tag{1.6}$$

The change of capital stock over time $\frac{dK}{dt}$ is determined through investment I minus depreciation γ of the capital stock

$$\frac{dK}{dt} = I - \gamma \cdot K \tag{1.7}$$

Unfortunately, Keen (2013) does not define the (important) workers' share of income here. Leaning on Goodwin (1967) and Harvie (2000) while using Keen's (2013) denomination, workers' share of income can be defined as $\frac{w \cdot L}{Y}$. Using the definition for L in equation (1.2) we have $\frac{w}{a}$ as workers' share of income. Capitalists' share of income would then be $1 - \frac{w}{a}$.

The model hence consists of 4 differential equations[67]:

The level of employment (over time)

$$\frac{dL}{dt} = L \cdot \left(\frac{1 - \frac{w}{a}}{v} - \gamma - \alpha \right)$$

The real wage (over time)

$$\frac{dw}{dt} = (-c + d \cdot \lambda) \cdot w \qquad (1.8)$$

Labour productivity (over time) and

$$\frac{da}{dt} = \alpha \cdot a$$

Population growth (over time)

$$\frac{dN}{dt} = \beta \cdot N$$

α and β depict the annual percentage growth of labour productivity and population respectively. In the original Goodwin model, parameters α, β, v, c and d are random variables with their respective error terms (Harvie, 2000). However, in the Keen model, these parameters are either fixed (v) or constants (α, β, c, d).

The economic explanation for the resulting cycles of the Goodwin model starts out during the boom phase. When profits are at their highest, employment is at an average level. However, the high growth rate in output pushes the employment level to its maximum[68] level. With employment levels being at their maximum value, wages will increase which leads to a reduction in the profit rate (to its average value). The negative effect on investment and savings (of capitalists only) reduces not only (economic) growth but leads also to a slowdown in job creation. Due to the constant labour force growth and technological progress (that replaces humans with machines) (Blatt, 1983), the slowdown in job creation leads to a push back of the employment rate towards its average value. With profit and growth at their lowest levels, output and employment fall well below the full employment level. At increasingly low levels of employment, productivity rises faster than wage rates. This way, profitability is restored to its average value. Improved profitability

[67] A detailed and easy to follow explanation regarding the needed calculations arriving at the system equations can be found in Gandolfo (2009: 457-460) and in Blatt (1983:211-214), whose explanations are a bit less user friendly. The authors derive the two (complete) system equations, the workers' share of national income and the employment rate over time, that define the behaviour of the system. Gandolfo (2009) uses Goodwin's (1967) notation while Blatt's (1983) notation is the one used by Keen (1995, 2011, 2013).

[68] Please note that maximum employment here does not correspond to full employment. Full employment in the strict mathematical model sense would mean $\lambda = 1$. $\lambda = 1$ implies that everyone in the workforce is working. Unemployment would be 0. In the 'usual' economics sense, the phrasing 'full employment' to represent maximum employment would be acceptable (most people are working and only a very small fraction is not). However, Blatt (1983) points out that this is one distinct difference in the Goodwin model – full employment means everyone is working which cannot be achieved within the model.

will lead to increasing profit and growth, signalling the onset of a new cycle where unemployment is reduced and wages gradually rise (Goodwin, 1967; Blatt, 1983; Harvie, 2000; Gandolfo, 2009; Keen, 2013). As Goodwin (1967) and Gandolfo (2009) point out, the newly improved profitability however may be the cause of future crises. If the expansion triggered by the increased profitability is too strong, so goes the argument, then reserves within the workforce will deplete to very low levels. These low levels of workforce reserves put workers in a stronger position which will enable them to demand (and receive) higher wages. This of course will again squeeze capitalists' profits, triggering an economic downturn. The apparent conflict between capitalists and workers over income shares (Goodwin, 1967), represented via employment levels, profits and wages, can be linked to Marx's approach to the repeated swings within capitalist economies (Goodwin, 1967; Harvie, 2000).

However, Goodwin (1967) maintained that the resulting closed cycles and growth rates are, due to the simplifying assumptions of the model, unrealistic. To resolve this issue, and to link the growth cycle to the FIH (Sordi & Vercelli, 2014), Keen not only amended the assumptions about the linear Phillips curve and the investment function[69], turning them into nonlinear functions, but, while leaning on Blatt's (1983) suggestions, he also introduced the possibility for firms to finance investment via debt (Keen, 1995, 2011, 2013). If the wish to invest exceeds retained earnings, firms are now able to borrow. To express uncertainty surrounding investment, Keen (1995, 2011, 2013), introduces an exponential function[70] to describe investment behaviour, with which trend extrapolation can be captured. In an uncertain world, firms base their investment decisions and future expectations on recently realised profits. Hence, during times of a boom, when profits are high, the desired investment exceeds retained earnings. During times of a downturn when profits are low, the desire to invest is less than profits. This investment behaviour of firms enforces the current (upward or downward) trend (trend extrapolation) leading to gradually inflating (and rapidly deflating) boom and bubble episodes. The same (generalized) exponential function is used to describe the behaviour of wages. During boom periods with high levels of employment, wages rise rapidly while wages fall slowly during times of a downturn when the employment level is low. The generalized exponential function can be written as follows:

$$GenExp(x, x_{val}, y_{val}, s, min) = (y_{val} - min) \cdot e^{\frac{s}{(y_{val} - min)} \cdot (x - x_{val})} + min \qquad (1.9)$$

The parameters to describe the resulting Phillips and investment curve are determined by Keen (2013). Unfortunately, it is not quite clear where these parameters and their respective values come from. For the investment function, the parameter x_{val} corresponds to the profit rate in percentage terms while y_{val} corresponds to investment as percentage of output. For the nonlinear Phillips

[69] By assumption, investment equals profits in the Goodwin model. Hence, the investment function is represented by equation 1.5.

[70] The exponential function can be found in Blatt (1983, as cited in Keen, 1995:615).

curve x_{val} corresponds to λ and y_{val} to $\frac{dw}{dt}$, both in percentage terms. S describes the slope of the respective curve while min identifies the lowest point of the curve in the $x - y$ plane. From this lowest point, an ever upward sloping curve can be observed due to the positive relation of investment and profit (or employment levels and wages).

The introduction of debt D into the model, enables firms to bridge the gap between retained earnings and investment (Keen, 2013; Sordi & Vercelli, 2014). The evolution of the level of debt over time depends on desired investment I[71] and actual profits Π and can be expressed as follows:

$$\frac{dD}{dt} = I - \Pi \tag{1.10}$$

Profit must now be redefined as interest payments on existing debt $r \cdot D$ which reduce overall profits.

$$\Pi = Y - w \cdot L - r \cdot D \tag{1.11}$$

The inclusion of credit turns the model into a 3-dimensional dynamic system (Sordi & Vercelli, 2014), defined through changing levels of output (over time)

$$\frac{dY}{dt} = \left[\frac{I\left(\frac{\Pi}{v \cdot Y}\right)}{v} - \gamma\right] \cdot Y,$$

changes in wage (over time) via the non-linear Phillips curve

$$\frac{dw}{dt} = P_h(\lambda) \cdot w \tag{1.12}$$

and the evolution of debt

$$\frac{dD}{dt} = I\left(\frac{\Pi}{v \cdot Y}\right) \cdot Y - \Pi,$$

with productivity growth and labour force growth being defined as:

$$\frac{da}{dt} = \alpha \cdot a \text{ and } \frac{dN}{dt} = \beta \cdot N.$$[72]

The inclusion of debt and the distributional changes made to the Phillips curve and investment function turn the conservative non-linear system (Goodwin, 1967) into a dissipative[73] dynamical system that depends sensitively on its initial conditions

[71] There is no definition for the investment function other than the generalized exponential function. Just like in the Econophysics approach, Keen (2011, 2013) fits a curve to the assumed investment behaviour of firms without employing the usual behavioural equations.

[72] For both, the original Goodwin cycle and the altered Goodwin cycle, Keen (1995, 2011, 2013) does not actually calculate the system out. Blatt (1983: 211-214), Harvie (2000) and Gandolfo (2009: 457-460) present the system equations for the former, Sordi and Vercelli (2014) for the latter system.

[73] Dissipative systems are based in physics where the total energy of the system changes during the motion. In conservative systems the energy does not change. Applied to this model, though not mentioned by Keen (1995, 2011, 2013), a dissipative economic system is indicative of a complex system with changing stability

(Keen, 2013). As suggested by Blatt (1983), the inclusion of debt also changes the properties of the initial system's neutral equilibrium.

The altered Goodwin model has two[74] distinct equilibrium points (Keen, 2013, 2017; Sordi & Vercelli, 2014). One unique stable equilibrium at the centre of the orbit which is defined in terms of the employment rate, profit rate and the debt to output ratio (Keen, 2013, 2017; Sordi & Vercelli, 2014). If initial conditions are close to this equilibrium, the system will converge towards it (Keen, 2013). This more desirable situation for the economy (Sordi & Vercelli, 2014) can be explained by less optimistic capitalists and their lower willingness to invest (Keen, 2017). With a low propensity to invest so Keen (2017) argues, the system stabilizes. The debt ratio rises to a constant level while cycles in the employment rate and wage share gradually converge towards equilibrium values. The second equilibrium point is also stable (Keen, 2017) and is reached from all starting points (initial conditions) close to it (Keen, 2013). This equilibrium is, according to Sordi and Vercelli (2014), meaningful in a Minskian framework of the economy that allows not only for boom (and bubble), but also for crisis episodes. The equilibrium point at which the system arrives, displays characteristics of an unstable cyclical breakdown (Keen, 2013), where the economic system simply has collapsed. The employment rate and the wage share approach zero, while debt is increasing indefinitely (Sordi & Vercelli, 2014). Keen (2017) attributes cycles that lead to a crisis to the greater optimism of capitalists and hence their higher willingness to invest. The increased propensity to invest induces a debt driven crisis à la Minsky (Keen, 2017).

