EXPLORING HOUSE PRICE DYNAMICS: AN AGENT-BASED SIMULATION WITH BEHAVIORAL HETEROGENEITY

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ABSTRACT

EXPLORING HOUSE PRICE DYNAMICS: AN AGENT-BASED SIMULATION WITH BEHAVIORAL HETEROGENEITY

In contemporary capitalist economies, housing is not only a shelter that satisfies a basic human need. It is also a commodity produced for exchange in markets and an asset for storing and enhancing wealth. As such, its mispricing can have repercussions for individuals, firms, industries, nationwide economies, and for the global economy. The purpose of this dissertation is to explore the price dynamics of this complex entity in an analytically tractable framework. In agreement with a recent but growing body of literature, the study shares the view that incorporating insights from behavioral economics can be valuable in such an undertaking.

To support this statement, the dissertation first presents a theoretical framework that situates differing views on house prices in a wider split between neoclassical and behavioral economists. Then, the study proposes an agent-based simulation by extending a prominent real estate market model known as the Four Quadrant Model. Specifically, the extended model seeks to explore the extent to which behavioral heterogeneity and dynamic market behavior enhance the existing explanations of house price dynamics. The dissertation validates the proposed model by running a set of experiments with empirical data obtained from Istanbul's housing market between January 2010 and September 2015. The results suggest that both the inclusion of behavioral heterogeneity and dynamic behavior are relevant in the exploration of house price dynamics. Based on the theoretical framework and the simulation results, the dissertation calls for action on the part of policy makers, researchers, and members of civic and professional organizations.

ÖZET

KONUT FİYATI DİNAMİKLERİNİN ARAŞTIRILMASI: ÇOKTÜREL DAVRANIŞLAR İÇEREN ETMEN-TABANLI BİR BENZETİM

Günümüzdeki üretim ve paylaşım düzeninde konut sadece barınma ihtiyacını karşılama işlevinden ibaret değildir. Konut, aynı zamanda piyasalarda ticareti yapılmak üzere üretilen bir meta ve yatırım amacıyla satın alınan iktisadi bir varlıktır. Konutların yanlış fiyatlandırılmasının bireyler, firmalar, endüstriler, ulusal ekonomiler ve nihayet küresel ekonomi için ciddi olumsuz sonuçları olduğu bilinmektedir. Bu çalışmanın amacı bu karmaşık varlığın fiyat dinamiklerini analitik bir çerçeve içinde araştırmaktır. Çalışma, son yıllarda yapılmış olan benzer araştırmalardan yola çıkarak, henüz gelişmekte olan davranışsal iktisadi kuramlarının bu amaca katkı sunabileceği tezini öne sürmektedir.

Bu tezi desteklemek amacıyla, çalışma önce konut fiyatlarına dair farklı bakış açılarını, neoklasik ve davranışsal iktisatçılar arasında son yıllarda süregelen bir tartışma bağlamında kuramsal bir çerçeveye yerleştirmektedir. Sonrasında ise, Dört Kadranlı Model olarak bilinen bir modeli geliştirerek analitik olarak izlenebilen çok etmenli bir benzetim modeli sunmaktadır. Söz konusu geliştirilmiş model, bilhassa davranışsal çoktürelliğin ve dinamik davranış değişikliklerinin mevcut modeli ne ölçüde geliştirdiğini araştırmaktadır. Çalışma, önerdiği modeli İstanbul konut piyasasından Ocak 2010 ve Eylül 2015 tarihleri arasında elde edilen veriler ile sınamaktadır. Sonuçlar hem davranışsal çoktürelliğin hem de dinamik davranış değişikliklerinin konut fiyatlarının araştırılmasında önem arz ettiğini ortaya koymaktadır. Çalışma, çizdiği kuramsal çerçeveye ve önerdiği benzetim modelinden edilen bulgulara dayanarak konut piyasalarıyla ilgilenen karar alıcıları, araştırmacıları ve sivil toplum örgütlerini eş-güdüm dâhilinde harekete geçmeye davet etmektedir.

Filiz ve Mehmet Özbakan'a

PREFACE

Before beginning this dissertation, I had been personally and professionally involved in situations that required making sense of the price tag humans put on the built environment. Personally, I had owned a home in the US, which I was fortunate enough to sell before the infamous housing bubble imploded in 2006. Professionally, I had submitted and evaluated several bids on construction projects. In most of these situations, it was apparent that construction costs and desired profit levels did not suffice to explain the market price on the built environment.

During the early phases of this dissertation, I thought I had found the answer. I was particularly impressed with the arguments of critical theorists from a variety of disciplines including geography, planning, and sociology. Although these theories referred to a wealth of subjects including culture, social classes, power, neoliberal politics and so on, they did not lead me to propose a satisfactory theoretical contribution. At that point, Prof. Kale guided me to broaden the scope of my readings to include competing perspectives, including the behavioral one. As I did so, first, it seemed like there were simply too many theories to consider, and it was impossible to put them into a consistent whole. Fortunately, as I kept reading, pieces began to fall into their places.

This study rests on contemporary theories in behavioral economics and utilizes simulation as a research method. Both the disciplinary background and the methodology allow making precise statements about complex social mechanisms such as competitive markets. On the downside, it is necessary to reduce this complexity to a system of relations between simplified computational constructs. I used mathematical notation to express these relations, but also included diagrams and text to make them accessible to audiences with diverse backgrounds.

At the end of this dissertation, I am pleased to present what I hope to be a step forward in understanding how humans determine the price of the built environment. Having used Istanbul’s housing market as the empirical context for validation purposes, I hope that the study you are about to read serves as a springboard for other researchers who tackle the same problem in different contexts.

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

Symbol	Definition
φ	Adaptive Expectations Intensity
π	Annual Capital Gain/Loss
δ^p	Annual Price Depreciation Rate
ω	Annual Maintenance Cost Rate
C	Construction Activity (Flow)
C^c	Construction Cost
C^d	Construction Delivered
C^s	Construction Started
D	Demand
$*$	Equilibrium Superscript
f^c	Fitness of Chartist Strategy
f^f	Fitness of Fundamentalist Strategy
u	Cost of Ownership
A	Demand Constant
E	Demand Instrument
r	Discount Rate
$\in$	Expectations Operator
i	Inflation
ζ	Intensity of Choice
y	Income
n^m	Memory for Chartist Extrapolation
n^u	Memory for Strategy Comparison
r^m	Mortgage Rate
m	Mortgage Availability
ψ	Percentage of Chartists
N	Population Size
P	Price
ε	Price Elasticity of Demand
η	Price Elasticity of Supply
ρ	Probability of Recruitment
θ	Probability of Self-Conversion
Q	Quantity (Flow)
Q^d	Quantity Demanded
Q^s	Quantity Supplied
μ	Required Capital for Mortgage Credit
V	Rent (Revenue Flow)
r^{rf}	Risk Free Interest Rate
γ	Risk Premium Rate
S	Supply (Stock)
δ	Stock Depreciation
B	Supply Constant
n	Supply Lag
t	Time

LIST OF ABBREVIATIONS

Abbreviation	**Definition**
ABM	Agent-Based Modeling
CBRT	Central Bank of the Republic of Turkey
CME...................	Construction Management and Economics
CPI	Consumer Price Index
EMH...................	Efficient Markets Hypothesis
EU	Expected Utility
FQM...................	Four-Quadrant Model
HAM	Heterogeneous Agent Model
MAPE	Mean Absolute Percentage Error
NUE	New Urban Economics
REH	Rational Expectations Hypothesis
SEU....................	Subjective Expected Utility
TOKİ..................	Housing Development Administration of Turkey
TURKSTAT.......	Turkish Statistical Institute

CHAPTER 1

INTRODUCTION

Spectacular booms in the US financial markets marked the 1990s. Then, beginning with the turn of the millennium, the real estate market “took off”. Within a few years, the average real home price increased around 50% until 2004 and reached its peaks in 2006. In the meantime, the excitement spread across the globe to a number of countries and particularly to a several international “glamorous cities” including Bombay, London, Madrid, and Istanbul among others (Shiller, 2005).

Following its peak in 2006, the increase in the US housing markets came to an abrupt end. This came to be known as the infamous “housing bubble” of 2006, which drove the US economy into its most severe economic crisis since the Great Depression. As a result, by the end of 2008, over two million homes entered foreclosure proceedings and about 2.5 million people lost their jobs (Magdoff and Yates, 2009, pp. 17-87). Between 2007 and 2013, the home prices in the US declined around fifty percent (Shiller, 2014). Similarly, home prices in the Netherlands, Spain, Iceland, and Ireland suffered significant falls (Ambrose, et al., 2013; Levitin and Wachter, 2013).

Although several residential markets have experienced severe corrections recently, house prices in Turkey have been rising steadily. To be precise, between 2010 and late 2015, nationwide *real* house prices increased 32.67%, while Istanbul’s housing market nearly doubled this rate at 64.20% (*Sources*: The New House Price Index”, CBRT; “The Consumer Price Indices”, TURKSTAT). Interestingly, during this upsurge, the supply of housing units kept increasing as well, amounting to a change in stock equal to 14.83% and 12.54% in Turkey and in Istanbul respectively (*Sources:* “Building Permits Statistics” and “Building Census 2000”, TURKSTAT).

There are differing opinions about whether or not this trend is healthy. On the one hand, some analysts argue that the dynamics of the market are consistent with *economic fundamentals*. For example, according to the ex-president of the Housing Development Administration of Turkey (TOKİ), there was an “immediate housing demand of 2.5 Million units” around the year 2007, which necessitated a national “housing production campaign” (Bayraktar, 2007). Citing similar statistics of housing supply and demand, a study published by Deutsche Bank Research reported a need for “more than 5 Million housing units within the 10 years in the country” and highlighted “investment opportunities” in the Turkish residential markets (2008). Similarly, a recent corporate analysis suggested that the Turkish real estate market dynamics were consistent with “macro-economic factors” such as construction costs, interest rates and inflation. The analysis further argued that current price-to-rent and price-to-income ratios disproved the idea of an anomaly in the market (Cushman & Wakefield, 2014). Along the same line of reasoning, another group of analysts quoted a survey that focused on the emerging trends in European real estate, and listed Istanbul as the highest scoring city in terms of *expectations* of capital gain from real estate investments, surpassing Zurich, Munich, London, Paris, and Moscow (PricewaterhouseCoopers LLP, 2013).

On the other hand, some analysts voice concerns about a potential *mispricing* in the residential market. For example, the Vice President of the Association of Real Estate Investment Companies (GYODER) pointed to the “imbalance” between housing prices and rents in Istanbul, and argued that rents no longer justified the prices (Azizoğlu N., quoted in Karayalçın, 2010). A real estate research firm further detailed this observation by demonstrating that renting houses in Istanbul became a more “attractive option for consumers” than purchasing them since 2009 (Reidin, 2013). In support of this claim, several analysts from the International Monetary Fund (IMF) cautioned that in a number of member countries in the Organization for Economic Co-operation and Development (OECD), the price-to-rent ratio was above historical averages, “leaving room for price corrections down the road”. The study listed Turkey as the country with the sixth highest rate of price increases among 52 countries in the second quarter of 2013, and concluded that “the result could be a bust if this is not well managed” (IMF, 2013). Similarly, a prominent real estate developer objected to the recent housing policy and voiced his anticipations of a “huge crisis” in the near future (Mutlu, 2013).

