Araya, Dahalan and Muhammad (2021). Model of Heterogeneous Agents and Noise Traders' Risk: A Case of Conceptual Framework. International Journal of Business Society, 5 (12), 493-502

Journal Homepage: www.ijo-bs.com

International Journal of Business Society

Contents lists available at: https://www.ijo-bs.com/issue.html

Model of Heterogeneous Agents and Noise Traders' Risk: A Case of Conceptual Framework

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Information of Article

Article history:
Received: 15 Oct 2021
Revised: 16 Oct 2021
Accepted: 28 Nov 2021
Available online: 1 Dec 2021

Keywords:
Model of Heterogeneous Agents, Noise Traders' Risk, Conceptual Framework

ABSTRACT

Purpose: This paper aims to review the market assets bubble and demonstrate how this asset bubble is related to the financial market, including the housing market, using a heterogeneous agent model.
Design/ Method/ Approach: Our approach to this work is first, review the market asset bubbles, which includes its history, second review the diverse processes of assets bubble in the financial markets, including the housing market.
Findings: Since this paper is a conceptual approach toward the market asset bubbles, the heterogeneous agent-based system under the noisy rational expectation equilibrium model has been discussed.
Research limitations: The studies of market asset bubbles are abundant; however, most of the properties of the models under rational expectation equilibrium can fully capture the elements of market asset bubbles. Similarly, our paper has this inherent research limitation, too, for which much work is needed in this area of study.
Practical implications: This reviewed work of ours will impact the market asset bubbles regarding the heterogeneous model used here since works related to applying this model in the asset markets are limited.

1. Introduction

Irrational investors of behavioural finance are forcefully accepted to play a more distinct role in modern finance theory than rational investors of classical finance. For example, Bayer, Geissler, Mangum, & Roberts (2020) argued that speculators are permitted to play a more nuanced role in modern finance theory than the classic arbitrageurs of efficient markets theory. According to the Efficient Market Hypothesis (hereafter referred to as EMH), predicting stock returns should not be possible since market prices will reflect all available information (Audrino, Sigrist, & Ballinari, 2020). Further, "Price setting by the equilibrium between supply and demand of multiple investors with varied sources of information usually ensures the correct valuation, allowing an efficient and rational allocation of resources to the different sectors of the economy" (Westphal & Sornette, 2020, p.3). However, the extent to which speculators' demand can account for these phenomena in equilibrium is debatable, not least given the difficulty in empirically identifying the demand curves and information processing of different investor groups. One source of the uncertain phenomenon in equilibrium is the information behind several findings that contradict the equilibrium theory in financial markets (Paule-Vianez, Prado-Román, & Gómez-Martínez 2020). The rational and irrational decisions of investment have been the subject of extensive discussion. There has been growing empirical evidence reported by behavioural finance researchers since the early 1990s showing that the stock market is driven by investors' psychology (Audrino et al., 2020). Behavioural literature has analysed how players of different markets' heterogeneous behaviour affect the economy (He & Xia, 2020). According to (Audrino et al., 2020), there are various explanations for this finding in behavioural finance, such as the misattribution bias, which says that people make risky decisions depending on their mood states. In almost all cases, information uncertainty is behind several findings contradicting the equilibrium theory in financial markets; thus, several authors have documented that uncertainty regarding social, political or economic conditions significantly influences investor sentiment (Paule-Vianez et al., 2020). Considerable empirical evidence suggests that most financial assets, such as equities or equity indexes, currencies, and interest rates, are attributed to fundamental information flow and noise (Bayer et al., 2020).