However, the Goodwin growth cycle, even in the altered form, mainly considers the real side of the economy and arguably a passive financial sector, where debt and loans simply seem to appear. Specifically, increasing purchasing power through endogenous money creation via loans is not considered. To resolve this issue, Keen (2011, 2013) extends his model by the so-called Godley table found in the stock-flow consistent approach popularized by Wynne Godley and Mark Lavoie.

2.2. Stock-flow consistent (SFC) modelling and the inclusion of the Godley table

SFC models can be found predominantly in the Post-Keynesian literature. Those models are models of the macroeconomy attempting to integrate (financial) stocks and flows of the economy (Caverzasi & Godin, 2013). They consist of two main parts: an accounting framework and behavioural equations. Keen (2011, 2013) concentrates his efforts on the accounting framework of this approach in order to

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levels where sudden changes in the behaviour of the system could occur (e.g. symmetry breaking – from stable to unstable). While dissipative systems do have an equilibrium, the motions or movements of the system may be not close to that equilibrium and are hence out of equilibrium movements. Therefore, a model portraying a dissipative system can experience chaotic fluctuations, stable states and a system breakdown. For an in-depth explanation, please refer to Gandolfo (2009: 455-456).

[74] There are in fact three equilibrium points. However, only two of which are economically meaningful. Hence, the third equilibrium is not analysed (Sordi & Vercelli, 2014).

create the identities for the financial side of his model. The behavioural equations of the real side of the economy in his model are taken from the adjusted Goodwin growth cycle.

The accounting framework (referred to as the Godley table) is characterized by a quadruple entry system which reproduces all the transactions and capital gains of each of the institutional sectors of the economy. At the centre of this type of accounting is the premise that each (financial) inflow corresponds to an outflow somewhere in the model (Caverzasi & Godin, 2013). In each period, stocks generate flows. These flows in turn will influence and update stocks. These updated stocks also generate new flows.

As mentioned above, Keen (2011, 2013) utilizes the Godley table to define the fundamental equations of the financial side of his model[75]. For this purpose, and in tune with the equations stemming from the Goodwin growth cycle, Keen (2011, 2013, 2017) categorises three groups, or as he refers to them 'social classes'. All wage earners are grouped into the class 'workers', all profit earners are grouped into the class 'capitalists' and all rent earners are grouped into the class 'bankers' (Keen, 2017:27-28). These three classes find specific application in the Godley table via households, firms and banks. Flows of the banking sector (rentiers) are recorded via changes of the bank vault B_v , which represents the banking sector's monetary assets, and via a bank transaction account B_T through which all expenditure and interest payments flow. Flows of firms (capitalists) are recorded via a firm loan ledger F_L which does not store money but simply records outstanding debt owed to the banking sector, and a firm deposit account F_D into which borrowed money by the firm sector is deposited. Households (workers) are represented via the household deposit account H_D into which wages are paid in (Keen, 2013:17).

Keen uses time constants[76] τ for all his monetary functions (lending of the existing money stock not in circulation as a function of the profit rate $\frac{B_v\,(t)}{\tau_v(\pi_r(t))}$, bank consumption $\frac{B_T(t)}{\tau_B}$, household consumption $\frac{H_D(t)}{\tau_H}$ and the rate of loan repayment as a function of the profit rate $\frac{F_L(t)}{\tau_L(\pi_r(t))}$). The value of any given point in time for all these monetary functions, depends on the rate of profit at that time. Combining table 1 and table 2 of the Keen (2013:18-22) paper, the Goodley table looks as follows:

[75] For a refreshingly easy to follow explanation on the financial market equations using the Godley table please refer to Keen (2013).

[76] Time constants describe the speed at which a process occurs. Keen (2011,2013) fixes the time constants for banks and household consumption and for price setting.

Table 1: The reconstructed Godley table taken from Keen (2013: 18-22)

Row	Transaction	Type	Bank vault B_v	Bank transaction B_T	Firm loan ledger F_L	Firm deposit F_D	Household deposit H_D
1	Lend money	Money transfer	$-\frac{B_v(t)}{\tau_v(\pi_r(t))}$			$+\frac{B_v(t)}{\tau_v(\pi_r(t))}$	
2	Record loan	Ledger entry			$+\frac{B_v(t)}{\tau_v(\pi_r(t))}$		
3	Compound debt	Ledger entry			$+r_L \cdot F_L(t)$		
4	Pay interest	Money transfer		$+r_L \cdot F_L(t)$		$-r_L \cdot F_L(t)$	
5	Record payment	Ledger entry			$-r_L \cdot F_L(t)$		
6	Deposit interest	Money transfer		$-r_D \cdot F_D(t)$		$+r_D \cdot F_D(t)$	
7	Wages	Money transfer				$-W(t) \cdot L(t)$	$+W(t) \cdot L(t)$
8	Deposit interest	Money transfer		$-r_D \cdot H_D(t)$			$+r_D \cdot H_D(t)$
9	Consumption	Money transfer		$-\frac{B_T(t)}{\tau_B}$		$+\left[\frac{B_T(t)}{\tau_B} + \frac{H_D(t)}{\tau_H}\right]$	$-\frac{H_D(t)}{\tau_H}$
10	Repay loan	Money transfer	$+\frac{F_L(t)}{\tau_L(\pi_r(t))}$			$-\frac{F_L(t)}{\tau_L(\pi_r(t))}$	
11	Record repayment	Ledger entry			$-\frac{F_L(t)}{\tau_L(\pi_r(t))}$		
12	Investment finance	Money cre-ation				$+Inv(\pi_r(t)) \cdot Y(t)$	
13	Record loan	Ledger entry			$+Inv(\pi_r(t)) \cdot Y(t)$		
	Sum of flows		$\frac{F_L(t)}{\tau_L(\pi_r(t))} - \frac{B_v(t)}{\tau_v(\pi_r(t))}$	$r_L \cdot F_L(t) - \left\{r_D[F_D(t) + H_D(t)] + \frac{B_T(t)}{\tau_B}\right\}$	$\frac{B_v(t)}{\tau_v(\pi_r(t))} - \frac{F_L(t)}{\tau_L(\pi_r(t))} + Inv(\pi_r(t)) \cdot Y(t)$	$[r_D \cdot F_D(t) - r_L \cdot F_L(t)] - W(t) \cdot L(t) + \left[\frac{B_v(t)}{\tau_v(\pi_r(t))} - \frac{F_L(t)}{\tau_L(\pi_r(t))}\right] + \left[\frac{B_T(t)}{\tau_B} + \frac{H_D(t)}{\tau_H}\right] + Inv(\pi_r(t)) \cdot Y(t)$	$r_D \cdot H_D(t) + W(t) \cdot L(t) - \frac{H_D(t)}{\tau_H}$

A central part of endogenous money creation is not only the borrowing of money by firms from the banking sector $\frac{B_v(t)}{\tau_v(\pi_r(t))}$ (row 1), but also the investment share of output by firms $Inv(\pi_r(t)) \cdot Y(t)$ (row 13). Without the actual usage of the additional purchasing power on investment, though endogenous money creation would take place in principle via row one, it would not affect economic dynamics per se. Hence the ‘usage’ of that additional purchasing power is crucial in the creation of boom and bubble episodes[77]. Hence, the investment share of output measures the share of (new) investment in total production in each time step since not all changes in output relate to new investment. Additionally, so Keen (2013) states, *all* investments by firms are financed via loans[78].

Dropping the subscript for time t, the equations for the financial system derived from the Godley table can then be defined as follows:

The evolution of monetary assets of the banking sector over time $\frac{dB_v}{dt}$ is defined as the rate of loan repayments by firms $\frac{F_L}{\tau_L(\pi_r)}$, which is a nonlinear function of the profit rate, minus the lending of the existing money stock (not in circulation)

$$\frac{dB_v}{dt} = \frac{F_L}{\tau_L(\pi_r)} - \frac{B_v}{\tau_v(\pi_r)} \tag{2.1}$$

Changing bank transactions over time $\frac{dB_T}{dt}$ are depicted via the firms’ sector payments on loans $r_L \cdot F_L$ with r_L being the loan interest rate, via interest payments that are made towards the firm and household sector’s deposits $r_D \cdot (F_D + H_D)$ and through consumption of the banking sector $\frac{B_T}{\tau_T}$ [79],

$$\frac{dB_T}{dt} = r_L \cdot F_L - r_D \cdot (F_D + H_D) - \frac{B_T}{\tau_B} \tag{2.2}$$

The development of loans of the firm sector over time $\frac{dF_L}{dt}$ depicts the level of debt in the model and is explained via the lending of the existing money stock not in circulation as a function of the profit rate $\frac{B_v}{\tau_v(\pi_r)}$, the rate of loan repayment as a function of the profit rate $\frac{F_L}{\tau_L(\pi_r)}$ and the investment share of output as a nonlinear function of the profit rate $Inv(\pi_r) \cdot Y$,

$$\frac{dF_L}{dt} = \frac{B_v}{\tau_v(\pi_r)} - \frac{F_L}{\tau_L(\pi_r)} + Inv(\pi_r)^{80} \cdot Y \tag{2.3}$$

The evolution of deposits of the firm sector over time $\frac{dF_D}{dt}$ are interpreted via interest payments towards firms’ deposits minus firms’ interest payments on loans $r_L \cdot F_L$, the (aggregate) money wage for labour $W \cdot L$, the lending of existing money stock to firms and the rate of loan repayment, bank consumption and household

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[77] For example, Glyn (2006) argues that the sudden and rapid increases of purchasing power (of households via consumer credit including credit cards) led to the boom and bubble episode in Sweden in the 1980s (which ended in a banking crisis).

[78] Please note that this is different to the explanation of the altered Goodwin growth cycle discussed in 3.1 where loans and earnings are used to finance investment.