While news and commentaries on the future of Turkish housing markets are common in the national media, from time to time, international media cover the topic as well. For instance, a columnist in the Wall Street Journal warned against the booming Turkish real estate sector and pointed to the possibility of overheating, instability and a potential bust (The Wall Street Journal, 2012). Similarly, another analyst from the New York Times suggested that the inventory of unsold housing supply, which amounts to 1.5 million units, was “alarming”. (The New York Times, 2014). Another article on the subject expressed similar concerns because of the inconsistency between the housing markets and the rest of the economy (SE Times, 2012).

These are serious concerns; and unfortunately, several renowned economists share them. For example, as early as 2005, Robert Shiller listed Istanbul as one of the cities where significant risks existed in the housing markets (2005). More recently, Daren Acemoğlu informed the Turkish public to be cautious against a bubble similar to those observed in the US and Spain, based on the argument that housing prices have been soaring despite low interest rates (2012). Finally, Nouriel Roubini cautioned that bubbles were appearing in the major urban centers of Turkey (2013).

1.1. The Importance of House Prices

In contemporary capitalist economies, housing is not only about the basic human need for shelter. It is also a commodity produced for exchange in the markets and an asset for storing and enhancing wealth. As such, its mispricing has repercussions for individuals, firms, industries, nationwide economies and even for the global economy.

In order to have access to housing, individuals in contemporary capitalist economies inescapably need to make some kind of "consumer choice" concerning the purchasing or renting of housing units. However, most individuals are relatively inexperienced in housing related transactions and to make matters worse, these transactions involve large sums. In fact, the primary housing units appear as the most important component of households' net worth, comprising 44% to 90% in the euro area (Mathä, et al., 2014) and about 50% in the US (Iacoviello, 2011). For households who rent, housing related expenses are also significant. For example, the average housing costs for the overall population amount to 22.5% and 25% of disposable household income in the EU (Pittini, 2012) and in Turkey (TURKSTAT) respectively.

At an industry level, the importance of housing related projects for the construction industry is obvious. In Turkey, for instance, 75% of all building construction is residential (KONUTDER, 2013). In addition, every new unit of housing triggers economic activities in other industries, due to the various furnishing needs of households. In contemporary economies, housing markets also stimulate an important share of activities in the finance industry, where housing projects are increasingly "financialized" to produce gains for investors (Hudson, 2010; Gülhan, 2011).

At a societal level, the importance of housing prices became evident after the implosion of the infamous "housing bubble" in the US. As the country went into its most severe economic crisis since the Great Depression, the disturbance spread across national borders and immediately affected almost every economy, including those of Ukraine, Argentina, Russia, Mexico, Poland, and Hungary (Dadush, et al., 2009). Turkey was no exception, as the economy literally "collapsed" in the second quarter of 2009, with soaring unemployment rates and an accompanying decline in GDP growth (Kazgan, 2012, pp. 286-289).

1.2. Various Perspectives

As the trouble caused by mispricing in housing markets unfolded, researchers from a multitude of disciplines proposed theories to explain the observed trends. These theories conflict with each other, demonstrating the diversity of the methodological, epistemological, and ideological commitments of the researchers involved in this effort.

For instance, economists committed to the *neoclassical* perspective explain house price changes with *market fundamentals* such as inflation, income levels, population growth, supply levels, etc. Commonly, they argue that market prices reflect the true value of housing units, which is consistent with their firm belief in competitive markets as "ideal mechanisms of distributive justice and efficiency" (Hunt and Lautzenheiser, 2011, pp. 129, 398). Furthermore, they remain confident in individuals' abilities in making pricing decisions based on the assumption that they make *rational* choices by utilizing all publicly available information. As the upcoming chapters will further expound, although these assumptions are subject to criticism, neoclassical theories provide a mathematically elegant, analytically tractable, and generalizable framework for studying housing markets. As such, they represent the most common approach in studies of residential price dynamics, with abundant applications in the Turkish context (e.g., Sari, et al., 2007; Hepşen and Kalfa, 2009; Öztürk and Fitöz, 2009; Bekmez and Özpolat, 2013).

On the other hand, critical scholars from various disciplines such as geography, sociology, and planning contest the core arguments of neoclassical economists. For them, prevailing market prices do not necessarily reflect the intrinsic value of housing units because; simply stated, competitive market mechanisms *systemically* favor the interests of the capitalist class. Accordingly, they argue that the recent developments in contemporary housing markets are part of a “class project” (Hodkinson, et al., 2012) that seeks to accumulate more capital by way of dispossessing the working class of their right to urban land (Harvey, 2010, p. 310) and by way of “speculative redevelopment” (Brenner and Theodere, 2002). Furthermore, critical theorists argue that the neoclassical “preoccupation with the niceties of mathematical analytics can be more of a barrier than a help” in understanding urban phenomena and suggest that they intentionally blur important factors that govern market dynamics (Harvey, [1973] 2009, pp. 139,193). Many studies on Turkish residential markets seem to concur, as they describe the recent market dynamics in reference to a wealth of subjects including culture, status, institutional and political power with less emphasis on analytical tractability (e.g., Keyder, 1999; Keyder, 2005; Bal, 2010; Bora, 2011; Gülhan, 2011; Özdemir, 2011; Karaman, 2013; Bal, 2015).

Yet, over the recent years, an alternative strand of theories has gained prominence. These theories come from *behavioral economics,* which offers a perspective that is at odds with both neoclassical and critical approaches. In contrast to the neoclassical perspective, this strand of research embraces the possibility that markets can malfunction and warns against potential long-term asset mispricing. Furthermore, by referring to psychological research on biased human decision-making, the perspective relaxes the neoclassical assumption that individuals are fully rational. However, methodologically, these theories do not depart from their neoclassical counterparts; i.e., they utilize a mathematical framework that allows analytical tractability. On the other hand, similar to the critical studies, the perspective acknowledges the role of various socio-cultural phenomena in the formation of the trouble in global markets including the recent “capitalist explosion” (Shiller, 2005, pp. 33-36). However, according to behavioral theorists, the problem is not necessarily systemic, i.e., it originates from “the character of human intelligence, reflecting its limitations as well as strengths” (Shiller, 2005, p. 248). As of the time of this writing, behavioral studies applied in the Turkish housing market are scarce, if not non-existent.

1.2.1. The Construction Management and Economics Perspective

Construction management and economics (CME) research recently began to address problems in various housing markets in the core journals of the discipline. For example, studies on the Korean housing markets include a comparative study on the effects of supply side policies (Park, et al., 2010) and a model based on the interaction between house prices, construction companies' earnings, and vacancy rates (Hwang, et al., 2013). Similarly, studies on Chinese residential markets include an investigation of price anomalies (Hui, et al., 2011), an interpretation of the market trends based on changing income levels (Hui, et al., 2012) and a price model based on market participants' utility maximizing behavior (Zhang, et al., 2013). Finally, studies on Mexico include a risk assessment study (Fernandez-Dengo, et al., 2013), and the impact of globalization in housing construction profitability (Cariaga and El-Diraby, 2013). These studies, which initiated a valuable research effort within the CME domain, remain within the bounds of the neoclassical economic perspective.

1.3. Purpose, Thesis Statement, Structure and Limitations

The purpose of this dissertation is to contribute to the exploration of price formations in the built environment, particularly in residential markets. In agreement with a recent but growing body of literature, it shares the view that incorporating insights from behavioral economics can serve such a purpose.

To support this statement, the study first presents a theoretical framework that situates differing views on house prices in a wider theoretical split between neoclassical and behavioral economists. Although the framework focuses on their differences, it echoes the view that the two perspectives can be *complementary*. Second, utilizing this framework, the study proposes an analytically tractable simulation based on a prominent real estate market model (Wheaton, 1999) and extends it by including behavioral heterogeneity among market participants. Finally, the study validates the model with data from Istanbul's housing market; and concludes with a discussion of the extent to which behavioral theories improve the benchmark model.

For conducting inquiries into the nature of complex phenomena, the principle of *Ockham's razor* holds that explanatory variables "should not be multiplied beyond necessity"; and when multiple theories compete, "simpler of them is to be preferred" (Baggini and Fosl, 2010, pp. 209-211). The price mechanism in contemporary housing markets is extremely complex, and any scientific inquiry into their nature needs to reduce this complexity. This dissertation attempts to do so by limiting the scope of the theoretical framework to two economic perspectives only, although it acknowledges the credibility of other existing explanatory research efforts. Furthermore, within the bounds of the two perspectives, the proposed model is inevitably limited in terms of the abstraction necessary for computationally representing social and behavioral constructs it employs. In dealing with this methodological limitation, the study aims to balance its parsimony and accuracy by preferring “to err on the side of simplicity” (Davis, et al., 2007).

CHAPTER 2

THEORETICAL FRAMEWORK

This dissertation is concerned with two interrelated questions: What are the determinants of house prices, and what are the possible interpretations of house price changes over time? In this chapter, the objective is to present a framework for contemporary economic theories that explore these questions.

The framework rests on a recent debate that has been developing over the last four decades. The two sides of this debate are neoclassical economists and behavioral economists who have different takes on the determinants of house prices as well as on the interpretation of price changes. Neoclassical economists represent the mainstream economic school of thought. For them, house price changes are in line with rational expectations of individuals who not only successfully read market fundamentals, but also correctly predict future values of economic variables. Accordingly, they maintain that there is no mispricing in housing markets, i.e., prices are right. Behavioral economists on the other hand, represent an alternative perspective, which principally maintains that individuals do not make their pricing decisions rationally. They propose the consideration of psychological, sociological, and cultural factors in interpreting housing market behavior. From their viewpoint, prices are not always right and long-term mispricing does exist.

This particular debate about house prices is part of a wider theoretical split on asset pricing found in the differing positions of two of the 2013 Nobel Prize Laureates (Academy of Sciences, 2013). One of the Laureates is Eugene Fama, who received the Prize in recognition of his neoclassical contributions, including the *Efficient Markets Hypothesis* (EMH) that he formulated in the early 1970s. According to the hypothesis, market prices accurately reflect the true values of assets, known as the *fundamental value*. If an asset is mispriced, then rational acting agents will take advantage of it in order to maximize their profits and thereby drive the price to its fair value. The emergence of an asset bubble, which connotes a persistent mispricing, is therefore impossible once EMH is accepted.

Robert J. Shiller, on the other hand, received the Prize for his contributions to behavioral economics. His work challenged neoclassical tenets in various forms: by presenting empirical evidence against market efficiency; by drawing attention to historical data that suggest the presence of asset bubbles; and by highlighting psychological research output that refutes neoclassical assumptions of human rationality.