In his basic financial markets model, Black (1986, p.529) pointed out that noise contrasted with information because people sometimes trade on noise as information. Investors' wealth from stock market appreciation is well documented to boost consumption in a virtuous economic expansion circle (Westphal & Sornette, 2020). Indeed, the word noise traders had first been coined by Black (1986), describing them as investors who do not trade based on information of the fundamental analysis. It has been suggested that "people do not evaluate prospects by the expectation of their monetary outcomes, but rather by the expectation of the subjective value of these outcomes (Kahneman & Tversky, 2013, p.341-342). Noise traders are defined as those who "falsely believe that they have special information about the future price of risky assets" (De Long, Shleifer, Summers, & Waldmann, 1990b). A "noise trader" is a term that is used to describe a market participant who makes investment decisions without the use of finance fundamentals, exhibits poor market timing, follows trends, and tends to overreact or underreact to good and bad news (Ramiah, Xu, & Moosa, 2015, p.90). These investors often simplify their decision-making processes using behavioural heuristics that might cause systematic errors

https://dx.doi.org/10.30566/ijo-bs/2021.12.70

in judgment and lead to good investment choices but not maximise utility (Shah, Ahmad, & Mahmood, 2018). However, evidence indicates that noise traders use technical analysis in the "head-and-shoulders" chart pattern (Bender, Osler, & Simon, 2013). Earlier works have demonstrated the activeness of noise traders and the influencing power that noise traders have on market prices, for example (Lee, Shleifer, & Thaler, 1991). A significant amount of empirical evidence shows that noise traders have been involved in speculation (De Long et al., 1990b). As noted above, the argument that the market is inefficient results from the broader stream of the research study of the participants' subjective nature to common errors from heuristics and biases, as behavioural finance indicates. However, these common errors of investors affect stocks and other asset classes of the financial market, including the housing market, as the voluminous studies have already indicated, which is a vital issue of the present study.

This study offers an asset pricing model with three traders who can learn and turn the trading strategies via the noisy expectation equilibrium mechanism. The emphasis of the analysis is on the estimation of sets of multivariate models to find significant effects of noise traders' risk on market returns (volatilities) for both individual and institutional investors. The remaining sections of this research are designed as follows: Section 2 defines and reviews the literature; Section 3 focuses on the research method; Section 4 analyses the methodological process of the paper, and Section 5 represents the conclusion which includes future research directions.

2. Literature Review

2.1 Booms and Busts in Asset Prices

The history of capital markets is full of booms and busts in asset prices that are difficult to reconcile with underlying economic conditions see, for example, (Bordo & Jeanne, 2002); (Jaeger & Schuknecht, 2007); (Semmler & Bernard, 2012). Financial markets have given room for behavioural finance to justify business behaviour (Lam & Hui, 2018). Following the work of (Black 1986); (De Long et al., 1990b), several writers have estimated that overconfidence has the potential to destabilise financial markets. For example, noise traders in the market may cause asset prices to diverge from their underlying values, especially in the stock market. In a specific financial bubble, the unreasonable expectations of future returns rather than the present economic reality urge the typical investor to enable bubble-driven expansion and finally bust (Sornette, 2014, p.32.33). Trading behaviours create the market price, and heterogeneous investors have different beliefs and expectations about the price making it hard to understand the complicated dynamics of the futures market in traditional economic theories (Gong, Tang, & Xu, 2021). Arbitrage in the spot and futures markets plays a crucial role in pushing the basis reversion, referring to the difference between the spot price and the futures price (Gong et al., 2021). The trading behaviour of fundamentalists, technical traders, and other speculators will influence market volatility (Lin, Chou, & Wang, 2018). When the basis widens largely, arbitrageurs buy futures and simultaneously sell the spot, pulling the fundaments down to an average standard. When the basis narrows, arbitrageurs trade in reverse.

The overreaction hypothesis implies that the investors overreact due to the new knowledge initially, causing the prices to deviate from their fundamental values and then correct by taking the prices back to the fundamental values (Reddy, Qamar, Mirza, & Shi, 2020). However, the name "price bubble" conjures a mental picture of a swelling soap bubble, which is doomed to burst suddenly and irreparably (Shiller, 2015b). According to (Garber 1990), an asset bubble is a situation in which asset prices do not behave in ways explainable by economic fundamentals and can be described as "any unsound commercial undertaking accompanied by a high degree of speculation. Among the substantial study on the global financial crisis in 2007 and 2008, the disagreement on price bubbles in financial markets is long-lasting, and it has been widely accepted that price bubbles could distort market transactions since prices are the most crucial signals for traders (Mao, Ren, & Loy, 2020).