[79] Which type of consumption the banking sector has is not further explained.

[80] $Inv(\pi_r)$ maintains its functional form. Hence $I(\pi_r) = GenExp(x, x_{val}, y_{val}, s, min) = (y_{val} - min) \cdot e^{\frac{s}{(y_{val} - min)} \cdot (x - x_{val})} + min.$

consumption $\frac{H_D}{\tau_H}$ (which depends on household income) as well as the investment share of output

$$\frac{dF_D}{dt} = (r_D \cdot F_D - r_L \cdot F_L) - W \cdot L + \left(\frac{B_v}{\tau_v(\pi_r)} - \frac{F_l}{\tau_L(\pi_r)}\right) + \left(\frac{B_T}{\tau_B} + \frac{H_D}{\tau_H}\right) + Inv(\pi_r) \cdot Y \quad (2.4)$$

And finally, the development of households' deposits over time $\frac{dH_D}{dt}$ are explained through interests paid on household deposits by the banking sector, wages paid by the firm sector and household consumption

$$\frac{dH_D}{dt} = r_D \cdot H_D + W \cdot L - \frac{H_D}{\tau_H} \quad (2.5)$$

A direct link to the real side of the economy can be observed for household deposits H_D via money wages and the level of employment upon which wage payments depend $W \cdot L$. Firm deposits F_D and firm loans F_L are linked directly to the real side via the non-linear investment function (as share of output) $Inv(\pi_r) \cdot Y$. Bank transactions B_T and the (changes in the) bank vault are only indirectly linked to the real side of the economy via the rate of loan repayment $\frac{F_L(t)}{\tau_L(\pi_r(t))}$ and via household deposits H_D respectively. The initial conditions for the financial variables, the interest rates for loans and deposits as well as the time constants are given by Keen (2013).

Having defined the financial system dynamics, Keen (2011, 2013) moves on to link the financial side of his model more closely to the real side of the model which will be accounted for in the following part.

2.3. Finishing the monetary Minsky model

The real and financial equations of the model, so Keen (2013) argues, are linked via prices. Therefore, capital and output are henceforward defined in real terms.

The real level of output is now determined by real capital and the (fixed) accelerator

$$Y_R = \frac{K_R}{v} \quad (3.1)$$

With a fixed accelerator, real output solely depends on real capital.

Similarly, the level of employment is defined via real output and labour productivity

$$L = \frac{Y_R}{a} \quad (3.2)$$

Increases in labour productivity will, if output remains constant, lead to a fall in the level of employment.

The evolution of prices over time (inflation) depends not only on the profit rate at any given time, it also depends on a mark-up factor $(1-\sigma)$ and the workers' share of income $\frac{W}{a}$

$$\frac{dP}{dt} = -\frac{1}{\tau_P} \cdot \left(P - \frac{1}{(1-\sigma)} \cdot \frac{W}{a}\right) \tag{3.3}$$

Prices are understood to converge towards an equilibrium where the $(1-\sigma)$ equals $\frac{W}{a}$. This equation, Keen (2013) states, holds empirically and was derived employing the equilibrium values of physical output and physical demand.

The evolution of wages over time (represented as money wage) is determined via the (nonlinear) Phillips curve relation derived in the altered Goodwin growth cycle $P_h(\lambda)$, the evolution of the employment rate over time $\frac{d\lambda}{dt}$ (hinting towards the level of labour demand) and the development of the level of inflation over time $\frac{dP}{dt}$

$$\frac{dW}{dt} = W \cdot (P_h(\lambda) + \omega \cdot \frac{1}{\lambda}\frac{d\lambda}{dt} + \frac{1}{P}\frac{dP}{dt} , \tag{3.4}$$

with $\omega < 1$ being a weighing factor for the impact on wages when the employment rate changes.

The evolution of the employment rate over time $\frac{d\lambda}{dt}$ depends on real growth g, the rate of technological advancements α and on the rate at which the population grows β. α and β both remain constant.

$$\frac{d\lambda}{dt} = \lambda \cdot (g - (\alpha + \beta)) \tag{3.5}$$

The real growth rate is determined by the rate of investment which depends on profit and corresponds to the generalized exponential function derived in the altered Goodwin growth cycle $Inv(\pi_r)$[81], the constant depreciation rate δ and the fixed accelerator.

$$g = \frac{Inv(\pi_r)}{v} - \delta^{82} \tag{3.6}$$

Hence, with a fixed accelerator, real growth depends positively on investment and negatively on depreciation.

[81] This non-linear investment function cannot only be found in the altered Goodwin model. This investment function is also found in the Godley table as part of the investment share of output depicting money creation in row 12 and 13.

[82] δ appears to be an incorrect denomination. The previous denomination of the depreciation rate is γ. When looking through the appendix to identify the fixed values, only γ is considered but not δ. Hence it can be assumed that δ really should be γ. However, since this thesis does not attempt to actually run the model via a computer program, this mix-up is not that upsetting.

The rate of growth of the real capital stock over time $\frac{dK_R}{dt}$ is determined by the real growth rate

$$\frac{dK_R}{dt} = g \cdot K_R \tag{3.7}$$

Changes in the capital stock therefore depend on investment (positively) and depreciation (negatively).

The rate of profit which determines the profit relative to the capital used can now be defined in monetary terms

$$\pi_r = \frac{P \cdot Y_R - W \cdot L - (r_L \cdot F_L - r_D \cdot F_D)}{P \cdot K_R} \tag{3.8}$$

With all else being constant, increases in the monetary value of the real capital stock will decrease the profit rate which might hint towards the tendency of the rate of profit to fall.

Labour productivity (over time) is defined as

$$\frac{da}{dt} = \alpha \cdot a \tag{3.9}$$

while population growth (over time) is defined as

$$\frac{dN}{dt} = \beta \cdot N \tag{3.10}$$

The equations presented here in combination with the Godley table, constitute a strictly monetary model of Minsky's FIH (Keen, 2013). The equation system in (3.11) depicts the complete model[83]:

$$\begin{gathered}
\frac{dB_v}{dt} = \frac{F_L}{\tau_L(\pi_r)} - \frac{B_v}{\tau_v(\pi_r)} \\
\frac{dF_L}{dt} = \frac{B_v}{\tau_v(\pi_r)} - \frac{F_L}{\tau_L(\pi_r)} + Inv\,(\pi_r) \cdot P \cdot Y_R \\
\frac{dF_D}{dt} = (r_D \cdot F_D - r_L \cdot F_L) - W \cdot L + \left(\frac{B_v}{\tau_v(\pi_r)} - \frac{F_l}{\tau_L(\pi_r)}\right) + \left(\frac{B_T}{\tau_B} + \frac{H_D}{\tau_H}\right) + Inv(\pi_r) \cdot P \cdot Y_R \\
\frac{dH_D}{dt} = r_D \cdot H_D + W \cdot L - \frac{H_D}{\tau_H} \\
\frac{dB_T}{dt} = r_L \cdot F_L - r_D \cdot (F_D + H_D) - \frac{B_T}{\tau_B} \\
\frac{dK_R}{dt} = g \cdot K_R
\end{gathered} \tag{3.11}$$

[83] The equations are taken form a draft paper by Keen (Keen, 2011). The subscript (t) is dropped for coherency and denominations for household consumption and bank consumption are adjusted to match the denominations here.

$$\frac{d\lambda}{dt} = \lambda \cdot (g - (\alpha + \beta))$$

$$\frac{dW}{dt} = W \cdot (P_h(\lambda) + \omega \cdot \frac{1}{\lambda}\frac{d\lambda}{dt} + \frac{1}{P}\frac{dP}{dt}$$

$$\frac{da}{dt} = \alpha \cdot a$$

$$\frac{dN}{dt} = \beta \cdot N$$

According to Keen (2013), the model is capable of reproducing economic behaviour of the last 50 years. When examining figure 9 and figure 10 in Keen's (2013:25-26) paper, the following can be stated: real output increases over time while inflation and unemployment both decrease with movements seemingly ceasing - a phenomenon that was observable during the Great Moderation. The debt to output ratio increases with workers' share of output decreasing while capitalists' share of output stabilizes. Similarly, banker's share of output increases only very slowly. Notably, the debt to output ratio increases at a faster pace even before the crisis hits. When the crisis breaks out, output declines (moderately). Before, deflation had already begun with unemployment increasing rapidly shortly after the slowdown in output. Workers' and capitalists' shares of output tumble with decreasing output, whereas the banks' share of output increases rapidly.

While this model may seem convincing at first sight as Keen (2013) recreates realistic looking movements for the evolution of real output, inflation and unemployment, for the debt to output ratio as well as for various income distributions and for the behaviour of loans and deposits, all whilst moving from an economic boom to a crash phase, the devil lies in the detail. Unfortunately, the Keen (2013) model remains, just like the Goodwin growth cycle, a highly schematized model of cycles in growth rates. Sophisticated, complex and complicated as these types of models may be, they can be criticised in terms of their capacity to understand and especially represent the workings of real capitalist economies- even if their theoretical grounding is sound. The following section 3 presents a critical approach towards the Keen (2013) model in explaining endogenous cycles and economic bubbles. The conclusion in section 4 critically assesses the overall value of economic models of this type.