In the presentation that follows, the intention is not to take a side in this debate. On the contrary, this study intends to strongly echo the view that both neoclassical and behavioral approaches offer valuable insights into the formation of house prices (see e.g., Shefrin, 2008, p. xix; Watkins and McMaster, 2011). The presentation begins with a section that elaborates on the epistemological and methodological issues that underpin this chapter. The following section presents a historical background that shows the evolution of the neoclassical and behavioral perspectives accompanied by major events in asset markets. The next section focuses on house price theories based on these two distinct approaches. Finally, the presentation of the theoretical framework concludes with a summary.

2.1. Epistemology, Methodology and Limitations

This theoretical framework is essentially a review of economic theories. Before proceeding to the actual review, however, this section briefly presents the author's epistemological assumptions about the nature of economic theories themselves. Next, the section defines the methodology used in the review and discusses its compatibility with the underlying epistemological assumptions. Finally, the section closes by discussing the limitations of the study.

The first epistemological assumption that underpins this review pertains to the continuity in economic thought. This implies that knowledge of economics grows in a process of action and reaction, in which theorists either extend the ideas of their predecessors or move towards new directions as a reaction to extant ideas. The second assumption is about the "reciprocal interconnection" between economic theory and socio-historical events and processes (Hunt, 1979, p. xv). Under this assumption, economic theory develops in response to changes in the social environment as well as to internal forces within the discipline. Finally, the third assumption asserts the existence of an "ideological" dimension in the development of economic theory (Hunt, 1979, p. xvi).

This may stem not only from an individual theorist's subjectivity, but also from the inter-subjectivity across groups of theorists who, like other members of society, "coalesce into groups because of social pressures, common interests, and ideas" (Brue and Grant, 2007, p. 5).

Given the underlying epistemological assumptions above, this study adopts a specific methodology for reviewing economic theories as explained by Kazgan (2012, pp. 27-31). Simply summarized, this methodology positions each economic theory within distinct *perspectives*, which define the broader epistemological and historical context of the theories in question. This assists the reviewers of economic theories in recognizing the degree of continuity in theory development and in seeing the implicit commitments of the theorists. Furthermore, by drawing attention to the historical setting in which economic perspectives gained or lost prominence, this approach elucidates the interconnection between economic theories and the accompanying socio-historical events and processes.

This methodology differs from the two other common approaches used in reviews of economic thought. The first one assumes that economics is a "pure science" like the natural sciences. Hence, it prescribes presenting economic theories as stand-alone systems independent from a given perspective. Although this approach appears to be "objective" and universally applicable, it risks neglecting the implicit philosophical assumptions that underpin the theories in question. At the polar opposite, the second alternative explicitly assumes the immutability of a given economic perspective and presents economic theories that favor it. As a result, liberal scholars may ignore important economic insights that contradict the idealization of "free-markets" and likewise, critical theorists may attempt to reduce all economic phenomena to a fundamental theory such as "class conflict".

While the methodology utilized in this review may help in avoiding the pitfalls above, important limitations remain. First, this study focuses on two economic perspectives only; therefore, it is by no means a presentation of price theories in their entirety. Such an attempt would need to cover other important economic perspectives such as Marxism, which is outside the scope of this theoretical framework. A second limitation pertains to the depiction of neoclassical and behavioral approaches as distinct monolithic blocks. Due of this limitation, the review overlooks subtle divisions *within* the two perspectives because of their limited relevance to the core discussion. Finally, the study is limited in the coverage of socio-historical events and processes that may have guided theory development, focusing on the major movements in asset markets only.

2.2. Background

In accordance with the methodology outlined above, this section stages a historical background by juxtaposing the evolution of neoclassical and behavioral perspectives along with the major price movements in asset markets. Figure 2.1 depicts this background in a timeline. The top panel represents notable price changes observed in financial and real estate markets dating back to early 1900s. Below, the middle and bottom panels depict the development of neoclassical and behavioral perspectives, starting in late 1800s and 1900s respectively. In both panels, connecting arrows represent continuity of ideas with preceding economic schools of thought. Furthermore, the dotted lines show the chronological order of the key theoretical advancements that contributed to the distinct characteristics of the two perspectives. The following presentation follows the structure of this figure in the sequence explained above.

2.2.1. A Brief History of Financial and Real Estate Markets

As previously mentioned, this subsection lists major asset price movements that took place over the last century. The identification of the specific movements draws heavily from Shiller (2005, pp. 1-30) with additional data from Shiller (2014). Before the presentation begins, it is important to note that the intention here is not to discuss the causes of these movements (for such studies; see, Kindleberger and Aliber, [1978] 2005; Garber, 2000). Rather, the purpose is to establish the chronological order of the major events that accompanied the evolution of the neoclassical and the behavioral perspectives.

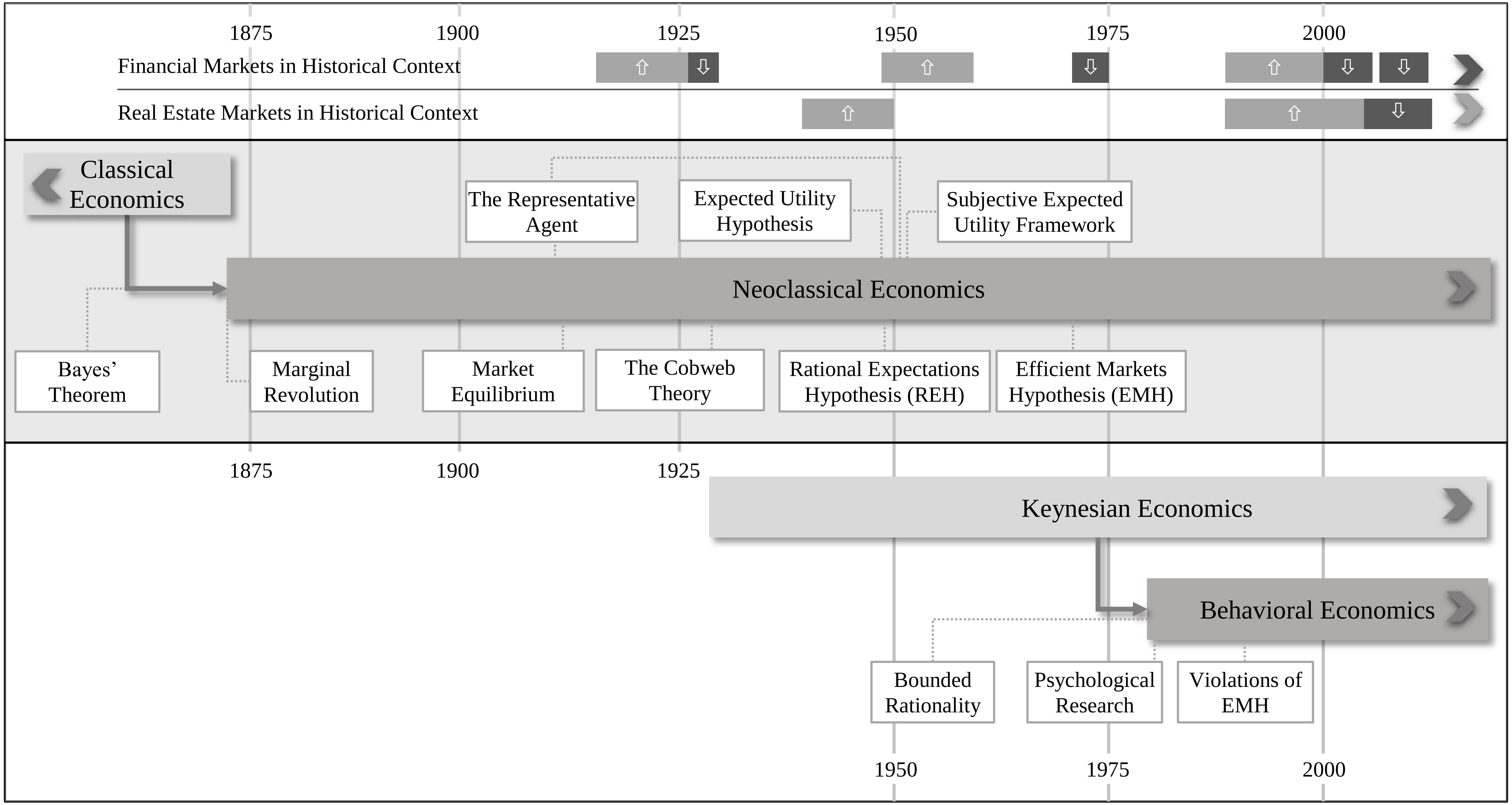

Figure 2.1 Timeline for the neoclassical and the behavioral perspectives. The top panel depicts key asset price movements, whereas the middle and bottom panels show the evolution of the neoclassical and behavioral perspectives respectively.

As shown in the top panel of the timeline, the first major boom period in the 20th century was the “famous run up” of the US stock market between 1920-1929, which ended with the “The Great Crash” of 1929 (Galbraith, 1954). The subsequent “Great Depression” that followed this boom remains as one of the longest and deepest economic crisis in modern capitalism. Recovery from this crisis came in the post-war period in the early 1950s, when prices of both financial assets and real estate assets increased significantly. Specifically, from 1948 to 1964, the prices of financial assets more than quadrupled and home prices nearly doubled. In the following decades of 1970s and 1980s, real estate and financial assets preserved their levels except the “debacle” that the financial markets experienced from 1973 to 1974.

Spectacular booms in both financial and real estate markets marked the 1990s. In this decade, the stock markets tripled in five years between 1995 and 2000, not just in the US, but also in Brazil, China, France, and Germany. During the same period, the Turkish stock market more than doubled despite the 1997 earthquake that devastated the country (Mutan and Topcu, 2009). A few years later in 1998, the real estate market “took off” in a manner that matched the spectacular worldwide boom in the financial markets. The average real home price in the US increased around 50% until 2004 and peaked in 2006. The upsurge in home prices spread across to globe to “glamorous international cities” including Bombay, London, Madrid, *and* Istanbul among others.

The next decade was disastrous. The 2000s began with the “dotcom bubble” which set back the net worth of US households more than the annual disposable income of the US (Turner, 2008, p. 28). Similar declines took place globally, particularly in Brazil, China, France, and Germany again. Around the same time, Turkey went through a financial crisis from 1999 to 2002, which economists identified as “Turkey’s most devastating crisis ever” (Kazgan, 2012, p. 221). The sharp decline in asset prices continued throughout the second half of the decade. Following the implosion of the “housing bubble” in 2006, the US went into its most severe economic crisis since the Great Depression. By the end of 2008, over two million homes entered foreclosure proceedings and approximately 2.5 million people lost their jobs (Magdoff and Yates, 2009, pp. 17-87). Between 2007 and 2013, the home prices in the US declined around fifty percent (Shiller, 2014). Similarly, home prices in the Netherlands, Spain, Iceland, and Ireland suffered significant falls (Ambrose, et al., 2013; Levitin and Wachter, 2013). As of the time of this writing, the global unrest that started in 2006 continues.

The following subsections will present the evolution of the neoclassical and behavioral economics juxtaposed onto the highs and lows of the markets. As it will become evident, the neoclassical perspective flourished during the 1950s and 1960s when both financial and real estate markets soared. On the other hand, the behavioral perspective gained wider recognition starting with the global turmoil of the early 2000s.