The credit boom preceding the 2008 financial disaster has spurred economists' interest in the relationship between debt, trading decisions, and asset prices (Braggion, Frehen, & Jerphanion, 2020). The great recession was preceded by a very rapid expansion of credit and was followed by a collapse in home prices and consumption, which did not restore its pre-crisis level for three years (Di Maggio & Kermani, 2017, p.2). The current study in the housing market reveals a growing feeling of controversy surrounding the speculative character of housing market prices that have been implicated with asset bubbles as behavioural finance has highlighted various facets of it. Central to this dispute is that "the asset pricing literature has highlighted numerous aspects: first, bubbles appear to align with broad trading volume; second, they are frequently correlated with cycles of radical technical or financial innovations; third, they tend to coincide with low-interest rates and high leverage" (Penasse & Renneboog, 2018, p.1). Lower inflation, the gradual drop in the prices of capital goods, and a shift in economic activity towards information technology with low demand for capital have reduced investment demand, triggering a worldwide decrease in the real interest rates, which has led to bubbles in asset prices (Teulings, 2016).

2.2 Efficient Market Hypothesis

In the past two decades, there has been a methodological change in the analytical debate of efficiency of the economy due to the impact of investors' future expectations combined with the evidence against the Efficient Market Hypothesis (EMH) brought by the field of behavioural finance (Long, Shleifer, Summers, & Waldmann, 1989a); (Shleifer & Summers, 1990). Samuelson (1965) argued that stock prices should follow a random walk if rational competing investors

https://dx.doi.org/10.30566/ijo-bs/2021.12.70

sought a fixed rate of return and demonstrated that stock prices are close to a random walk. As a result, the stock in the efficient markets hypothesis rallied (Shleifer & Summers, 1990). As specified by (Fama 2021), the efficient market refers to the market in which prices can fully represent the available information and provide reliable signals for resource allocation. According to EMH, the forecast of stock returns should not be possible since market prices will represent all available information (Audrino et al., 2020).

The EMH is based on assumptions that the futures price is expected to represent fundamental information equal to the fundamental value. As the maturing date approaches, the futures and spot prices technically converge. EMH, which embodies the critical understanding that a powerful corrective factor influences securities prices (Daniel, Hirshleifer, & Teoh, 2002), has been recognised as the fundamental theory underpinning all aspects of finance. However, a growing amount of empirical evidence has shown that the futures price may deviate significantly from the spot price in price discovery, suggesting the existence of mispricing (Jacobs, 2016). Therefore, based on three distinct forms of market efficiency and evaluations, much of modern investment theory and practise is predicated upon the EMH (Lo, 2005).

EMH implies that markets are perfectly efficient, correctly, and instantaneously integrate all available information into asset prices. A market is efficient if prices "fully reflect" public information. A market is "efficient concerning an information set" if prices are unchanged by exposing that information to all participants. This last concept is the secret to checking (empirically) the EMH. In an efficient market, prices can adjust only when new and unanticipated knowledge exists. It is generally believed that the price should represent fundamentals, which cannot change rapidly and significantly in the short term. Instead, recent research has shown that trading practices and investor structure significantly impact the relationship between futures prices and spot prices (Chen & Chang, 2015); (Park & Shi, 2017). Since the information and, consequently, price changes are anticipated, prices will be random. The random walk hypothesis has formed the backbone of financial economics theory. Many of the core pillars of EMH are portfolio theory, option pricing model, the Capital Asset Pricing Model, extended factor models of asset values, and separation theorem Tobin (Sornette, 2014). Under the assumption of EMH, all market players are rational investors who always act in their self-interest and make investment decisions optimally by trading off costs and gains, weighted by the statistically correct probability and marginal utilities (Lo, 2005); (Hodnett & Hsieh, 2012). Rational investors mean risk-averse investors, and the idea of risk-averse derives from the anticipated utility theory, which analyses the decision-making process of investors in the presence of risk (Hodnett & Hsieh, 2012). The EMH began in the 1960s and was considered an immediate success, both in theory and empirical as a result, early empirical work provided overwhelming support to EMH (Ruppert, 2004). Jensen (1978) claimed that "no other assumption in economics has more robust empirical evidence. However, extensive evidence opposing EMH has altered the early enthusiasm.