3. The appropriateness of the model when attempting to explain economic bubbles

Keen's attempts to create a Minsky inspired model need to be appreciated, not only due to the level of sophistication of this mathematical approach, the vast array of definitions and equations and their complex interplay within the model, but also due to the strong grounding in an economic theory that allows for bubble episodes. Keen has managed to extend the simple Goodwin growth cycle and its resulting limit cycle in an attempt to create a more realistic representation of the economy. The altered Goodwin growth cycle generates a more desirable result in that the model dynamics have moved on from the closed orbits of a conservative system, towards a spiralling movement of a dissipative system that allows for endogenously created, debt-driven breakdowns. Keen has also managed to link the Goodwin growth cycle model, that is only concerned with the real (producing) side of the economy, to the financial side of the economy via the Godley table, where money is not only specifically considered, but where endogenous money creation becomes possible. With the inclusion of debt (via endogenous money creation), changing system stability in a Minskian sense is considered. At the same time, a more realistic account for investment is given, which is now financed via debt. The author has (partially) succeeded in recreating the FIH in mathematical model terms, specifically with regards to the importance of debt (creation) during boom and bubble episodes (inducing crises). And even though swings within the artificial economy are endogenously created (at least for some time) through the interplay of the model equations, the explanatory power of the model with regards to the behaviour of real capitalist economies needs to be challenged. In the following, these and other issues will be raised.

3.1. An unfinished model

The greatest issue of the Keen (2013) model is the non-consideration of bankruptcies. After the economic crash in the Keen model, inflation falls towards zero with unemployment soaring. In the model, capitalists' income share of GDP decreases into the negative region, workers' share of GDP crashes and bankers' income share of GDP skyrockets[84]. The dramatically increasing bankers' share of income, while all other income shares decline rapidly, implies that banks might be too big to fail even without a government sector. Banks in this model never incur losses or experience defaults on loans by their customers. While an inclusion of defaults may simply increase the severity of the cycle in this model (but not fundamentally change it), in reality, banks incur losses and hence, change their portfolio compositions and investment strategies. This in turn plays an important part (or possibly induces) the economic crisis that follows bubble episodes (Minsky, 1970). And though Keen (2013) points to the increasing bank reserves during economic collapses justifying the increasing bankers' income share of GDP, this thesis argues that the relevant graph and equation do not account for that. The graph shows the income streams and not the stock (reserves) that is, as explained earlier, influenced by these streams. Hence, in the model, bankers are able to increase their income via increasing income streams during the onset of a crisis while all other sectors of the economy decline. If bankruptcies were allowed in the model, the model behaviour would surely change, especially with regards to increasing bankers' income shares during crash episodes.

The bigger mathematical issue with not allowing for bankruptcies is however, that once the bubble bursts, the economy does not restart. The endogenous never-ending cycles of the original Goodwin model would come to an end – a situation that, from a modellers point of view, is less than desirable. Only when all the incurred debt is paid, and debt levels are back to zero (initial condition), the cycle can restart. Unfortunately, in its current state, it appears that the payback of all incurred debt is not possible via the model. The onset of the crisis in the model is caused by firms not being able to meet their debt. As investment and output decline, unemployment rates increase rapidly. Hence, and in the absence of a big

[84] Taken from figure 9 and the figure 'income distribution' in Keen (2013:25;27).

government, household consumption decreases rapidly[85] leading to even lower profit rates. Therefore, even fewer debt can be paid back inducing a downward spiral. Throughout the model, it is not quite clear what exactly firms do in this situation. It seems as if the economy would nearly be at a standstill while firms attempt to pay back their loans. And even if all the debt might be paid back at some point, there is no indication in the model equations why firms (on aggregate and at the same time) might want to start investing again, other than the fact that profit might increase with decreasing debt (equation 3.7). Of course, this assumes that firms still own capital and produce output that is being consumed by banks and households. However, the way the model is set up, there is no reason to believe that households would be able to consume. Additionally, in Minsky's theory, the sell-off of existing capital to meet debt payments is part of and enhances the economic downward spiral. Hence it is questionable if firms would still be able to produce. More importantly, when attempting to link the model to actual market behaviour, where increasing bankruptcies are a symptom of an economic downturn or crisis and where cycles restart even when not all debt has been paid back, it becomes clear that bankruptcies cannot be omitted. However, the solution to this problem seems to be a tricky one as Keen implies to have been aware of this for some time.

Additionally, and in line with Minsky's original work, only firms, but not households can incur debt in Keen's model. Though the author is aware of this shortcoming stating that debt for households can easily be added (Keen 2011, 2013), so far this has not happened. However, the importance of increasing household debt for household behaviour, economic performance and especially the implications for system stability since the 1980s cannot be overlooked. While there may be different reasons for this phenomenon[86], increasing household debt has far-reaching implication for economies, specifically when considering their degree of system instability, which in turn might be indicative of the susceptibility to economic bubbles. Arguably, the increases in household debt is one of the factors contributing to the Subprime crisis in the US. The slowdown in speculative growth leading to the onset of the global financial crisis in 2007/2008 was not initiated by firms failing to meet their debt (as would be the explanation in Keen's model), it was households that were unable to meet their (increasing) mortgage payments that triggered the slump and the following crisis. Hence, if household debt is not included in the model, the 2007/2008 crisis cannot be explained as often proclaimed by Keen (2013, 2017).

Furthermore, Keen (2013) acknowledges that the government sector is missing in his model. For that reason, automatic stabilizers are missing. These automatic stabilizers are social payments from governments to citizens. During economic crises, these social payments increase with bankruptcies and rising unemployment. While this is seen as a great social improvement in securing

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[85] Though considered in the Godley table, a decline in household consumption is not specifically mentioned by Keen (2013) and are hence theoretical assumptions made by this author.

[86] Financialisation of economies with ever falling wage shares and reduced government involvement possibly all play a role in this.

people's livelihoods during periods of (economic) hardship, one can argue that also economically these payment streams are helpful during times of economic downturns. Though unemployed households will not receive wage income, they do receive income via the social welfare state. These payment flows will not only put a lower boundary to decreases in demand, but also enable firms to eventually start investing again – much sooner than would be the case in the absence of such transfer payments from the government to the public. While the inclusion of a government sector may not change the cycle at first glance, this thesis argues that, depending on the level of government involvement and regulation, the emergence of bubbles could possibly be avoided and would hence, change the results in Keen's (2013) model.

Additionally, and in line with Minsky (1982, 2008b), big governments can and should increase spending via debt financed investment projects during times of economic slowdowns. Governments simply have more purchasing power than any other actor within the economy. Hence governments can initiate relatively big investment projects by taking on greater loans than any other investor in the market could. To be executed, these bigger investments in turn need firms and workers. Therefore, governments could, via an expansive fiscal policy, counteract a declining economy by increasing the demand for output of firms. In that way, the never-ending downturn observed in the Keen (2013) model can, in reality, be avoided. Further, big governments do not simply react to crises situations. They could, with the appropriate action (and political will), counteract the formation of economic bubbles by not only reducing governmental spending but also through legislative measures. Governments and the respective policy structure exert a great influence on whether economic systems are stable or not and hence influence if economic bubble episodes (are allowed to) emerge. Thus, if one attempts to understand economic bubbles, policy measures tied to an understanding of the importance of governments within a system cannot be ignored.

Similarly, central banks, that are also not considered in the model can, with an active monetary policy, influence economic performance and somewhat determine whether economic boom phases turn into bubble episodes leading to crises. It has been argued (for example Shiller, 2005) that the expansive monetary policy of the Fed (Federal Reserve) with its consistently low interest rates during the build-up of the Subprime bubble in the US and the observable Fed policy of only intervening when financial market prices decrease (but not when they increase) (Glyn, 2006; Varoufakis, 2013) have caused asset prices to climb unsustainably, supporting the bubble. On the other hand, the increased supply of liquidity to banks during the Subprime crisis to avoid a credit crunch (which of course was not avoided but would probably have been worse and taken longer to resolve without interventions) can also be credited to the US (and other) central bank(s). Hence, central banks play an important role in determining economic behaviour, including that of financial markets. Therefore, even if Keen (2011, 2013, 2017) claims that in this calibrated model of the economy the Great Moderation is portrayed, this phenomenon cannot be meaningfully explained if an inflation rate targeting central bank (among other things[87]) is not considered. Keen's (2013) price function alone (that may approach an equilibrium value) cannot account for the price stability observed during the Great Moderation.

However, the impossibility of including (all the relevant) factors might, due to a further increase of complexity of the already very complex model, not be feasible. Additionally, intangible (not measurable) elements (such as policy regimes) simply cannot be included in such models. Again, this raises the question of whether formal models of the economy in general are useful tools to correctly and thoroughly analyse economic behaviour in a timely manner, especially if the detection of bubbles is the goal. A paradigm shift away from such models might be necessary to do just that.

While this subsection has pointed towards matters that have not yet been included or addressed in the model (equations), the following subsections identify possible theoretical and empirical issues.

3.2. The heavy reliance on 'real' growth ignoring financialisation

Goodwin's growth cycle model that is used as a base model for the Keen (2011, 2013) model only considers the real side of the economy. The cycle is driven by growth in production, which depends on investment and profit, as well as on the level of employment and the distribution of income (in terms of GDP). Though Keen (2011, 2013) links the producing side of the economy to the financial side and considers the demand for loans by firms, it is unclear where the funds for loans come from. While Keen (2013) states that banks give out loans and look for the needed funds later, the model itself does not account for that. Banks' funds simply appear out of nowhere with a rather passive financial market. As Leijonhufvud (2009a) notes, banks generally give out loans and attempt to raise the needed funds in due course. And at least part of those funds (if not all of them) are raised through financial market operations (buying and selling of financial instruments). Without active financial markets however, this would not be possible. Hence, it could be argued that overall lending would be more prude if funds could not be (easily) raised via financial markets. This in turn could mean that a bubble episode might not even emerge. Unfortunately, financial markets and the workings of such markets are not considered throughout the model.