2.2.2. A Comparative Review of the Two Perspectives

The neoclassical perspective shown in the mid panel of Figure 2.1 is the dominant school of thought in contemporary economics. As the term neo-classical signifies, the perspective rests on the foundations that the classical economists had laid out in the late 1700s. As such, the perspective carries forward their central tenets and simply defines human behavior to consist of rational and calculated attempts to maximize utility. Similarly, it echoes the classic belief in the "automatic" nature of competitive markets as "ideal mechanisms of distributive justice and efficiency" (Hunt and Lautzenheiser, 2011, pp. 129, 398).

Although its roots extend back to the classical school of economics, the distinguishing characteristics of the perspective became evident the 1870s. This was due to "the Marginal Revolution", which not only led to the improvement of earlier classical economic theories, but also to the development of a powerful and tractable framework for analyzing economic quantities. Two more groundbreaking theoretical advancements came with the *Rational Expectations Hypothesis* (*REH*) and the *Efficient Markets Hypothesis* (*EMH*), which took place in the early 1960s and the 1970s, followed by the sharp increases in asset prices globally (Hommes, 2013, p. 7). In effect, these two hypotheses further reinforced confidence in the accuracy of individuals' predictions as well as the fairness of the market prices. Although the evolution path of the perspective is marked with revolutionary theoretical advancements, today it represents the mainstream, orthodox, traditional, or standard economic paradigm.

In contrast, the behavioral perspective represents an alternative to the mainstream. As shown in the bottom panel of the timeline, its roots go back to the works of Keynes (1921; [1936] 2015), who made reference to the words "psychology", "confidence", "sentiment", "human caprice" and "animal spirits" in describing human behavior, as well as "beauty contest" for describing the markets as early as the 1920s. According to Keynes, with their limited insight into the functioning of the markets, individuals primarily followed the market sentiment; therefore, prices reflected a collective impulsivity and *not* the true value of assets. Later in the 1950s, economists continued to question the neoclassical assumptions. Simon (1955) led this effort by raising concerns about the neoclassical definition of the "economic man" and his "impressively clear knowledge" of the future. Hence, Simon argued for *bounded rationality*, by emphasizing the limits of individuals in accessing information and their computational capacities.

In the mid-1970s, objections to individual rationality gained impetus again, this time with groundbreaking contributions from psychologists, for whom it is "self-evident that people are neither fully rational nor completely selfish, and that their tastes are anything but stable" (Kahneman, 2012, p. 269). A main driving force of this line of research was Tversky and Kahnemans's (1974) finding that human beings could make "systematic and predictable errors" in making decisions under uncertainty. These errors stem from documented psychological biases of individuals, which tended to intensify when influenced by social dynamics. In a market context, this meant that asset prices could fluctuate in a manner similar to that of fads or fashions (Academy of Sciences, 2013). In the 1980s, econometric research led by Shiller reinforced the behavioral perspective by presenting empirical evidence against the EMH. Specifically, this line of research drew attention to the observed volatility and predictability in the markets, which were at odds with standard economic theory.

As the presentation will further expound, behavioral theories often point to patterns of human acts that contradict with the assumptions of individual rationality. However, it is important to note that behavioral economists do not read these patterns as the result of extreme human irrationality, "but rather of the character of human intelligence, reflecting its limitations as well as strengths" (Shiller, 2005, p. 248). With this note, the remainder of the section presents a comparative review of the neoclassical and behavioral perspectives. The structure of the comparison rests on four key differences between the two perspectives pertaining to: (1) *individual rationality*, (2) *determinants of market prices*, (3) *individual interactions*, and (4) *market efficiency*.

2.2.2.1. Individual Rationality

The neoclassical perspective assumes that individuals are rational. Following Barberis and Thaler (2003) and Hommes (2006), this specifically means that individuals (1) update their existing beliefs *correctly* when new information becomes available and (2) make deliberate decisions based on expectations of utility.

The first tenet of rationality holds that individuals make their decisions according to the *Bayes' Theorem* (1763) which describes the “posterior probability” of an event conditional upon a “prior probability” of another event. While the theorem underpins the modern approaches to epistemology, statistics, and models of learning, it also has important implications for decision-making under uncertainty (Joyce, 2008). In particular, the theorem specifies the set of rules to weigh prior probabilities against the probabilities of future events correctly; hence, it allows individuals to know exactly how they should change their mind in the light of new evidence. For example, if there is a known prior probability of occurrence of a recession next year and an economic model with known accuracy rates predicts a recession to be coming; the theorem gives the exact posterior probability that such a recession would indeed occur.

While the assumption that individuals can apply the Bayes' theorem is unproblematic for neoclassical economists, psychologists argue otherwise. In particular, Tversky and Kahneman (1974) identified obvious violations of the Bayesian model in cases where individuals failed to weigh the prior probabilities correctly and “exaggerated the diagnosticity of new evidence” (Kahneman, 2012, p. 154). The authors attribute this particular deviation from rationality to the *representativeness heuristic*, which signifies a distinct behavioral procedure that individuals utilized in order to simplify complex decision-making tasks when given new information. Like other heuristics identified by the authors (i.e., *availability* and *anchoring*), relying on representativeness is helpful in making decisions under uncertainty, but introduces systematic errors.

The second neoclassical tenet of rationality holds that individuals base their decisions on expectations of utility. The origins of this notion are found in the philosophy of Bentham ([1789] 1907, p. 4), who defined utility as a property of things, which either produces “benefit, advantage, and pleasure” or prevents the happening of “mischief, pain, and unhappiness” to human beings. At its core, this philosophy assumes that humans make their decisions by evaluating the utilities of all probable consequences and then rationally choosing the one with the highest utility. Bentham's utility-based definition of rational decision-making influenced all of the classical economists of the 17th century. However, precise definitions of the notion came around 1870s after *the Marginal Revolution*. This important development in economic theory related human decisions to *marginal utility*, i.e., the association of a commodity's utility with its consumption levels. The main contributions came from Jevons ([1871] 1957, p. 60), who argued that a "perfectly wise being" made utility maximizing decisions by equating the ratio of marginal utilities driven from commodities to their consumed quantities.

Utility based definitions of human rationality expanded in the post-war era to include decision-making processes in the presence of *uncertainty*. These definitions go back to the *Expected Utility (EU) Hypothesis*, which proposes a set of "mathematically complete" and "perfectly general" axioms that define rational behavior (von Neumann and Morgenstern, [1944] 1953, p. 31). Specifically, these axioms are completeness, transitivity, independence, and continuity of individual preferences, which, in turn, allow representing rational behavior using expected utility functions. However, the hypothesis mainly deals with decision-making processes such as game playing or gambling where individuals know the probability of outcomes. The *Subjective Expected Utility (SEU) Hypothesis*, which came a decade later, relaxes this limitation by addressing situations in which individuals do not know the probabilities of future events. Similar to its earlier counterpart, the hypothesis proposes "a highly idealized theory of the behavior of a 'rational' person" and postulates a "personalistic" decision making theory based on expected utilities (Savage, [1954] 1972, p. 7).

In addition to rejecting the assumption that human beings update their beliefs correctly when given new evidence, psychologists raise objections to the assumption that they make their decisions solely on expectations of utility. Among these objections, the Prospect Theory (Kahneman and Tversky, 1979) stands out in terms of representing empirical evidence against the utility-based models. In particular, the theory emphasizes the significance of *the certainty effect*, which leads people to exhibit risk aversion in choices involving sure gains and risk seeking in choices involving sure losses. In addition, it draws attention to *the isolation effect*, which means that humans make inconsistent preferences when they face the same choice in different forms. Later extensions of the theory emphasize *the framing effect*, which encapsulates the observation that subtle variations in the wording of a choice problem can sometimes lead to changes in preferences (Tversky and Kahneman, 1981; Kahneman and Tversky, 1984). The effects mentioned above present contradictions to the EU based decision-making theories in which future outcomes have known probabilities. However, the SEU based theories, which address situations with unknown probabilities, also received significant objections from psychologists. In particular, theories of *ambiguity aversion* highlight human behavior that SEU based decision-making fail to capture (e.g., Heath and Tversky, 1991; Fox and Tversky, 1995; see Camerer and Weber, 1992 for in-depth treatment).

Given the mounting theoretical and empirical studies that challenge the neoclassical assumptions of individual rationality, behavioral economists in the mid-1990s developed models in which market participants make decisions compatible with the principles identified by psychologists. In particular, Epstein and Wang (1994) provided a formal model of asset price determination in which ambiguity aversion plays a role. Benartzi and Thaler (1995) and Thaler et al. (1997) focused on "myopic loss aversion" based on the observation that stock market investors are more sensitive to losses than their gains. Similarly, Barberis, et al. (2001) focused on prospect theory and proposed a decision making model where investors derive utility not only from consumption but also from fluctuations in the value of their financial wealth.

This subsection presented a key difference between the two perspectives concerning the nature of individuals. Similarly, the next subsection presents another important divergence, but this time about the determinants of market price. As the subsection expounds, while the neoclassical perspective maintains that market prices have a rational basis in terms of "fundamentals", the behavioral perspective highlights the role of structural, cultural, and psychological factors in affecting market prices.

2.2.2.2. Determinants of Market Price

Identifying the determinants of market price has been a challenge throughout the history of economic thought. For the classical economists, price was determined on the supply side of the markets depending on the cost of production consisting of wages, materials, rents, plus the suppliers' profit. For the early marginalists, price was primarily a demand side phenomenon, depending "entirely upon utility" (Jevons, [1871] 1957, p. 1). It was the neoclassical economists, particularly Marshall, who effectively synthesized the supply and demand sides of the markets by considering the costs of the suppliers and the diminishing marginal utility of the consumers (Brue and Grant, 2007, pp. 277-288).

As the following paragraphs expound, Marshall's equilibrium solution provides a mathematical representation of what proponents of the *invisible hand* had argued since the 17th century: Competition not only equalizes the rates of profit for all firms, it also minimizes the costs of production and allows consumers to buy all commodities at the lowest possible price. In other words, market prices emerge out of a competitive process between rational individuals who read the *market fundamentals* correctly; and at the end, this process brings about "universal advantages" for the entire society (Hunt, 1979, p. 281).

Marshall's ([1890] 1920) competitive equilibrium theory represents supply (S) graphically in a curve, consisting of a series of quantities that matches a series of prices. This depiction places the quantities on the horizontal axis and the prices on the vertical one; resulting in a curve that is sloped upward and to the right, meaning that the higher the product price, the larger the quantity supplied. The exact form of the curve depends on *elasticity of supply*, which defines whether "a given rise in price will cause a great or a small increase in the offers which sellers accept" (Ibid., p. 456). Similar to its representation of supply, the theory depicts demand in a curve (D) consisting of quantity-price pairs. The curve slopes downward in a concave manner in compliance with the "universal law" of diminishing marginal utility, which asserts that individuals desire less of a given commodity with every increase in their possession (Ibid., p. 102). Based on this conception of utility, the theory formulates the idea of *elasticity of demand*, which measures whether the diminution of desire is slow or rapid with respect to various quantities. As such, the theory mathematically formulates elasticity of demand as the ratio of percentage changes in price to percentage changes in quantity demanded. In turn, a ratio equal to 1 means "unitary" elasticity of demand; and ratios of less or more than 1 indicate inelastic or elastic demand respectively.