Shiller (2000) labelled EMH as "the most surprising miscalculation in the history of economic thought." The random walk theory, which is the basis of EMH, has been a topic of empirical studies since behavioural finance frequently conflicts with EMH (Ruppert, 2010). Proponents of behavioural finance claim that subsets of investors often do not make investment decisions based on a company's fundamentals and can impact stock prices through unexpected shifts in their emotions (Verma & Verma, 2007).

Behavioural finance, a contribution of (Kahneman, 2003), is an extension of behavioural economics, employing psychological insights to inform economic theory. Kahneman (2003) recognised the essential role of emotion and intuition in people's decision-making, which leads to systemic and predictable errors in some situations. Indeed, according to Thaler (2010), behavioural finance is simply a moderate, agnostic approach to researching financial markets. Researchers such as Shleifer & Summers (1990, 19-20) have sought an alternative to the methods of the efficient market, and their approach rests on two assumptions. First, some investors are not rational, and their demand for risky assets is affected by their beliefs or sentiments that are not fully justified by essential news. Second, arbitrage, defined as trading by entirely rational investors not exposed to such sentiment, is risky and limited. Shleifer & Summers (1990) claimed that arbitrageurs do not fully counter changes in investor mood and affect securities returns and suggested that such an approach to financial markets is better than the efficient market's paradigm.

Further, it has been argued that stock and bond prices are more volatile than proponents of rational, efficient market theory would expect (Thaler, 2010). For example, scholars debated as to whether the increased stock price and the ensuing market crash of 1929 were due to reasonable emotions (White, 1990); (De Long & Shleifer, 1991) or perhaps "Irrational exuberance (the psychological basis of a speculative bubble)" pushed the prices above fundamental values (Shiller 2000). "Irrational exuberance is described as a speculative bubble as a situation in which news of price increases spurs investor enthusiasm, which spreads through psychological contagion from person to person, in the process amplifying stories that may justify the price increases and bringing in a larger and larger class of investors, who, despite doubts about the real value of an investment, are drawn to it partly through envy of others' successes and partly through a gambler's excitement (Shiller, 2015a). Moreover, recent studies have indicated the rapid rise and fall of technology stocks due to overly bullish sentiments that began returning to more normal levels in the spring of 2000 (Brown & Cliff, 2005). Researchers emphasised the potential influence of the media in building asset bubbles and triggering market crashes example (Shiller, 2000); (Garcia, 2013). In the field of behavioural finance, Behavioural biases such as 'conservatism' or 'over-confidence have become logical reasons for several investor sentiments in asset pricing that are hard to reconcile with a rational

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decision-making system (Cornelli, Goldreich, & Ljungqvist, 2006). Investors' future anticipation can contribute to the overpricing or under-pricing of stocks and hence change the pricing models of the efficient market.

Furthermore, there is evidence that noise traders adversely affect the information efficiency of the market, but only when informed traders have essential private knowledge (Bloomfield, O'hara, & Saar, 2009). The question currently is not whether investor sentiment affects stock prices or not. Different research has presented supporting evidence favouring investor sentiment in determining stock price behaviour and how the effects of investor sentiment are assessed and quantified. The literature has identified many different investor sentiment indicators, and one approach is direct via economic variables (Baker & Wurgler, 2007). Much of earlier investigations in behavioural finance provide a theoretical framework outlining the relevance of investor sentiments in asset pricing, most notable the research of (De Long et al., 1990a). Noise traders are classified as those who "falsely assume that they have unique knowledge about the future price of risky assets (Long et al., 1989); (De Long et al., 1990a); (Verma & Verma, 2007). Some study on heuristic biases has succeeded in explaining the abnormalities in financial markets (Barberis, Greenwood, Jin, & Shleifer, 2018). The primary purpose of these works has been to provide observable measures that can explain the existing data pattern of the relative effects of fundamental and noisy trading on the generation of conditional volatility and evaluate the relationship between sentiments and the mean of stock returns following (De Long et al., 1990a). However, the extent to which 'sentiment' (as opposed to rational) investor demand can account for these events in equilibrium is debatable, given the difficulty in empirically defining the demand curves and information processing of distinct investor groups. Therefore, this study proposed a conceptual framework based on behavioural approaches and the alternative to the efficient markets approach to research the role of sentimental investors that helps identify the informational updating among investors. Based on the studies cited above, investors are assumed to be boundedly rational. Therefore, they can learn and adjust their strategy according to the payoffs. The model demonstrates the nonlinearities resulting from bounded rationality, which are potential drivers of mispricing.