Additionally, financial markets do not exist secluded from producing markets. Instead, they exert a great influence on the performance on the real economy, especially in highly financialised economies. A rise in financial market speculation and overall increases in asset prices (especially during bubble episodes) are important indicators of the overall instability of the system. In a Minskian framework, the pro-cyclical supply of credit is just as an integral part of any bubble episode as increasing asset prices are (Kindleberger & Aliber, 2005). De Antoni, (2010) asserts that the crisis for Minsky starts in financial markets which further supports the notion that such markets need to be actively considered. Additionally, so Kindleberger and Aliber (2005) argue, most bubbles in the 20th century have

[87] These 'other things' could be for example exchange rate dynamics which could have (had) an effect on the inflation rate.

centred around real estate and stock markets (Kindleberger & Aliber, 2005: 29), affecting the real side of the economy (positively and negatively). And in line with Kindleberger's and Aliber's (2005) observation for the 20th century, the 2007/2008 Subprime crises was centred around assets in financial markets as well as speculative finance, influencing the real side of the economy. Hence, a more active financial market needs to be considered in the Keen (2013) model to comply more strongly with the FIH on the one hand and to have a more realistic model on the other hand.

Further, loans throughout the model are only given to firms and are solely used for investments in production. Similarly, all profits in the model are made by firms and are only made via real (production) output. However, and more relevant for the current economic situation of capitalist economies, the behaviour of such economies has changed with the onset of financialisation[88]. Especially for highly liberalised and financialised economies such as the US and the UK, the profit of formerly producing firms increasingly depends on the firms' financial market activities (Krippner, 2005; Driver & Temple, 2013). In countries such as the UK, the overall investment share of manufacturing has, in line with manufacturing output, declined rapidly since the 1970s (Driver & Temple, 2013). The decline in manufacturing as part of GDP has been balanced by the accelerated increase in the share of GDP by the FIRE industries. Similar observations can be made for the US (Krippner, 2005). Hence, in highly financialised countries, investment shifted away from productive towards financial investment. Then it can be argued that the observable rising indebtedness of firms is not (only) caused by increased investment in production, as assumed in Keen's model, but by increasing speculation in financial markets as well as the heavy reliance on external financing (via shares and stocks). Unfortunately, the very simplified approach in Keen (2011, 2013) can by no means account for the rapidly increasing share of GDP by the FIRE industries in highly financialised economies, the increasing indebtedness of firms and the accompanied increased overall economic instability (hinting towards increasing susceptibility to economic bubbles and crises).

Changes towards liberalisations made in the 1980s and onwards (Crouch, 2009; Foster & Mcchesney, 2012; Bellofiore, 2013) have caused fundamental adjustments within economies. Previously prevailing economic structures have changed greatly, leading to dramatically different outcomes (Stockhammer, 2010; Driver & Temple, 2013; Panico & Pinto, 2018). Economic growth models have changed, similar to the composition of sectors within an economy and their importance to the overall economy. These dramatic changes require a differentiated analysis of economies and their system states. Hence, models attempting to portray current economic behaviour such as the Keen (2013) model, need to adjust to these changed circumstances and employ a more differentiated approach. Put differently, it is important that financialisation is recognized within economic modelling. This recognition requires the separate analysis of financial and productive investment and profit. It also requires a separate consideration of sectors defining GDP. It is not enough to assume that the economy grows (or does

[88] Please see chapter II section 3.3. for a more detailed discussion on financialisation.

not grow) It is also important to understand where that growth comes from (financial or productive). Only then can the overall instability of the system and its susceptibility to bubble episodes be identified and portrayed. Unfortunately, Keen's model (2011, 2013) does not make these distinctions. Financialisation is imagined away with productive growth at the core of the model. Same can be said about spatial considerations that would allow to analyse specific bubble episodes. However, in doing so it has to be questioned if Keen's (2011, 2013) model portrays economic behaviour that can be linked to current economies. Attached to that is the question of whether the model can really be used to predict economic bubbles in real time. On the flipside however, adding even more components to the already complex model to account for economic and policy changes might not be feasible. Increasing the number of parameters and system equations could deem the model unmanageable and hence, unusable.

A re-occurring theme of this thesis – the (economic) justification of equilibrium considerations in dynamically evolving social systems that allow for emergent bubble episodes will be considered throughout the following subsection. Since this has been touched up on multiple times already, the subsection will be kept rather short.

3.3. The equilibrium assumption and two possible system states

As explained in section 2.1. of this chapter, the Keen model exhibits three equilibria (Sordi & Vercelli, 2014) which are defined by workers' share of GDP, the employment rate and debt. The first equilibrium is defined by a positive employment rate and positive debt while the workers' share of GDP equals zero. Since this equilibrium cannot be explained economically meaningfully and therefore simply represents a mathematical possibility it can, henceforward, be ignored. The second equilibrium is an equilibrium that had already been present in the original Goodwin model[89] (Goodwin, 1967; Gandolfo, 2009; Harvie, 2000). This equilibrium can be found at the centre of each (open) cycle and is defined by the average values of the employment rate, workers' share of income and debt. In the third equilibrium both the employment rate and workers' share of output take on a value of zero, while debt is defined through an infinite level (∞) (Sordi & Vercelli, 2014). Both equilibria are locally stable which means that when the system's initial conditions are close enough to the equilibrium, the dynamics of the system will inevitably move towards the respective equilibrium. Depending on the system's initial conditions, the system will either move towards the second or towards the third equilibrium. Hence, there are two feasible outcomes within the system (Keen, 2017). The second equilibrium is the desirable stable system state describing a stable economy. In such an economy, capitalists are not overoptimistic which leads to moderate but stable growth in output and a constant level of debt. Cycles in the employment rate and wage share gradually converge towards equilibrium values (Keen, 2017). The third equilibrium however implies that if the initial conditions of the system are close to that equilibrium, the economic system will converge towards collapse and crisis (Sordi & Vercelli, 2014; Keen, 2017). Capitalists are constantly overoptimistic which will lead to a boom and end in a crisis.

[89] The difference of the equilibrium in the Keen (2013) model lies in the changed stability condition from neutral in the Goodwin (1967) model to stable in the Keen (2013) model.

It is not quite clear why this equilibrium discussion was picked up by Keen (2013, 2017). As pointed out previously, this line of argumentation appears to be ill suited when attempting to explain bubble episodes, and with that, the emergent behaviour of capitalist economies. The inevitable convergence of a system towards the one or the other equilibrium in this particular Keen model has to assume that, though the model moves in time, all underlying structures (economic, financial, political, social, agents' behaviour and expectations and so on) remain static. Otherwise, it would be implausible for an evolving social system to arrive at a pre-defined equilibrium state with certainty. Even if the economy started out close enough to a stable equilibrium, technological advancements, new discoveries, and political changes – in short, a future that cannot be foreseen, will alter the path on which the economic system moves. It can then not be guaranteed that the economy would end up in the equilibrium it was supposed to end up in.

As the economic system as a complex system evolves over time, it will go through various system states, all describing a different level of stability (Minsky, 1970, 1982, 2008b; Sornette, 2003; Scheffer et al., 2012). These different levels of stability include, among others, stable states, boom episodes, bubble episodes and recessions. Complex systems do not stop to evolve once the stable state or once a crisis stage is reached as is suggested by the above equilibrium assumptions. Complex systems move from one system state to the next, while the previous system state is needed in defining the next system state (after a crisis comes recovery and eventually a boom which is followed by a crisis). However, when focusing on equilibrium assumptions, these differing system states that are needed for a system to evolve over time are either ignored or believed to simply be adjustments towards the true equilibrium state. Observable and repeated (never-ending) cycles within economies would simply not occur or, at least they would stop at some point (when the equilibrium is reached). Hence, the behaviour of economies as complex evolving systems cannot be explained. Additionally, while mathematically it may be easy to define initial conditions and the accompanying equilibria, in real markets one is left to wonder what these initial conditions might be and where the relevant equilibrium could be located, considering that the economic system is ever changing. The impossibility (or the great difficulty) to match empirically observable (market) data to these assumptions does give clues as to whether this is a route worth pursuing. Hence, the hypothesis of this thesis in arguing that (presumed) equilibria are not needed when attempting to understand complex, evolutionary, social systems such as the economy (and with that emergent bubble behaviour) is not only maintained but questions the adequacy of models that fall back on that equilibrium notion.

The following subsection will pick up the issue of matching real data to the model. Additionally, empirical issues within the model assumptions will be discussed and evaluated further.

3.4. Possible empirical issues and missing real data

3.4.1. A calibrated model

Keen's (1995, 2011, 2013) model is a calibrated model. This means that no real data is used to generate the model's dynamics. Due to the model's sensitive dependence on initial conditions it could be argued that, if different data points were used, the dynamics of the model could change. Hence, if in fact real data were to be used (which must be different from the data used to calibrate the model[90]), the dynamics that are observable in the calibrated model might change. Therefore, though Keen (2013) seemingly replicates qualitative features of economic dynamics of the past 50 years (Keen, 2017), it is questionable if these qualitative characteristics (or good visual fits) are sufficient for models which attempt to represent actual market behaviour, specifically in the absence of mathematical tests. An issue that has been brought forward by, among others, Keen when (rightly) criticising Sornette's (2003) attempts to fit a log-periodic power law structure to financial market price dynamics just before a downturn (Gallegati et al., 2006). Though the visual fits seemed promising in this case, quantitatively Sornette's (2003) attempts were not satisfying (Gallegati et al., 2006).

Complex models of financial markets have long been capable of creating endogenous fluctuations in (asset) prices via the interaction and trading strategies of chartists and fundamentalists (for example Day & Huang, 1990; Lux, 1995; Brock & Hommes, 1997; Westerhoff, 2004). These models in the New Keynesian (behavioural economics and behavioural finance) tradition are, just like the Keen model, calibrated. And they are, just like Keen's model, able to generate qualitatively realistic dynamic behaviour of financial markets endogenously. Keen's (2013) main advantage is not only the inclusion of debt (which is missing in these other models), but also the close link to a believable underlying economic theory in the Minskian tradition, that can explain the economic dynamics of the model. New Keynesian complex dynamic models of financial markets are not as concerned with grounding the model theoretically. Though theoretical assumptions stemming from the New Keynesian literature are hidden in the model equations, the overall consideration of a theory is not as complex, coherent or important than it is in Keen (2013). Hence many dynamics (booms, bubbles and crashes) that evolve endogenously in *both* types of models, can theoretically only be explained in the Keen model.