The core argument of the theory is that "forces of demand and supply bring themselves into equilibrium with one another" (Ibid., p. 330). This process takes place over three distinct time periods with various lengths. In the short run, the supply consists of the existing stock. During this time period, prices and quantities emerge out of the "higgling and bargaining" between buyers and sellers (Ibid., p. 333); and changes in demand have a relatively high influence on prices because of the inelasticity of supply. In the long run, however, supply is elastic. Therefore, prices converge to the "normal price", which depend on the average cost of production. Denoted by P^* henceforth, this equilibrium price emerges at the intersection of the two curves and exactly balances supplied and demanded quantities. Finally, in the very long run, the cost of production changes according to availability of labor and materials required for producing the commodity.

In his analysis, Marshall assumed that in the short run, “the general circumstances of the market” (Ibid., p. 342) remains unchanged and the supply and demand curves retain their positions. Specifically, on the demand side, he assumed that no changes occur in the “fashion or tastes” of individuals and no new substitutes enter the market. Similarly, on the supply side, he assumed that no technological advancements affect the cost of production. He allowed these variables to change only in the long run, and represented their new values by shifting the entire curve to left or right. For instance, if production costs go down such that the revenue of the suppliers exceeded their cost, more capital enters the industry and the entire supply curve shifts rightward. Conversely, if the revenues do not cover an increase in production costs, capital withdraws, and the curve shifts leftward. Similarly, any changes in the demand side variables such as individuals’ tastes, their wealth, purchasing power of money, and prices of substitutes shifts the entire demand to the right or left (Ibid., pp. 62, 95).

Contemporary neoclassical economists typically model Marshall’s theory using the Cobb-Douglas functional form. Accordingly, they represent quantity-demanded (Q^d) as a function of price (P) with a constant elasticity of demand (ε) in the exponent. In addition, they calibrate the relationship between the variables with the demand constant (A) as shown below:

$$Q^d = AP^{-\varepsilon}. \tag{2.1}$$

Using the same form, they typically model quantity-supplied (Q^s) as a function of price with a constant elasticity of supply (η) and with a supply constant (B) used for calibrating the relationship between quantities and prices:

$$Q^s = BP^{\eta}. \tag{2.2}$$

Contemporary neoclassical economists also enhance the list of variables which Marshall’s theory kept constant during the short run analysis. They collectively refer to these variables as market fundamentals and seek to explain changes in prices with changes in their values (Garber, 2000, p. 4). On the demand side, they often look for changes in population or in household income in order to explain changing prices. Likewise, on the supply side, they attempt to relate changes in input cost or advancements in available technology to price behavior (see any introductory text such as Hall and Lieberman, 2008, pp. 60, 67-69; Lipsey and Steiner, 1981, pp. 62-64, 67-70).

The left panel of Figure 2.2 represents the above equations and the corresponding equilibrium quantities of (Q^*) as well as the prices (P^*). The middle and right panels show the effects of changing fundamentals on the demand side and on the supply side respectively.

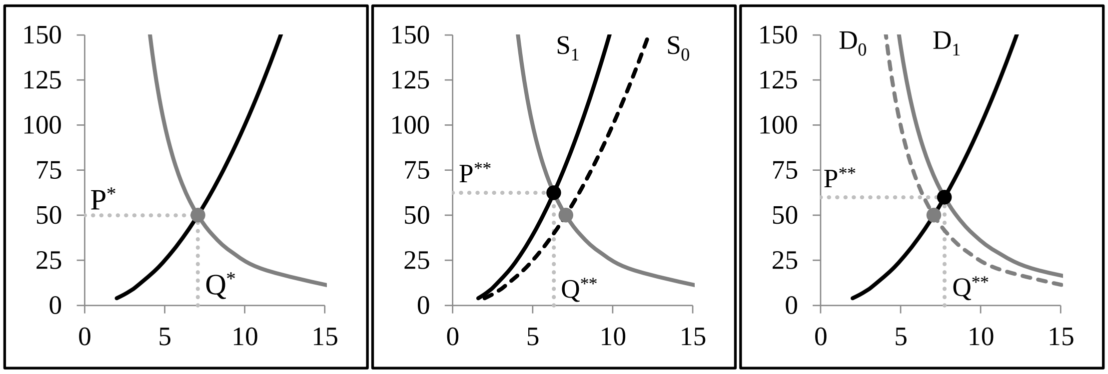

Figure 2.2 Neoclassical supply and demand with equilibrium prices and quantities with $\varepsilon = 0.50$, $\eta = 0.50$, A = 50, and B = 1 in the left panel. The mid and right panels show the effect of changing the demand and supply constants by 20%, respectively.

So far, the discussion in this subsection focused on the neoclassical foundations of pricing of commodities, i.e., of goods produced for consumption or for exchange in the markets. In the following paragraphs, the focus shifts to the neoclassical theories on the pricing of capital goods or financial assets. As the presentation emphasizes, similar to their counterparts on commodity pricing, neoclassical theories of asset pricing propose that market prices have a rational basis in terms of fundamentals.

The neoclassical asset price theories originate from the present value relationship dating back to the works of Fisher (1907). Simply stated, the relation says that, under *certainty*, the price of a capital good or asset equals the summed discounted value of the stream of revenues (i.e., dividends or rents) that the asset generates. Consequently, two fundamentals govern the pricing of assets in a given period (P_t): the discount factor (r_t) and the revenue generated by the asset (V_t). Under the assumption that asset bubbles do not occur, the relation takes the following form:

$$P_t = \sum_{i=1}^{\infty} \frac{V_{t+i}}{\prod_{j=0}^{i-1}(1 + r_{t+j})}. \tag{2.3}$$

In addition, if the discount rate for each period is a constant (r), the relation simplifies to:

$$P_t = \sum_{i=1}^{\infty} \frac{V_{t+i}}{(1 + r)^i}. \tag{2.4}$$

Finally, in the special case in which the incoming revenue stream is constant over time, it takes the well-known perpetuity form (see LeRoy, 2008 for the derivations):

$$P_t = \frac{V}{r}. \tag{2.5}$$

It is important to note that the above equations only hold *ex-post,* i.e. they require that all future revenues and discount rates are known with certainty at the time of determining the asset price. The upcoming section on market efficiency presents how neoclassical models deal with this difficulty by using theories of expectations, which enable developing *ex-ante* models of price determination under *uncertainty*. At this point in the discussion, it suffices to say that using the various extended forms of the basic neoclassical framework outlined so far, many studies have focused on fundamentals such as stock dividends or interest rates in order to explain the movements in financial markets. Similarly, studies that concentrated on the real estate markets related price formations to fundamentals such as "population growth, construction costs, interest rates, or real rents" (Dieci and Westerhoff, 2012).

However, these explanations were not satisfactory for the behavioral economists who pointed to the "irrational exuberance" of the global markets after the mid-1990s. Shiller (2005; 2008) led this effort by showing that the recent price dynamics were hard to explain from a point of view that solely relied on market fundamentals. For example, in demonstrating that the price increases in the US stock market were unwarranted in light of the earnings from 1994 to 2000, Shiller noted the tripling of prices although profits had risen by less than 60%. Similarly, in refuting the validity of the models that explained the price increases based on the long-term interest rates, he highlighted the weakness of the theoretical approach (Shiller, 2005, pp. 7-8). Regarding the increases in the real estate markets, he characterized the popular explanations as “myths”. One such explanation was that home prices had gone up because of the scarcity of land arising from population pressures, which he refuted simply by pointing out the steady and gradual population growth during the decades in question. Furthermore, he contested the explanations of price increases based on construction costs by showing their compatibility with the long-term trends. Finally, he argued against the extent to which interest rates may have played a role in the upsurge of home prices by comparing similar periods in the history of markets (Shiller, 2008, pp. 55-67).

In addition to demonstrating the shortcomings of the market fundamentals in explaining the movements in asset prices, Shiller (2005, pp. 31-176) suggested looking into alternative factors residing in spheres that are outside of markets. The factors in the first group are structural; and consist of political, technological and demographic “precipitating factors” as well as the accompanying “amplifying mechanisms” inherent in investor behavior. The precipitating factors (e.g., the expansion of capitalist ideals, new information technology, and changes in birth rates) drive the markets, whereas the amplifying mechanisms, which involve investor confidence and investor expectations, further complicate their effects on market prices. The second group includes cultural factors such as the widespread public interest in financial news and the “new era” economic thinking that propels investor confidence. These factors play an important role in “setting the stage for markets” and further increase the complexity of price determination. Finally, the third group involves psychological factors. In spearheading the exploration of these factors, Shiller mainly argued that economic and financial definitions of asset prices are poor and difficult for the public to compute; therefore, it was inevitable for the individuals to rely on some psychological anchors for assessing their market value. Moreover, by pointing to research findings from social psychology, sociology, and epidemiology, Shiller drew attention to the possibility that market participants can exhibit “herd behavior” in following the opinions of others, often regardless of their validity.

As summarized in Figure 2.3, this subsection compared the differences of the neoclassical and the behavioral perspectives with respect to market price determination. As it was evident in this comparison, the neoclassical perspective emphasizes the importance of the fundamentals, which influence the equilibrium of prices and quantities by impinging upon the supply and demand forces in competitive markets. In contrast, the behavioral perspective draws attention to a variety of structural, cultural, and even psychological factors in order to enhance this understanding. Another key feature of these behavioral models is the assumption that market participants could hold different beliefs about future outcomes and behave differently from each other. As the next subsection will further expound, allowing this kind of heterogeneity among individuals provides insights into asset price dynamics that neoclassical models had failed to capture previously.

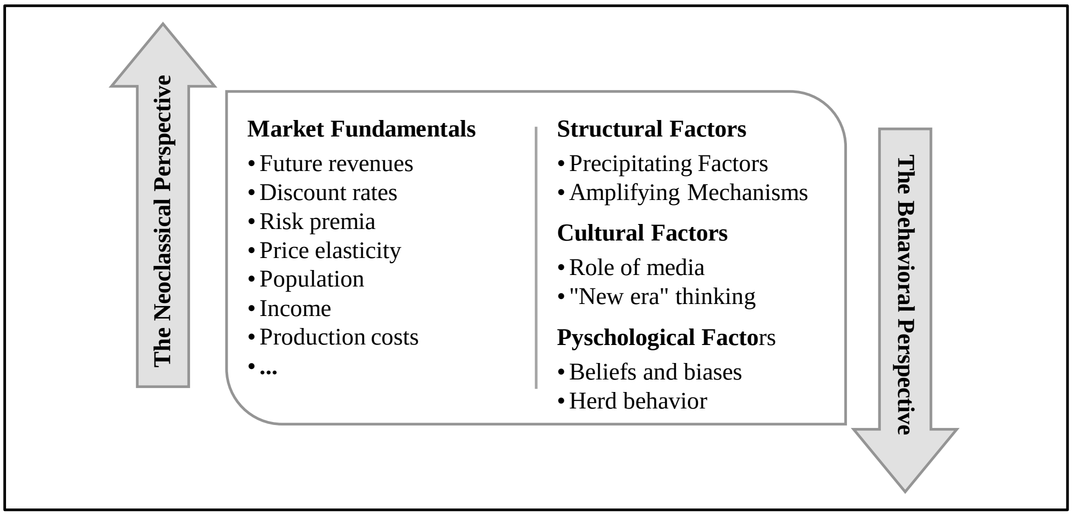

Figure 2.3 Determinants of market price in neoclassical and behavioral perspectives. The behavioral factors on the right hand side outline Shiller (2005).