2.3 Relevant Studies

Several empirical studies have shown that investor sentiment plays a significant role in asset pricing ((Jawadi, Namouri, Ftiti, & Control, 2018). Several researchers have investigated the relationship between determinant economic factors and housing prices in Malaysian contexts. For example, Law & Lim (2017) studied seasonally adjusted quarterly data from 2006 through 2015. Using the Static ARDL model, they examined the relationship between Loans for residential property purchases and residential property prices, income level, and residential property prices to understand housing prices. They found a significant long-run relationship between residential property loans and prices. They stated that the subprime mortgage crisis produced a drop in residential property prices in the long run. They also noticed complex short-run linkages to identify negative and statistically significant error correlations. Using a hedonic regression technique (Wong, Azhari, Abdullah, & Yip (2019) studied yearly panel data from 1988 to 2016 to explain correlations between socioeconomic determinants of crime rates and home prices and discovered a tangible, robust negative link between crime rates and housing prices. LIM & LAU (2018) evaluated the association between the cost of housing and its pricing using quarterly data from 2000 through 2016. They employed a static autoregressive distributed lag (ARDL) model and a positive link between Interest rates and house prices.

Using 14 years (quarterly) time series Baharuddin, Isa, & Zahari (2019) examined the relationships between interest rates, inflation rates, and GPD to understand housing prices. They used VECM to describe the relationships and found Negative relationships between interest rates and housing prices, Negative relationships between inflation rates and housing prices, but A positive relationship between GPD and housing prices. Using dynamic heterogeneous panel data of a quarterly frequency from 2005 through 2013, Wong, Lee, & Koong (2019) explored the link between real gross domestic product, population, foreign inflow, and property prices to explain supply and demand. They found significant relationships between wages, population, foreign influx, and housing prices. Kok, Ismail, & Lee (2018) analyse the relationships between exchange rate, actual gross domestic products, and Interest rate and housing using quarterly data from 2002 through 2015. They utilised Structural vector autoregressive regression (SVAR), and their conclusion revealed that 1) exchange rate, and real gross domestic products have a considerable effect on housing prices (2) interest rate shock has negligible influence on housing prices. Using quarterly data from 2000 through 2010 and VECM, Pillaiyan (2015) explored the association between inflation rate, stock index, money supply, and numerous residential loans and housing prices. It found the substantial long-term impact of these factors on housing prices. Thaker, Ariff, & Subramaniam (2020) used dynamic autoregressive-distributed lag (DARDL) To explain changes in home prices over a defined timeframe in Malaysia (from the year 2007 to 2018). The key results will be focused on the primary model of dynamic ARDL. First, the R-square value (91.56 per cent) provides highly explanatory power in describing the variance in residential prices in Malaysia with a significant level of F-statistics. Capital gain and losses (CCGL) positively correlate with home prices.