However, and again, that does not automatically mean that the generated qualitative features of the Keen (2013) model are applicable to real economic behaviour. For example, when Harvie (2000) tested the Goodwin growth model, he found that qualitatively the model is in fact convincing. For all the observed countries, cycles (in employment and workers' share of GDP) could be reported.

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[90] For example, the initial conditions for debt, the level of employment, the real wage, population and prices are 0; 300; 300; 300 and 1 respectively (Keen, 2013:29). Clearly, this combination alone will be hard to find in real markets. It is also worth pointing out that, though in the initial Goodwin growth cycle, the employment rate cannot be $\lambda = 1$, Keen's (2013) initial conditions ignore this fact (for more on this please see page 100, footnote 68).

Hence, high levels of employment were followed by increasing worker's share of national income, which was followed by a falling employment rate and a falling worker's share of national income (at least during the observation period from 1956 to 1994 and for the observed countries). However, quantitatively the model's performance is rather disappointing. In all the observed cases, the estimated parameters for the equilibrium points (unemployment rate and worker's share of GDP), lie outside the actual cycle. The discrepancies between the observable average values of the rate of employment and worker's share of GDP and the estimated values are (except for one country) systemic (Harvie, 2000). Hence, while qualitatively promising, quantitatively the model is unsatisfactory. These findings suggest, that even if Keen's model might qualitatively represent market behaviour that is backed up by a coherent theory, the inclusion of, or the testing with real data could change that.

Additionally, Keen inserts constant parameters in his model which, in reality, appear not to be fixed[91]. For example, the accelerator (equation 1.1. and 3.1. in section 2 of this chapter) is fixed at the value 3 (Keen, 2013). Though not explained by Keen (2013) theoretically, this fixed relation goes back to the original Goodwin growth cycle, where a constant output ratio is assumed (Goodwin, 1967; Harvie, 2000): $v = \frac{K}{Y}$ [92]. This constant output ratio links, according to Harvie (2000), to Marx's constant composition of capital. However, Harvie (2000) finds that, when testing the Goodwin growth cycle and its restrictions, this assumption is not justified. Hence, it is questionable if a model relying on this assumption can quantitatively yield credible results (especially in highly financialised and service-based economies). And again, if these constants were adjusted to change over time to represent a more realistic description of market behaviour, it is unclear if the calibrated model would then be able to replicate previous outcomes.

On a more general note, it has to be questioned if a calibrated model such as the Keen (2013) model can in fact be used to analyse and possibly predict specific economic bubble episodes across regions. Though this model replicates Minsky's basic ideas that increasing debt levels may be related to boom and bubble episodes which, depending on the level[93] of debt lead to an economic crash, the representation of the economy is, just like in the Goodwin growth cycle, very simplistic and schematized. The way the model is set up seems to favour productive economies such as Germany or China. However, when employing the model, Keen repeatedly refers to the Subprime crisis which started in the US, a highly financialised and finance driven economy, where production as part of GDP has dramatically declined (Krippner, 2005). Unfortunately, the finance sector is not as active as it should be if the US Subprime crisis really had to be explained with

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[91] Among the fixed parameters are the rate of change of labour productivity, population growth and the weighing factor on the impact of change in the employment rate on the wage setting. All parameters are fixed at positive values.

[92] If the original symbols are used, one gets: $\sigma = \frac{k}{q}$ (Goodwin, 1967; Harvie, 2000; Gandolfo, 2009; Sordi & Vercelli, 2014).

[93] The important decreasing quality of debt observable during extended growth periods is not considered.

this model. Similarly, households cannot incur debt which makes it impossible to account for the Subprime crisis. Further, Germany as an export oriented, production economy did not incur such dramatic declines in output, investment and employment levels as suggested by the model. These dramatic developments were eminent in more financialised countries such as the UK or the US. While on a very basic level Keen's one-fits-all-approach might seem feasible in that too much debt will lead from boom to crisis, the model cannot be applied across regions and different types of economies. It can only give a very simplistic insight[94] into how debt generally might be affecting economic performance and possibly lead to economic crisis.

3.4.2. Assumptions about empirical regularities

One of the first alterations to the Goodwin growth cycle is the replacement of the linear Phillips curve with a non-linear alternative (exponential function) (Keen, 2013). With the non-linear Phillips curve, wages are believed to rise rapidly at high levels of employment and fall slowly at lower levels of employment. While Keen (2013) claims that the alteration from linear to non-linear does create a more realistic behaviour of wages with regards to the employment rate[95], it is questionable if this is empirically true. When financialisation is considered as well as changes away from unionisation (Shiller, 2005; Glyn, 2006) towards traumatized workers (Shiller, 2005; Bellofiore, 2013), it is debatable if wages actually rise with an increasing employment rate. Under such a scenario, workers simply do not have the bargaining power to demand higher wages, even in the vicinity of full employment. When looking at Germany, the UK and the USA for example it becomes apparent that (real) wages have stagnated for decades, even when near full employment (Stockhammer, 2010).

The debate, whether the Phillips curve relation still holds, (specifically after the global financial crisis) is not yet settled (Owyang, 2015; Blanchard, 2016b; Laseen & Sanjani, 2016; Haldane, 2017). Haldane (2017) believes that, structural changes such as technology and globalization as well as the changing nature and quality of work have contributed to a disappearing Phillips curve relation in countries such as the UK and US. According to Haldane (2017), not only a fall in unionisation, but also increases in self-employment, part-time work, temporary work and zero-hour contracts have contributed to a weak development in wages even if the rate of unemployment has fallen to very low levels. These developments have led to a flatlined Phillips curve where arguably the positive relationship of employment rate and wage share has ceased to exist. Blanchard (2016b) on the other hand asserts that the Phillips curve relation in the US still holds. Low levels of unemployment, so the author argues, will still lead to increasing inflation, whereas high levels of unemployment will have the opposite effect on inflation. However, Blanchard (2016b) does recognize that the slope of the Phillips curve depicting the effect of

[94] While the model equations are anything but simplistic.

[95] Sordi and Vercelli (2014) argue that this change was also mathematically necessary. The trajectories of the employment rate and workers' share of GDP generated by the model could lead to the employment rate exceeding output over the duration of a cycle which is, theoretically and as stressed by Goodwin (1967), impossible. The non-linear specifications of the Phillips curve and investment function solved this issue (Sordi & Vercelli, 2014).

unemployment on the inflation rate has declined since the 1980s. Hence, increasing employment levels will have a lower impact on inflation. This phenomenon, so the author argues, can be explained by decreasing levels of inflation (due to inflation targeting by central banks). Therefore, according to Blanchard (2016b), wages and prices are changed less often to accommodate for inflationary pressures. With the Phillips curve relation being such an important building block of the model, empirical clarity on whether the relationship indeed still holds (across regions) is required. If the relationship has however broken down, it is hard to see how Keen's model could then possibly work.

Similar arguments can be made for the non-linear investment curve. The assumed rapidly increasing level of (productive) investment at high levels of profit is not observable across regions (as is implied in the Keen model). While Driver and Temple (2013) assure that the relationship of increasing profits (via increases in productivity) still holds for Germany, it has apparently broken down for the UK where, according to the authors, investment opportunities via productivity and increasing profit growth are not taken up. Two issues arise with this observation. Firstly, it can simply not be assumed that increasing profits automatically lead to increasing investment in manufacturing. And secondly, the model cannot generically be applied across regions. Differences in growth models of countries, their level of financialisation and, with that, the importance of the different sectors of an economy need to be considered. However, and as mentioned before, the inclusion of these empirical regularities into such a schematized and abstract model might not be possible or feasible. Again, the question arises if such models in general are helpful in understanding the behaviour of economies.

Further, and on a more theoretical note, Keen's (2013, 2017) analysis of demand starts out by dividing society into three social classes: all wage earners are grouped together as workers, all profit earners are grouped together as capitalists, while all rent earners are grouped together as bankers (Keen, 2017). The rational to do this is the assumption, that the distribution of income within the respective groups does not change even if prices change. However, the grouping of society on the basis of similar behaviour due to the social affiliation with a specific class implies that there exists a representative demand function (for each class) as well as a representative agent of that class. The inadequacy of employing representative individuals to account for emergent macro-behaviour has been explained throughout the thesis. Moreover, it must be argued that today's society cannot be represented via such an oversimplified approach. As argued previously (in 3.2 of this chapter and in this section), policy changes since the 1980s towards increasingly liberalised markets and a steady decline in governmental involvement (Glyn, 2006; Crouch, 2009; Stockhammer, 2010; Bellofiore, 2013; Chang, 2014) have brought about fundamental changes in how firms make profit (financial vs. real) and which type of responsibilities must be taken on by household (vs. governments). For example, workers today must also be rent earners especially in highly financialised and asset based welfare systems (Doling & Ronald, 2010). In such systems workers not only invest into housing as a fall back for hard times, but they are also actively involved in financial markets via pension and insurance schemes. Therefore, many workers would belong to two classes namely those of workers and rentiers.