2.2.2.3. Individual Interactions

One of the key assumptions of the neoclassical perspective pertains to the homogeneity of individuals, as embodied in the idea of *the representative agent*. For the neoclassical economist, this assumption is essentially a “modeling device” which enables substituting “well-defined and mathematically derived” properties of the individual for the aggregate properties of an economy (Hartley, [1997] 2001, p. 4). In other words, the assumption conveniently bridges the gap between microeconomic and macroeconomic models by presenting the emergence of aggregate market outcomes out of the optimizing behavior of a single individual (Janssen, 2008). This individual can be a buyer or seller, a producer or a consumer, a bull or a bear investor, since the assumption amalgamates behavioral and structural differences across them.

In models that employ the representative agent assumption, *interaction* between individuals are practically nonexistent. These models allow only one type of interaction, which implicitly takes place between the representative agent and a central authority acting as an "auctioneer". The representative agent reacts to signals generated by a central authority; and in turn, prices and quantities of goods adjust in an aggregate manner. Once the adjustment process is complete, the representative agent does not have any reason to change its behavior (Kirman, 2008).

Such a view of homogenous and rational individuals fit into the globally stable economies of the early 1920s and the 1950s (Hommes, 2013, p. 3). Following the "debacle" of financial markets in the early 1970s, however, many empirical and theoretical studies challenged the representative agent assumption by presenting arguments that favored individual heterogeneity. Specifically, a number of economists presented detailed survey data, which showed that there was not a single homogenous strategy among stock market investors (Harrison and Kreps, 1978; Allen and Taylor, 1990; Frankel and Froot, 1987; Frankel and Froot, 1990). As a common theme, these studies identify some market participants as *chartists* who believe that the recent trends will continue and others as *fundamentalists* who predict that the market will eventually revert to its historical averages.

In stark contrast to neoclassical models based on the representative agent, models with heterogeneous agents allow interaction among individuals. In fact, this idea was not new since Keynes ([1936] 2015, pp. 12-V) had used the term "beauty contest" to describe how market participants would implicitly interact with each other. This metaphor suggests a similarity between the behaviors of investors and the behaviors of individuals in a newspaper competition in which the objective was to identify the prettiest faces from a set of photographs. Specifically, in these competitions, "the competitor whose choice most nearly corresponded to the average preferences of others" would receive the prize. Consequently, the competitors would not simply attempt to choose the prettiest face according to their own set of criteria; instead, they would strive to anticipate what others were thinking. Moreover, it was not enough for the competitors to pick the faces they thought that others would pick; they also needed to consider the third degree in which the challenge was to anticipate what the average opinion expected the average opinion to be.

As Keynes argued, some investors in the markets even practiced the fourth, fifth and higher degrees of anticipation.

While the representative agent of the neoclassical models does not change its behavior once markets reached equilibrium, heterogeneous agents can switch between various investing strategies based on their interaction with others. Consequently, individuals in these models *endogenously* change their behavior according to some economic performance measure, without receiving any signal from an exogenous source such as a central authority. While the literature on heterogeneous interactions has been growing rapidly since the 1990s (see Hommes, 2013 for an extended review), a particular strand remained focused on “herding” and “epidemics” in the markets. Some early examples of these studies were Scharfstein and Stein’s (1990) model of “mimicking behavior of investment managers”, de Long et al.’s (1990) analysis of investors’ “bandwagon” decisions, and Shiller and Pound’s (1986) presentation of survey data that showed “diffusion of interest” among institutional investors.

In this line of research, Kirman’s (1993) article was pivotal. In the study, the author referred to existing biological models of ant behavior in exploiting food sources and suggested that they were also relevant to modeling investment behavior. The system evolves as individuals meet in random where one of them recruits the other with a probability of ρ. In addition, individuals can change their behavior independently before meeting anyone with a small probability of θ, which connotes possible self-conversion due to arrival of exogenous news.

Figure 2.4 shows three distinct frequency distributions of the system. The left panel demonstrates the case in which sizes of both groups remain persistently close to each other over time. This occurs when the probability of self-conversion is high (θ = 0.15) and the probability of recruitment is low (ρ = 0.70). In other words, assuming that the two tandem groups are chartists and fundamentalists in a market consisting of 100 individuals, following each interaction, the numbers of both groups remain around 50. Next, the mid panel shows the case in which sizes of the groups do not follow a persistent pattern. This occurs when the low probability of self-conversion (θ = 0.01) and the relatively high probability of recruitment (ρ = 0.98) cause both chartists and fundamentalists to recruit from each other continually. As a result, the sizes of the groups take random values between 0 and 100, exhibiting a uniform distribution over time. Finally, the right panel simulates how individuals act in a herd like manner. This case occurs when the very low probability of self-conversion (θ = 0.005) and the high probability of recruitment (ρ = 0.99) persistently bring about a “large majority” that dominates the market. In this case, market participants concentrate on one of the two groups, leading to a high number around 100 in one of them and low number around 0 in the other.

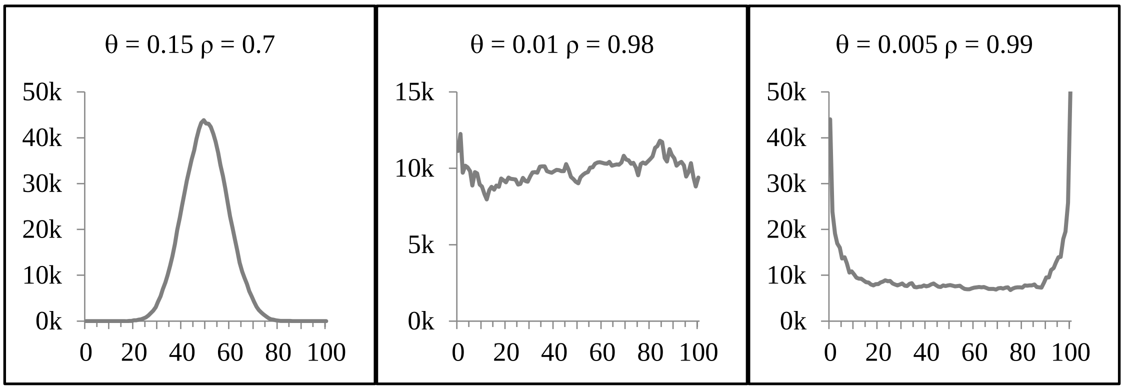

Figure 2.4 The distinct frequency distributions of the system (Kirman, 1993). The results show the numbers of individuals in one of the two tandem groups after 1,000,000 interactions.

According to Kirman, formation of majority groups in markets was likely because of the following reasons. First, some individuals can influence others due to having better information on the functioning of the market and thereby can spawn opinion shifts *en masse*. Second, even without the presence of such superior information, individuals can be tempted to follow others. In other words, as observed in the behavior of individuals making restaurant choices (Becker, 1991), the very fact that the first individual makes a particular choice can lead others to concur in that choice. Third, individuals can try to anticipate the majority opinion as Keynes had described in his “beauty contest” theory of the stock market.

As an influential study of herd behavior in asset markets, Kirman’s study received both criticism and support. Notably, Shiller (2005, p. 165) argued that parameters that drive a social phenomenon such as the markets are not constant like the parameters in formal mathematical theories of epidemics. Nevertheless, the study influenced several asset pricing models (e.g., Gilli and Winker, 2003; Boswijk, et al., 2007; Westerhoff, 2009) and remained as an oft-cited reference in major reviews of the heterogeneous financial modeling literature (e.g., LeBaron, 2001; Hommes, 2006; Hommes, 2013; LeBaron, 2000).

Together with this last discussion of individual interactions, the preceding subsections presented the topics on which the neoclassical and behavioral perspectives diverged. In addition to these, the next subsection will present arguably the most controversial topic among contemporary asset pricing theorists. This pertains to the neoclassical assumption of *market efficiency*, which behavioral economists overtly reject.

2.2.2.4. Market Efficiency

The Efficient Markets Hypothesis (EMH), widely attributed to Eugene Fama (1970; 1975), revolutionized the asset pricing literature after gaining rapid prominence in the early 1970s. The EMH rests upon an earlier influential hypothesis developed by Muth (1961), known as the Rational Expectations Hypothesis (REH). In fact, it is possible to conceive the EMH as just an application of the REH to the pricing of financial securities, because it implicitly accepts Muth's argument that in any given market, participants make use of *all* publicly available information to form their rational expectations (Mishkin, 2004, p. 150). Therefore, before proceeding to the specifics of the EMH, it is essential to cover economic theories on how market participants form their expectations.

2.2.2.4.1. Market Expectations

Expectations simply refer to how individuals predict the future in the presence of unknown variables. The neoclassical perspective accepts the REH, which proposes that individuals make correct predictions on average using all available information about future events (Muth, 1961). The behavioral perspective on the other hand, holds that individuals make *systematic errors* in predicting the future by extrapolating from their past observations. Accordingly, the latter perspective favors the use of backward looking expectation models that predate the REH.

The extrapolation schemes of the backward looking models take either naive or adaptive forms. Assuming that the unknown variable in question is price, the naive form of extrapolation simply carries the most recent known price into the future as shown below:

$$P_t = P_{t-1}. \tag{2.6}$$

On the other hand, the adaptive form adds a certain fraction of the latest change onto the latest observed price as determined by φ:

$$P_t = P_{t-1} - \varphi(P_{t-1} - P_{t-2}). \tag{2.7}$$

Studies that focus on the relationship between expectation schemes and price dynamics extend back to the *Cobweb Theory* (Ezekiel, 1938), which demonstrate the occurrence of systematic errors when suppliers naively plan their future productions based on the current prices. Precisely stated, the theory shows that when suppliers estimate quantity-supplied for the next period based on the log-transformed and dynamic version of equation (2.2) shown below,

$$Q^s{}_t = B + \eta P_{t-1}, \tag{2.8}$$

such a quantity leads to unexpectedly low or high prices on the demand side based on the log transformed and dynamic version of equation (2.1):

$$P_t = \frac{A - Q^s{}_t}{\varepsilon}. \tag{2.9}$$

Consequently, as shown in Figure 2.5, the theory predicts only two possible price dynamics under naive expectations: The convergent case, which occurs in cases where $\varepsilon > \eta$; and the divergent case, which occurs in cases where $\varepsilon < \eta$.