Table: 1 Summary of Relevant Studies

Author/s	Data	Methodology	Variables	Findings/Results

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(Hong & Li, 2020)	Month-on-month growth data for new and secondary housing prices for 70 large and medium-sized representative cities in China	GARCH (1,1) model	Monthly Housing Price Return, Investor Sentiment Index, Closed-End Fund Discount, Average First-Day Returns, and Consumer Confidence Index	An "interdependent" relationship between the housing prices and investor sentiment in terms of long-term investors
(Balcilar, Bouri, Gupta, & Kyei, 2020)	A daily newspaper-based index developed by Shapiro, Sudhof, and Wilson (2020)	Nonlinear Granger causality via a hybrid approach	Housing Returns (HR) Economic Sentiment Index (ESI	The result showed economic sentiment does predict US housing returns and volatility.
(Usta 2020)		Augments framework of Wang and Hui (2017)	Supply as the dependent variable, and housing prices, credit volume, industrial production, real effective exchange rate, and sentiment as the independent variables	The finding showed that the sentiment has short-run forecasting power of housing prices and supply of housing.
(He & Xia, 2020)	Data from the Chinese Statistical Yearbook from 1998 to 2017	DSGE model	Housing price, exchange rate and property tax	The finding showed that an unhealthy housing market negatively affects the output.
(Lam & Hui, 2018)	3-month lags and 6-month lags	Principal component analysis (PCA)	Residential property and 13 independent variables.	The finding showed that sentiment significantly, negatively correlated with future returns, with a lagged time from 3 months to 12 months.
(Hattapoglu & Hoxha, 2020)	Publicly available data from different sources	Fixed effects method	Monthly listings, Unemployment rate, Dow Jones index, Consumer sentiment, and Mortgage rate	The results show that the number of monthly listings has a significant and positive effect on the number of houses that go through a price reduction.
(De Jorge-Huertas & De Jorge-Moreno, 2020)	From the period 1977 m1 through 2019 m1	Interrupted time series	Consumer price index	The results showed the partial positive effects of legislative instrumentalisation in decreasing trends in housing prices
(Al-Masum, Lee, & Analysis, 2019)	Quarterly data series from the first quarter of 1991 to the fourth quarter of 2016	Cointegration test and a VECM.	104 observations for all variables	The results suggested a significant positive correlation between MHSP and POP, GDI and GDP at around 97 per cent. MHSP is strongly and negatively correlated with INTEREST (-0.75) and UNEMP (-0.84). A low negative correlation coefficient between HS and MHSP (-0.42) has also been observed
(Brzezicka, Łaszek, Olszewski, &	time horizon of quarterly data from 1Q2010 to 4Q 2016.	VAR model VECM method	Housing Prices, Real Property	Their main finding is that low-income households in metropolitan areas with more

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Waszczuk, 2019)		vouchers have experienced faster rent increases than those where vouchers are less abundant.

3. The Heterogeneous Expectation Model

To describe the interactions between heterogeneous investors, most researchers compared the heterogeneous agents' model (HAM) with adaptive belief, introduced in 1997 and applied to financial markets. In the last two decades, broad behavioural literature on heterogeneous agents' models (HAMs) with boundedly rational agents with heterogeneous expectations has developed; (Hommes, 2021). Before the crisis, Central Banks and other policy institutions extensively utilised the essential class of macro models: the Dynamic Stochastic General Equilibrium (DSGE) models (Hommes, 2021). However, the DSGE models have been questioned (Stiglitz, 2018). After the outbreak of the financial-economic crisis, a serious debate among macroeconomists about the future of macroeconomic theory has arisen (Hommes, 2021). There have also been more extreme recommendations for transforming macro through a paradigm change to adopting an interdisciplinary complex systems approach, behavioural agent-based models, and simulation (rather than analytical tools) (Battiston et al., 2016); (Dawid & Gatti, 2018); (Bookstaber & Kirman, 2018); (Haldane & Turrell, 2019); (Hommes, 2021).

The HAM literature has also been inspired by the noise trader literature in finance, pioneered by DeLong et al. (1990), who proposed models where one group of agents has rational expectations. Another type, the noise traders, has nonrational expectations. In the model of DeLong et al. (1990), noisy traders misunderstand their anticipation about the following period's price of a hazardous asset. They show that noisy traders can survive and achieve a more significant expected return than sensible traders. DeLong et al. (1990) investigate a noisy trader model with optimistic feedback traders and show that rational speculation can be destabilising in the presence of optimistic feedback traders. These examples go against the Friedman hypothesis that non-rational traders will be driven out of the market because they lose money against smart traders (Hommes, 2021). Instead, these instances indicate that non-rational merchants can survive competition with rational agents in a heterogeneous setting. A coherent early critique of the representative agent approach in macroeconomics has been given previously. The relevance of agents' interactions for the emergent aggregate behaviour has been emphasised as an alternative. A stochastic model of recruitment through local interactions, based on previous work, has been suggested and, more recently, developed (Hommes, 2021).