Additionally, and as mentioned previously, as real wages have not increased for many workers, not all are able to obtain such assets or accumulate wealth, specifically when at the lower end of the income scale. It is not sufficient to look at workers as one homogenous class. Income differentials within that class must be considered. And these income differentials are substantial when looking at different industries and different professions. Especially in highly financialised countries (such as the UK) a shift away from (many) manufacturing jobs towards (fewer) higher paid jobs within financial services has occurred (Stockhammer, 2010). Hence it can be argued that even if individuals who receive wages are classed as workers, one cannot assume that, when prices change, the income distribution within that class remains the same. Clearly, if financial market prices increase, those workers at the higher income scale who can afford houses and financial assets (and who have wealth 'stored' in financial markets) will be better off than workers who cannot afford financial assets. The income distribution within that class would then shift in favour of the wealthier workers. Therefore, the initial argument brought forward by Keen (2017) justifying the analysis via classes would not hold. A more sensible approach would be to analyse society through a balance sheet approach where an analysis would not be organised around class but around measurable income streams and (existing) wealth. In this way one could attain an idea of how income really is distributed within society. However, and specifically with regards to the model, this approach would result in a dramatic increase in complexity as well as an increase in the amount of equations. The model would become too big and possibly unusable.

4. Concluding remarks

The theoretical base for the Keen (2013) model is Minsky's FIH. The FIH[96] is very capable of explaining endogenously emerging cycles of the economy. Economic bubbles are an internal part of that theory, depend on the continuous availability of credit and are believed to occur endogenously through the internal workings of the economic system. The real and the financial side of the economy both play an equally important role in explaining economic behaviour and are hence, actively considered. However, as Keen (2013) notes, before his attempts, no mathematical model of the FIH had been developed. The reason for this is probably the complexity of the theory and the mathematics of the complex system approach that is needed to model the FIH. Though there exist complex models attempting to explain economic behaviour, they do not consider the emergent debt structures observable during boom and bubble episodes in a way Keen (2013) does. Therefore, Keen's (2013) attempts have to be appreciated. However, and as discussed throughout section 4 of this chapter, Keen's model unfortunately remains an oversimplified and rather schematic representation of emerging behaviour observable in capitalist economies. Especially the non-inclusion of bankruptcies has trapped the model's economic dynamics in a downward spiral. The desired 'restart' of the cycle has yet to be introduced.

[96] However, and as argued in chapter II section 3.2. the FIH needs extending by, for example financialisation.

While some of the issues presented throughout section 4 might in the future be addressed and resolved (e.g. inclusion of financial and productive investment and profit, inclusion of asset trade and a more active financial market), it is questionable if the resulting further increase in the number of model equations is something that should be aimed for. Arguably the already very complex model would simply become too complicated for anyone to understand while at the same time it would become increasingly difficult to dissect what has caused specific model outcomes.

Additionally, to empirically hold, the model does have to be adjusted for each country or region it is supposed to portray. Clearly, there need to be substantial alterations to the model's assumptions as well as its equations when looking at different countries. For example, the different behaviour of productive investment in the UK and Germany indicates that the investment function as portrayed in Keen (2013) might hold for Germany, but not the UK. While Keen (2011, 2013, 2017) attempts to explain economic behaviour across regions employing the same model, the model itself cannot deliver on that. The calibrated Keen model only yields a very general result of possible economic behaviour. In order to understand economic bubble episodes, to design economic policy aimed at economic stabilisation or to be able to indicate the level of economic fragility (and bubble behaviour), more specific results are needed. For example, it is not enough to assume that the rising debt levels of firms will lead to a crisis. One must know the relevant debt levels that might increase economic instability to a point of crisis. The Keen (2013) model is, unfortunately not capable of doing just that. Keen (2017) uses findings by Vague (2014, as cited in Keen, 2017:95-98) to identify countries, where a future debt induced crisis is most likely.

This then leaves the question of the model's aim. If the aim is to attempt to model a simplified and generalized mathematical representation of the FIH, one could argue that Keen (2013) has partially succeeded. But if the goal is to explain economic phenomena that have indeed occurred (for example the Great Moderation or the 2007/2008 Subprime crisis), the model, due to its oversimplified and generalized assumptions, cannot be used.
However, this problem is not solely tied to the Keen (2013) model. This thesis argues that calibrated, mathematical models of the economy, no matter how sophisticated they may be, all share that same fate. This of course is not to say that the economy should not be approached in a systematic (mathematical) manner, solely relying on theoretical explanations. Instead, the existing approach to (calibrated, equilibrium maintaining, complex system) models needs to be replaced by a more empirical approach tied to complex system knowledge. Only then can economic occurrences (such as bubble episodes) be detected and explained in a timely manner.

In the following thesis conclusion, main aims and arguments that have been brought forward throughout this thesis will be reemphasised.

Chapter VI: Conclusion

This thesis has systematically analysed recent literature, but specifically recent mathematical models attempting to explain and portray economic bubble behaviour, both within the orthodox and heterodox tradition. The distinction between the exogenous and endogenous bubble creation was maintained throughout this thesis.

It was found that theoretically, a coherent and concise definition of what exactly constitutes a bubble is missing. Specifically, within the exogenous (orthodox) literature on bubbles examined in chapter II, the understanding of bubble episodes, if considered at all, is questionable. It has been demonstrated that the highly idealised representation of the economy within these approaches makes it impossible to realistically account for and detect economic bubbles. The biggest issue within the orthodox literature has been identified as the equilibrium assumption which, for the accompanying theory to work, necessitates stringent presumptions about markets (which are generally efficient and self-regulating) and market participants (defined by various degrees of rationality or irrationality). And as was shown through the discussion in chapter II, the result of this oversimplified approach to economies leads to the conviction that bubble episodes are rare and once in a lifetime (outlier) events within an otherwise stable economic system. Therefore, and as maintained within this thesis, the orthodox interpretation is of no use when attempting to understand and identify bubble episodes in real time.

It has been maintained throughout the theoretical endogenous approach to economic bubbles in chapter II, that specifically Minsky's FIH offers a viable alternative to above discussed orthodox approaches. In Minsky's view, the economy is understood as a complex system that evolves over time. Both, the financial and the real side of the economy play an important role in generating varying stability levels within the economic system which may lead to endogenously emerging bubble episodes (depending on the level of instability). And in contrast to the exogenous bubble literature, bubbles here are just one of many possible system states. Hence, bubble episodes occur consistently and regularly from within. Therefore, it was argued that Minsky's FIH represents a feasible starting point for the analysis of economic bubbles.

However, and as pointed out in the introduction and in chapter II section 3.2. Minsky's analysis must be expanded by developments that emerged after Minsky established his FIH. For example, it has been pointed out that financialisation and the profound structural changes it has brought about not only for banking practices and financial markets (Stockhammer, 2010) but also on a societal level (changes of welfare states to asset based welfare states (Doling & Ronald, 2010)) leading to , among other things, increased social inequalities (Dymski, 2010; Stockhammer, 2010) as well as increasing levels of instability for the overall socio-political economic system, have to be considered if recent bubble episodes are to be understood. Further, and in line with Dymski (1999, 2010) and Dymski and

Shabani (2017), to be able to explain *specific* economic bubbles such as the Japanese asset price bubble in the early 1990s, the dot-com bubble in the US in the late 1990s or the US housing bubble leading to the Subprime crisis 2007/2008, spatial and historical considerations must be included into the analysis. The very general approach of the FIH, though helpful as a broad framework, cannot be applied across regions and across time to account for particular economic and financial bubbles. Hence, Minsky's FIH can (only) provide a general framework or stylized facts to guide the bubble analysis. Thus, to date, the identification of bubble episodes in real time and real markets remains challenging without an up-to date (theoretical) framework. Therefore, this thesis suggests an expansion of the FIH to include spatial as well as historical considerations whilst recognizing open economies and the accompanying cross border flows (and imbalances) (Dymski, 1999, 2010). It is argued that with these extensions, changing stability levels over time within socio-economic, political systems, and with that, emerging (or already existing) bubble episodes could be traced and identified.

Methodologically the same exogenous/ endogenous distinction is maintained. But when relating the mathematical explanations of bubbles episodes to the definition of bubbles laid out in chapter I, section 1, it becomes apparent that none of the mathematical approaches discussed throughout chapters III, IV and V can fully meet the proposed definition. As argued in chapter III, the theoretical shortcomings within the orthodox literature become even more apparent methodologically. In line with the criticisms towards the theoretical orthodox literature, the underlying equilibrium assumption for both, the sunspot as well as for the rational bubble model was identified as the main flaw. Tied to the equilibrium assumption is the belief of overall and general economic stability. It has been argued that due to this equilibrium and stability belief, the developed models are incapable to simulate endogenously emerging bubble episodes. In fact, for any type of movement or fluctuation to occur, these models must rely on consistent outside disturbances or shocks. However, the extraordinary large shocks that would be needed to generate bubble episodes have, in reality, not been observed (Shiller, 2005). And since the classical dichotomy holds, exogenous bubble models generally only portray parts of the economy (either real or financial, but not both). In addition to this, money is commonly ignored throughout the analysed models, deeming modern, capitalist economies to be simple barter economies, where money and debt do not exist. It was then not surprising to conclude that these models are unfit to explain or realistically mimic economic bubble episodes.

Econophysics discussed in chapter IV attempts to offer an alternative approach to economic bubble episodes than that developed within the neoclassical tradition. The recognition of Econophysics that financial markets are self-organized adaptive complex systems (Sornette, 2003; Suavoiu & Iorga–Simuan, 2008; Rickles, 2011; Kirman, 2018) with a hierarchical structure of traders (Sornette, 2003, 2014) where bubble episodes emerge endogenously marks a clear (and welcomed) break from the oversimplified exogenous bubble approach. However, unfortunately, and as examined in section 4 of chapter IV, Econophysics encounters great difficulties when attempting to explain bubble episodes in detail and when trying to tie complex system findings made within natural sciences to socio-economic systems (e.g. the usage of the Ising model to explain social influence, interactions and decision making). These difficulties also complicate efforts to relate Econophysics to the proposed bubble definition set out in chapter I. While theoretically, Econophysics is unclear of whether an equilibrium in financial markets exists, the equilibrium notion does generally not play a key role in theoretical explanations of bubble episodes. It is recognised that economies do not necessarily converge towards an equilibrium state. Nonetheless, methodologically, Econophysics is based on naturally occurring complex systems that *do* exhibit equilibrium states. The notion of global stability and fundamentals hinting towards equilibrium values, prevails. For example, the calculatable variance of α – stable Lévy distributions clearly implies an underlying fundamental (equilibrium) price that is tied to a stable distribution. And similar to sunspot and rational bubble models, Econophysics sticks to the classical dichotomy. Hence, only one market (financial) is analysed in isolation from the rest of the economy. The producing side of the economy as well as the labour market is, similar to exogenous bubble models, ignored. Same can be said about money and endogenous money creation which are both not touched upon. While the behaviour of asset prices is important in determining whether the system is approaching a critical point, which is of utmost importance to Econophysics, money does not enter the equation. This then supposes that, similar to the neoclassical models in chapter III, modern capitalist economies are simple barter economies where money or debt do not influence the various levels of stability within the complex socio-economic system. Hence, unfortunately Econophysics and its accompanying calculations, though theoretically an improvement to the models discussed in chapter III can, methodologically, also not account for bubble behaviour.