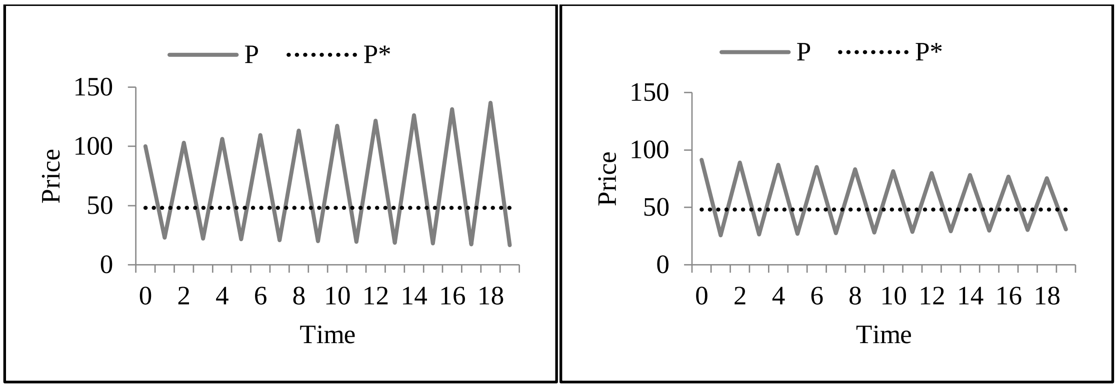

Figure 2.5 Time series prices of the cobweb model (Ezekiel, 1938). The left panel shows the divergent case with $\varepsilon = 0.51$, $\eta = 0.50$, and the right panel shows the convergent case with $\varepsilon = 0.50$, $\eta = 0.51$. The dotted line shows the equilibrium price P^*. The demand (A) and supply (B) constants are set to 50 and 1 respectively.

Economists may have been attracted to the cobweb theory in the 1930s since it explained both oscillations and long departures from equilibrium prices (P^*) after the events of the Great Depression. By the late 1950s, however, these were no longer attractive features, and the theory lost its appeal (Pashigian, 2008). In the 1960s, economists such as Mills (1961) heavily criticized the theory because of its implication that individual predictions are "systematically wrong". Instead, these critics suggested that rational market participants would discover the regularity in price cycles, learn from their systematic mistakes, and effectively reformulate their expectations. This was the argument that paved the way of the REH.

Muth (1961) introduced the hypothesis in his seminal article, which suggested that expectations of market participants are "essentially the same as the predictions of the relevant economic theory" because they are "informed predictions of future events". As such, the hypothesis implies that individuals do not make systematic forecasting errors; on the contrary, their future predictions are *correct on average*. Precisely stated, the hypothesis postulates that *expectations of price* are rational because they follow the "optimal forecast" (P^{of}) that uses all relevant information (Mishkin, 2004, p. 147):

$$P_t = \mathbb{E}_t \left[P_t^{of}\right]. \tag{2.10}$$

The exact distribution of the predictions simply depends on the information available; in the extreme case where information is complete, the hypothesis implies *perfect foresight*. Because such a prediction is identical to the long term equilibrium price, the hypothesis takes the following form (Campbell, et al., 1997, p. 275):

$$P_t = E_t [P_t^*]. \quad (2.11)$$

It is important to note that, as opposed to equations (2.6) and (2.7), equations (2.10) and (2.11) do not have any terms on the right hand side that connote past prices. Despite its straightforward formulation, however, the implementation of the REH requires complex algorithms based on iterative techniques. Figure 2.6 demonstrates a relatively simple implementation for the purpose of comparison to the backward-looking model in Figure 2.5. Their difference is easy to see: the backward-looking model generates price fluctuations around the equilibrium price; in contrast, the model based on rational expectations does not fluctuate; but smoothly converges to P^*.

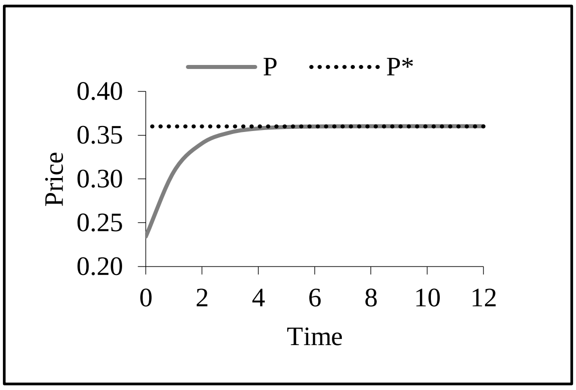

Figure 2.6 Time series prices of a rational expectations model showing the smooth convergence of price to its equilibrium value. Implementation draws from Strulik (2004).

2.2.2.4.2. Predictability, Volatility and Bubbles

As mentioned earlier, the Efficient Markets Hypothesis (EMH) was a revolutionary asset pricing theory. Fama (1975, author's italics) formally defined an "efficient" market as one,

> where there are large numbers of *rational profit-maximizers* actively competing, with each trying to predict future market values of individual securities, and where important current *information* is almost freely *available to all* participants.

Clearly, this definition echoed the earlier neoclassical assumptions of individual rationality, investor homogeneity, and the REH. Nevertheless, the following two claims of EMH influenced the asset pricing literature to an extent that far surpassed the earlier theories.

First, EMH formalized the claim that, "no investment strategy can earn average returns greater than are warranted for its risk" i.e., there is "no free lunch" in efficient markets (Barberis and Thaler, 2003, p. 1054). In other words, there are no unexploited profit opportunities in the markets and nobody can beat the system on a regular basis. This is because rational traders would immediately exploit such opportunities through a process known as *arbitrage*, as Friedman had suggested in the 1950s (1953, pp. 157-203; as cited in Academy of Sciences, 2013; Barberis and Thaler, 2003, p. 1054; Hommes, 2006, p. 1112; Hommes, 2013, p. 25). This confirmation of the functioning of market mechanism also implies that stock prices followed a random walk, meaning that they are not predictable.

The second, interrelated claim is that market prices always accurately reflect the intrinsic value of assets, i.e., their fundamental value. In its simplest version, this price is equal to the expectation, conditional on publicly available information at the time of the present value of future dividends discounted at a constant rate through time. The following formulation captures this idea, which is simply an extension of (2.4) formed by adding the expectations ($\mathbb{E}$) of future revenues conditional on the available information (Ω) to the right hand side of the equation:

$$P_t = \mathbb{E}_t\left[\sum_{i=1}^{\infty} \frac{V_{t+i} \mid \Omega_t}{(1+r)^i}\right]. \tag{2.12}$$

With this modification, it is no longer necessary to know the future revenues with certainty at the time of price determination. Furthermore, this claim implies that no persistent mispricing can occur in efficient markets. To this day, Fama has remained one of the most prominent skeptics of asset bubbles. In the words of the Nobel Prize Laureate, "markets work" and there is "no statistical evidence" that confirm the presence of price anomalies (Kestenbaum, 2013).

With the widespread acceptance of the EMH, countless neoclassical models of financial assets assumed rational expectations of future dividend growth, discount rates, and risk premia as the fundamental drivers of price (e.g., Campbell, 1991; Campbell and

Ammer, 1993; Fama, 1990; Fama and French, 1996). Following them, studies that focused on real estate markets, developed models based on the rational expectations of rents, interest rates, and housing premia (e.g., Campbell, et al., 2009; Clayton, 1996; Himmelberg, et al., 2005; Poterba, 1984).

Although the EMH became the dominating paradigm in economics and finance soon after its inception, several prominent economists started to raise objections in the late 1970s. Notably, Simon (1978) highlighted “certain grave theoretical difficulties” pertaining to the complexity of the hypothesis and drew attention to the problems associated with its policy implications. Rather humorously, Kindleberger and Aliber ([1978] 2005, p. 38) noted that only “clairvoyants” or individuals with a “Superman-like” vision could be fully aware of the long-term implications of the market news.

Other economists refuted the claims of the EMH on empirical grounds. For example, regarding the first claim that arbitrage would eliminate all unexploited opportunities in the markets, Shleifer and Vishny (1997) pointed to the cases in which the process was limited even when prices diverged far from the fundamentals. As this study showed, strategies designed to exploit the opportunity could be both risky and costly, and the market could remain inefficient (Barberis and Thaler, 2003, p. 1055). Another related objection was to the implication of the EMH that markets are not predictable. As Shiller’s (1981) remarkable study showed, at a horizon of a few years, the US stock market was indeed quite predictable as the market tended to move downward following periods when prices were high and upward when prices were low (Academy of Sciences, 2013). Furthermore, several other prominent studies demonstrated that perfect foresight models based on the present value relation could not successfully explain the observed volatility in the price dynamics (Grossman and Shiller, 1980; Shiller, 1980; Shiller, 1984).

As dissatisfaction with the hypothesis grew in the 1980s, economists turned to psychological research in order to find alternative specifications of how humans formed their expectations. Studies in this line of research emphasize that in assessing values of unknown future quantities, humans rely on their *beliefs* and not necessarily on sophisticated calculations based on available news (Barberis and Thaler, 2003, pp. 1063-1067). Consequently, belief based financial models revive the backward looking approaches that had become unpopular after the REH. For example, Daniel et al. (1998) emphasized the importance of the overconfidence and the self-attribution biases in influencing investor reactions to public news. In particular, their model relaxed the REH assumptions by proposing that investors credited “themselves for past success”.

Similarly, Barberis, et al. (1998) focused on how the representativeness heuristic could contribute to financial asset mispricing. Their model proposed a stock market in which investors "extrapolated past performance" of their earnings and updated their future forecasts accordingly. In parallel to this, models with heterogeneous market participants renewed interest in earlier cobweb models with adaptive expectations (e.g., Brock and Hommes, 1997; Brock and Hommes, 1998).

Based on the observed violations of the EMH and on the contributions of psychological research, behavioral economists insist that bubbles exist in asset markets. They do so by referring to history of markets and by interpreting asset price fluctuations as deviations of prices from their fundamental values. Their explanations of the phenomenon move beyond the boundaries of the neoclassical perspective and incorporate references to psychology, to social dynamics and to the imperfect nature of news media. The following quotation from Shiller (2005, p. 2 author's italics) encapsulates these references, as the author defines "speculative bubbles" as:

> a situation in which news of price increases spurs *investor enthusiasm* which spreads by *psychological contagion* from person to person, in the process amplifying stories that might justify the price increase and bringing in a larger and larger class of investors, who, despite *doubts about the real value of the investment*, are drawn to it partly through envy of others' successes and partly through a gambler's excitement.

2.2.3. Summary

This section presented a comparative review of the neoclassical and behavioral asset pricing theories. The structure of the comparison rests on the four key differences of the two perspectives as summarized in Table 2.1.