Works in behavioural finance began in the 1990s with models of noisy traders' risk advanced based on psychology and behavioural finance, for example (Long et al., 1989); (Shleifer & Summers, 1990); (De Long et al., 1990a). The evolution of noisy traders' models leads to further studies that have produced evidence favouring solid co-movements between investor sentiments and the stock market returns, recognising the existence of individual investor sentiments and institutional investor emotions (Verma & Verma, 2007). These models examine asset pricing from behavioural equilibrium perspectives and describe market dynamics with an evolutionary framework. Studies have shown that the nonlinearities stem from the interactions of heterogeneous investors and contribute to market volatility.

4. Methodology

4.1 Noisy Expectation Equilibrium Model

Housing prices evolve concerning demand and supply (Dieci & Westerhoff 2012, p. 6). Suppose the market in the model of this study is populated by three types of agents representing three types of traders: consumers, constructors, and investors. Consumers and investors are on the demand side of the market, while constructors are on the supply side. Using the frameworks of (Dieci & Westerhoff 2012) and (Wang & Hui 2017) to model housing prices as a function of housing demand and assuming that aggregate consumer demand for housing, (D^c_t) is determined by the house price index value at time t:

$$D^c_{t+1} = \alpha + bP_t, \qquad (4.1)$$

Where:

t is the time measured in quarters. P_t is the logarithm of the real house price index at time t.

Investors choose among two forecasting rules for determining the expected return $E(R_{t+1})$, called fundamentalist and chartist. The return Rt+1 is defined as the real log-price change P_{t+1}-P_t. The first rule, fundamentalist, is based on the expectation of mean reversion of the market price towards the long-term fundamental value.

$$E^f_t(R_{t-1}) = \chi(P_t - F_t) \qquad (4.2)$$

in which Ft is the log real fundamental price and α<0 is the speed of mean reversion expected by the fundamentalist investors. We assume that all investors are mean-variance maximisers with the same level of risk aversion (η) and with

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the same beliefs about the conditional variance of housing returns (σ^2). Under these conditions (Brock & Hommes 1998) show that the speculative demand of investors D_t^f is a linear function of the expected return:

$$D_{t+1}^f = \frac{1}{n\sigma^2} E_t^f(R_{t-1}) = k\chi(P_t - F_t), \tag{4.3}$$

in which η>0 represents the investors' risk aversion parameter, $\sigma^2 > 0$ is the constant variance of housing returns, and k = 1/ησ2>0. The second rule, which we call chartist, takes advantage of positive autocorrelation in housing returns, documented by (Case and Shiller 1988). Chartist expectations are given by

$$E_t^c(R_{t-1}) = \beta\left(\sum_{l=1}^{L} R_{t-1+1}\right) \tag{4.4}$$

in which β>0 is the extrapolation parameter, and L>0 is a positive integer indicating the number of lags. Chartists simply expect past price changes to continue in the future without considering the fundamental value. Given the assumption of mean-variance preferences, the speculative demand of chartists (Dct) is a linear function of past housing returns:

$$D_{t+1}^c = \frac{1}{n\sigma^2} E_t^f(R_{t-1}) = k\beta\left(\sum_{I=1}^{L} R_{t-I+1}\right) \tag{4.5}$$

Whereas agents in the model (Dieci & Westerhoff, 2012) switch based on the distance between price and fundamental value, investors in our model switch between the two forecasting rules depending on their recent prediction performance. For this purpose, we use a logit switching rule, as introduced by (McFadden 1981) and applied in (Brock & Hommes 1997); (Brock, & Hommes 1998), such that the weight of fundamentalists $W_t \epsilon < 0,1 >$ is given by:

$$W_t = \left(1 - \exp\left[\gamma\left(\frac{\pi_t^f - \pi_t^c}{\pi_t^f + \pi_t^c}\right)\right]\right)^{-1} \tag{4.6}$$