As argued in the introduction, mathematical models portraying Minsky's FIH are hard to come by. Hence, in chapter V only one model was analysed, namely Keen's (1995, 2011, 2013) Minsky inspired model of the economy. While it is appreciated that both, the financial and the real side of the economy, debt creation and money are all considered within a complex system setting, several issues arose when analysing the model. A first concern stems from the fact that, after the debt-induced breakdown within the system, the portrayed economy seems to be trapped. Fluctuations and hence the economy itself appear to approach a standstill. Presumably, the desired fluctuations would pick up if all debt was paid back. Though how this could realistically be accounted for within the model remains unclear. The inclusion of bankruptcies into the model may offer a solution to this issue as debt would not have to be fully paid back for the motions to start again. But as argued in chapter V section 3.1. while theoretically simple, mathematically the solution to this issue seems more complex and has yet to be solved. Additionally, and as argued throughout section 3.4. in chapter V, empirical and theoretical issues arise with the usage of fixed parameters throughout and with the allocation of parameter values needed for the model's calibration, which, at times, seem to be chosen to generate the desired model outcome. However, the most disappointing finding was the notion of (attainable) equilibria. While, in contrast to the models discussed in chapter III and similar to the Econophysics approach in chapter IV, the analysis does not start out with and is not focused on the equilibrium notion, global stability nevertheless persists. For the systemic breakdown of Keen's (1995, 2011, 2013) model to occur, the model's initial conditions must be close to that one equilibrium where a downturn is inevitable (Sordi & Vercelli, 2014; Keen, 2017), otherwise the, in the model observable downward spiral, does not occur. Nonetheless, and as argued within this thesis, the equilibrium assumption, when considering socio-economic complex systems that evolve over time, where endogenous money creation takes place and where people are not rational in the Muth (1961) sense, is uncalled for.

While theoretically the equilibrium notion is not needed to understand the evolution of socio-economic systems, mathematically there seems to be no way around it, at least for the analysed calibrated model(s) presented in chapter III and V and for the calculations found in the Econophysics approach. All of the analysed models or approaches are, in one way or another, methodologically tied to an underlying equilibrium. The reason for this is twofold. While the analytical starting point for models in the neoclassical tradition is a general equilibrium setting where the equilibrium is an agreed upon reference point towards which the economic system automatically tends (Dymski, 2014), mathematical models in the heterodox tradition that portray economies as complex socio-economic systems use the tools, calculations and methods employed for complex systems found in the natural sciences, where equilibrium systems clearly exist. Hence, while analytically the focus may not be centred around the equilibrium notion within the analysed heterodox approaches, methodologically an equilibrium is omnipresent (even if only very implicitly). Thus, it must then be questioned if (mathematical) models that are based on such calculations are able to realistically account for bubble behaviour in complex socio-economic systems where, as is asserted here, the notion of an equilibrium is unreasonable.

Further, the hierarchical structure of financial markets or for that matter network theoretical considerations in explaining changing stability levels over time is, theoretically, only considered by Econophysics. However, none of the analysed models or approaches has actually included such an analysis. Nonetheless and as indicated in chapter I section 2 and chapter IV section 3, the hierarchical structure of financial markets (Sornette, 2003, 2014) and tied to that, the degree of homogeneity within these markets is indicative of the overall system stability (Scheffer et al., 2012) which itself hints towards possibly emerging or already existing bubble behaviour. A failure to include such an analysis, it is argued here, results in the impossibility to identify bubble episodes on a general level and in real time.

Similarly, and contrary to what has been described to be a desired model (if the methodology is maintained) in chapter I section 2, all analysed models are calibrated models, with none of them employing real data. Of course, the question then remains how well such models would perform if real data was to be used to define parameter values. Due to the complexity of the models there is no easy answer to this question. However, specifically for the complex system models which are to be preferred (please refer to chapter I), a slightest change in parameter values could lead to a completely different system behaviour of the model. It may not produce the desired swings and breakdowns that can be observed if parameter values are chosen accordingly. At the same time the feasibility or the possibility to include real data in complex system models in a timely manner may not be given. There are two reasons for this. Firstly, not everything that would lead to bubble behaviour is measurable (e.g. sudden changes in confidence) or is known. Within complex systems it is impossible to know (or anticipate) and measure all the potential factors that, through the interplay with other factors, lead to complex system behaviour. Only an approximation of some general factors is possible (e.g. the connection of investment, money creation and speculation over a boom period). Secondly, the data that would be needed for an up to date model would have to be very current data that would have to be used in models somewhat instantaneously in order to portray economies in a timely manner. However, this data may not be as immediately available and usable as it would have to be to give a prompt indication of whether the economy is entering or already experiencing a bubble episode. Specifically, once the economy has entered a highly fragile stage, the needed time to get, evaluate and use the available data through a complex system model might be too long. Hence, once it is understood that the economy has entered such a stage close to the critical point employing the model calculations, in real time the downturn may have already happened.

Additionally, it must be pointed out that all models, orthodox and heterodox, as well as the Econophysics approach analysed here are generalisations of a representative economy (or financial market), solely portraying stylized facts of bubble episodes. While this may be obvious and arguably be the aim of orthodox models presented in chapter III, the objective of the Econophysics approach and the Keen (1995, 2011, 2013) model is distinctly different. While Sornette (2003) hints at specific bubble episodes in financial markets, Keen (1995, 2011, 2013) repeatedly refers to the Great Moderation, the Subprime crisis (Keen, 2013) as well as the recent housing crisis in Australia (Keen, 2017). Both authors clearly attempt to tie their findings to specific geographical regions and historical time. However, and as mentioned in chapter IV section 4 and chapter V section 4 and as discussed in the introduction and above, generalised models of that kind cannot account for country and time specific peculiarities of *specific* economic bubble episodes (Dymski, 2010; Dymski & Shabani, 2017). As maintained by Dymski and Shabani (2017), bubble episodes can only be understood if the geographic political economy that has generated such episodes is included into the analysis. The "one-size-fits-all" approach emphasised by calibrated mathematical models simply cannot deliver on that. Each model would have to be adjusted to meet country and time specific requirements.

All of above then leads to the realisation that none of the analysed models or analysed approaches can fully account for and explain specific bubble episodes such as the US housing bubble leading up to the 2007/2008 Subprime crisis. And as argued in chapter I, to be able to analyse, understand and describe bubble episodes in real economies, theoretical and methodological changes need to be made. While Minsky's FIH (Minsky, 1970, 1982, 2008a, 2008b) offers a valuable starting point on a general level, the FIH must be expanded for current developments such as financialisation while spatial and historical considerations must be added to the analysis (Dymski & Shabani, 2017) if one attempts to explain specific bubble episodes of the recent past. Methodologically however, a paradigm shift, away from calibrated mathematical models attempting to imitate economic fluctuations observable in real markets towards a more comprehensive approach is necessary if bubble episodes are to be accounted for in real time. Existing mathematical models of the economy, no matter how sophisticated and theoretically sound they may be, simply cannot account for bubble behaviour in a satisfactory way.

So, what would, according to this thesis' view be 'a desired model' representation of bubble episodes? Of course, the desired description of bubble episodes must satisfy the definition of bubbles put forward in chapter I section 1 and should include the model propositions suggested in chapter I section 2. And as pointed out in the introduction and throughout this thesis, the existing methodology must, due to the theoretically very different view proposed here and due to the deep neoclassical roots of that methodology, be replaced if bubble episodes are to be detected in real time. A way forward could be to use the extended FIH in combination with theoretical insights of complex, adaptive and self-organised systems to develop measures of system fragility in real time, using real data. Such fragility measures would be part of a general framework identifying varying system states (including bubble episodes) over time. Combined with spatial and historical peculiarities, a thorough understanding of bubble episodes would be possible. With such an understanding of bubble episodes, appropriate policy measures could be put into place to confine these re-occurring episodes of high and increasing instabilities to manageable levels. It must be stressed that this framework is not an attempt to create yet another economic model imitating market behaviour. The vison is that various economic, historic and socio-political measures within this spatialised framework would keep track of the evolution of socio-political, economic, complex systems and that these, if taken together, could indicate whether such systems enter unstable phases. The commitment to establish a framework where, with a focus on overall system stability, changes in stability levels and with that, bubble episodes, can be traced via empirical data and in real time, is left for future research.

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List of Abbreviations

BC	-	Business Cycle
DSGE	-	Dynamic Stochastic General Equilibrium
EMH	-	Efficient Market Hypothesis
Fed	-	Federal Reserve System
FIH	-	Financial Instability Hypothesis
FIRE	-	Finance Insurance Real Estate
GE	-	General Equilibrium
GT	-	General Theory
NCM	-	New Classical Macroeconomics
NKM	-	New Keynesian Macroeconomics
RBC	-	Real Business Cycle
RE	-	Rational Expectations
SFC	-	Stock Flow Consistent (models)