and the chartist weight is equal to $(1 - W_t)$, in which π_t^f *and* π_t^c are the observed forecast errors over the recent past of the fundamentalist and chartist rules at time t, respectively. The parameter γ>0 captures investors' sensitivity to differences in forecast errors between the two rules. Higher values of π_t^f and π_t^c imply more enormous forecast errors, and a positive value of γ then causes investors to give more weight to the better performing rule. The systematic investment performance, measured by π_t^f *and* π_t^c, is based on the observed absolute forecast errors of the fundamentalist and chartist rules in the previous K periods. That is,

$$\pi_t^f = \sum_{k=1}^{K} \left|E_{t-k}^f(R_{t-k+1}) - R_{t-k+1}\right| \tag{4.7}$$

$$\pi_t^c = \sum_{k=1}^{K} |E_{t-k}(P_{t-k+1}) - R_{t-k+1}|. \tag{4.8}$$

Total demand by investors is then the weighted average demand of fundamentalists and chartists and can be written as follows:

$$D_{t+1}^I = W_t D_{t+1}^f + (1 - W_t) D_t^c. \tag{4.9}$$

Apart from the demand for housing by consumers and investors, constructors build new residential structures and sell them in the market. The new supply by constructers (S_t) depends positively on the value of the house price index at time t:

$$S_{t+1} = c + dP_t \tag{4.10}$$

in which c>0 and d>0.

The overall change in the log real house price depends linearly on excess demand plus a random noise term ε_t, is assumed, which can be thought of as the impact of pure noise traders and is written as:

$$P_{t+1} - P_t = f(D_{t+1}^c + D_{t+1}^I - S_{t+1}) + \epsilon_{t+1}. \tag{4.11}$$

where f>0 is a positive reaction parameter. Filling in the different elements from Eq (1) to Eq (10), and Eq (11) yields the following equation for the housing price dynamics:

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$$R_{t=1} = f\left((a-c) + (b+d)P_t + W_t k\chi(P_t - F_t) + (1-W_t)k\beta \sum_{I=1}^{L} R_{t-I+1}\right) + \epsilon_{t+1} \tag{4.12}$$

Without loss of generality, we can assume that f = 1 and k = 1, because the utility function is invariant to a positive linear transformation, such that the empirical model can be written as follows:

$$\begin{cases} R_{t+1} = c' + d'P_t + W_t\alpha(P_t - F_t) + (1-W_t)\,\beta \sum_{I=1}^{L} R_{t-1+1} + \varepsilon_{t+1} \\ W_t = \left(1 - \exp\left[\gamma\left(\frac{\pi_t^f - \pi_t^c}{\pi_t^f + \pi_t^c}\right)\right]\right)^{-1} \\ \pi_t^f = \sum_{k=1}^{K} |\alpha(P_{t-k} - F_{t-k}) - R_{t-k+1}| \\ \pi_t^c = \sum_{k-1}^{K} \left|\beta \sum_{I=1}^{L} R_{t-k-I+1} - R_{t-k+1}\right| \end{cases} \tag{4.13}$$

c′ and d′ are intercepts of the model

5. Discussion and Conclusion

This study proposes a conceptual framework for a simple heterogeneous agent-based model for the asset market characterised by heterogeneous traders. The model is used to explain the relationships between heterogeneous traders. The resulting mechanism illustrates the development of asset prices and the elements of heterogeneous traders and thus, demonstrates how the information of various traders is aggregated to create the price.

Investors engage in market activity to optimise their utility and trading activities to establish the price. The expected and current prices converge to the fundamental value concurrently to achieve a steady-state as the market progresses. Therefore, the model has shown how analysis could be demonstrated as a self-organising mechanism to realise the price function.

In equilibrium, the price ultimately represents the fundamental information of an asset. However, in certain instances, the equilibrium can be destabilised by behavioural variables. For example, when investors have a high tolerance for risk, they trade in large quantities and affect the price. In such cases, the model can examine the combined impact of behavioural variables on market stability.

To a certain degree, heterogeneous investors' participation can help minimise aggregate excess demand in the market and reduce price volatility. However, the reality is more complex. Research evidence showed no association between arbitrage and its effect on the financial market, demonstrating how arbitrage fails to mitigate noise traders' risk. As a result, the asset price can deviate dramatically from the fundamental value, which does not indicate sound asset awareness.

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