Table 2.1 Summary of the comparison between the two perspectives

Key difference	The neoclassical perspective		The behavioral perspective
Individual rationality	Individuals are fully rational, i.e.,		Individuals are not fully rational, i.e.,
	They update their beliefs correctly according to the Bayes' Theorem.		They fail to update their beliefs correctly, and make systematic errors.
	They make decisions based on expectations of utility.		They make decisions that are incompatible with utility-based decision-making theories.
Determinants of market price	Fundamentals determine market price.		Social, cultural, and psychological factors influence market price.
Individual interactions	Individuals exhibit homogenous behavior as embodied in the representative agent.		Individuals are heterogeneous in their behavior.
	Individual interaction is limited.		Individuals persistently interact with each other.
	Individual behavior remains constant.		Individuals dynamically switch their behavior.
Market efficiency	**Rational expectations**	Market expectations are forward looking.	Market expectations are backward looking.
		Market participants use all available information.	Market participants use limited information.
		Market expectations are correct on average.	There may be systematic errors in market expectations.
	Price equals fundamental value; bubbles do not exist.		Price may deviate from fundamental value; bubbles *do* exist.
	It is not possible to extract excess returns on a systematic basis because of arbitrage.		There are limits to arbitrage; hence, markets may remain inefficient.
	Future prices are not predictable.		Future prices are predictable.
	Present value models capture price dynamics.		Present value models do not capture observed volatility.

The first of these differences is about individual decision-making. Regarding this subject, neoclassical economists hold that humans made their decisions in line with the individual rationality assumption. Accordingly, they assume that human beings not only consistently update their existing beliefs when they received new information but also make calculated decisions to maximize their expected utility. In contrast to this, behavioral economists argue that individuals are not capable of updating their prior beliefs correctly and show that they act in ways that utility-based theories cannot explain. Hence, in their models in which market participants are not fully rational, behavioral economists replace earlier decision-making theories with the psychological principles that govern the perception of decision problems.

The second difference pertains to the determinants of market prices. Regarding this important problem that puzzled economists for centuries, neoclassical economists consistently maintain that market prices have a rational basis in terms of fundamentals such as household income, inflation, or interest rates. In contrast, behavioral economists depart propose that market prices may also reflect social, cultural, and psychological factors.

Third, the neoclassical approach puts a single, representative agent in the center of economic analysis representing the average individual; and therefore does not consider the possibility that agents with different behaviors could coexist in the markets. On the contrary, the behavioral perspective emphasizes the presence of individual heterogeneity and explores market outcomes when market participants with different behaviors interact with each other and switch their behavior dynamically.

A final and important difference between the two perspectives pertains to the Efficient Markets Hypothesis (EMH). In their support of the hypothesis, neoclassical economists hold that individuals exhibit forward-looking behavior in forming their future expectations based on all publicly available information. Furthermore, they argue that market forecasts are accurate; hence, current expectations match what the future will bring. Accordingly, they hold that current prices always reflect the fundamental value of assets; and doubt that bubbles even exist. The proponents of the EMH also specifically argue that in efficient markets, nobody can systematically make excess profits because of arbitrage possibilities. Hence, in their view, markets react to genuine news on a daily basis; hence, prices are not predictable. On the other hand, opponents of the hypothesis argue that individuals form backward-looking predictions, meaning that they heavily rely on past observations and experiences in forming their expectations. As a result, these economists emphasize the significance of psychological biases inherent in human nature and demonstrate how these can lead to systematic errors in market expectations. In sharp contrast to the neoclassical economists, they argue that speculative bubbles *do* exist in asset markets, and refer to psychology, to social dynamics and to the imperfect nature of news media in explaining their formations. Furthermore, they emphasize the limits to arbitrage and argue that markets could remain inefficient persistently. They support this important claim with empirical studies showing the predictability and the volatility of asset prices which are at odds with EMH.

2.3. House Price Theories

The preceding sections of this study presented a contemporary debate between neoclassical and behavioral economists about the nature of asset prices. As the intention was to delineate a background that would assist in evaluating economic theories, there were minimum references to housing markets *per se*. Now, having established such a background, the focus of the presentation will gradually narrow down to the theories on house prices. However, before doing so, there needs to be a brief discussion of what makes houses unique economic entities.

While houses are commodities in contemporary capitalist economies, they have certain peculiarities that are distinguishable from other goods and services traded in markets. To start with, like other real estate properties, houses possess important locational characteristics because of their spatial fixity. In this sense, housing units are unique, as no other substitute can exactly match their locational qualities. Secondly, unlike many other goods and services, their supply is significantly inelastic in the short run because of supply lags. In other words, even when there are sharp increases in housing demand, supplied quantities do not immediately increase up to their desired levels because of the lengthy design and construction processes. Thirdly, houses are durable, meaning that they depreciate over a long period. As such, the existing stock of housing units dominates the supply, as the flow of new construction makes up only a small percentage in comparison to the stock.

Furthermore, from an individual's point of view, houses have unique characteristics that introduce a level of complexity to decisions involving their purchasing or renting. Firstly, simply stated, houses are expensive. In fact, primary housing units appear as the most important component of household net worth, comprising 44% to 90% in the euro area, and about 50% in the US (Iacoviello, 2011; Mathä, et al., 2014). For households who opt to rent, housing related expenses are also significant; as they amount to 22.5% and 25% of average monthly disposable income in the EU (Pittini, 2012) and in Turkey (TURKSTAT) respectively. Secondly, commonly viewed as assets for storing and enhancing wealth, houses are associated with a 'dividend' coming from the rent owners save by living in the house rent-free and a 'capital gain' from house price appreciation over time (Himmelberg, et al., 2005). As such, pricing decisions involve uncertain future expectations beyond the observable physical characteristics of housing units. What's more, in having to make decisions that involve large sums under uncertainty, most individuals are inexperienced because of the relative infrequency of housing related transactions.

In what follows, the presentation will focus on house price theories. The immediate subsection will cover studies that precede the EMH originating in the urban analysis tradition of the early 1960s. Viewing *housing as a commodity*, these studies associate house prices with the intrinsic characteristics of housing units and with rational locational choices of *consumers*. Following this brief presentation, the next subsection will expound house price theories since the 1980s that gained prominence after the widespread acceptance of the EMH. In contrast to their earlier commodity based counterparts, these theories view *housing as an asset* similar to other financial instruments such as bonds or stocks. Accordingly, they associate house prices with future revenues generated by the housing asset and the expectations of the *investors*.

2.3.1. Theories before the EMH

Early neoclassical house price theories treat housing as a commodity, i.e., as an object which is produced for consumption or for exchange in the markets. This strand of literature evolved in two phases. The theories in the 1960s mainly attempted to explain house prices by focusing on their location, thereby reducing their other peculiarities into a homogenous commodity. The theories in the 1970s, however, relaxed the assumption of homogeneity and examined house prices as a function of their heterogeneous characteristics.

The emphasis of early commodity based theories was on the spatial arrangements of households, firms, and capital in urban settings based on simplifying assumptions of price, markets, and individuals. Alonso (1964) pioneered this approach by proposing a general theory for land-use intended to be applicable to agricultural land as well as urban land. With later extensions by Muth (1967; 1969) and Mills (1972) this approach came to be known as the "*New Urban Economics*" (NUE), which analyzed house prices with respect to few causal factors but within a general theory based on mathematical and statistical analysis (Clapp and Tirtiroglu, 1994; McDonald and McMillen, 2010). While the contributions of the approach were limited in terms of explaining house prices, its underlying assumptions are important to note because of their influence on subsequent theories.

In line with the neoclassical assumptions about human nature, the NUE reduces market participants to the "economic man", who merely wishes "to maximize satisfaction" based on the "perfect knowledge of the market" (Alonso, 1964, pp. 15-16). As such, households are consumers of housing, who choose locations a certain distance from an urban center based on the utility they receive from land and other consumption goods under their budget. Assumptions about housing markets are equally simplistic. Extending earlier theories on agricultural land (e.g., von Thünen, 1826; Marshall, 1890), the NUE assumes that urban land is a "featureless plain" which can be "freely bought and sold unhampered by legal and social restraints". The term "price" simply refers to the money that occupants pay to owners for the right to use a unit of commodity, signifying both contract rent and sales price (Alonso, 1964, pp. 5,16,17).

Many applications that extended the NUE (see Fallis, 1985, p. 81) relied on its analytical framework "that could be checked against actual data" (Clapp and Myers, 2000). However, despite its popularity, the NUE received significant criticism in the literature. These criticisms centered on the need for restrictive assumptions for analytical tractability; incapacity to deal with durability, dynamics and short-run market behavior; and difficulty in dealing with observed patterns of evolution in real world cities (Gibb, 2003). Furthermore, from a pricing perspective, many studies highlighted the theory's shortcomings in explaining the determination and distribution of prices (see Clapp and Tirtiroglu, 1994; Watkins and McMaster, 2011). In particular, the source of controversy was the assumption that housing was a homogenous commodity traded in a unitary market (McMaster and Watkins, 1999).

The *Hedonic Price Theory* of the 1970s addressed the NUE's shortcomings imposed by the treatment of the housing stock as a homogenous commodity. At that time, Lancaster (1966) had laid out the grounding of the hedonic approach by modifying the existing consumer theory, which was mainly concerned with utility driven from a number of commodities. With his modification, the theory expanded to include the utility driven from the "characteristics" of commodities provided to the consumer in varying quantities. Later, Rosen (1974) completed the theoretical grounding of the hedonic approach by interposing a market for these characteristics in which suppliers and consumers interacted in equilibrium.

The pioneering applications of the hedonic price theory were concerned with the automobile markets. Following them, a study by Kain and Quigley (1970), applied the theory to the residential markets by focusing on various "qualitative" (e.g., proximity to schools, traffic, cleanliness) and "quantitative" (e.g., number of rooms, lot size, etc.) characteristics of houses; and represented them with separate regression coefficients. Today, the literature has expanded to include literally thousands of hedonic house price models and several meta-analyses (e.g., Braden, et al., 2011; Nelson, 2004; Sirmans, et al., 2006; Sirmans, et al., 2010). Although hedonic models contributed to the neoclassic house price literature significantly, they also have several shortcomings. In particular, given the durability of the housing stock and the supply lags caused by construction, the assumption of equilibrium and market clearing conditions is problematic. In order to address this, several studies attempted to implement hedonic models in disequilibrium only with limited success (see Malpezzi, 2003 for an in-depth treatment). Other difficulties with hedonic house price models included specification issues (i.e., the choice of the dependent and independent variables, availability and costliness of data, the choice of functional form) and violations of several econometric assumptions (see Anselin, 2003; Gillen, et al., 2001; Osland, 2010 for in-depth treatments).

In sum, commodity based models of house prices gained prominence in the 1960s, following the surge in real estate values and the intensified construction activity in the US. The hedonic models of the 1970s mostly maintained the spatial focus, but also allowed to incorporate the heterogeneity of house characteristics into the pricing models. The 1970s were also marked with the "efficient markets revolution" (Shiller, 2014) in finance and economics, which propelled the asset based theories discussed in the next section.

2.3.2. Theories after the EMH

Beginning in the 1980s, asset based theories of the housing markets gained prominence. These theories rely on the EMH; therefore, they do not only assume that house price changes were in line with rational expectations of individuals, but also maintain that there was no mispricing in housing markets. However, as researchers began to present evidence contrary to the assumptions of efficiency, house price theories gradually incorporated insight from behavioral studies. Figure 2.7 depicts this theoretical evolution in a timeline. The light colored arrow on the top left portion of the figure presents a group of studies that treat housing markets in line with the EMH starting with the mid 1980s. Next, the second arrow refers to a group of studies that question the applicability of the assumptions of efficiency to housing markets dating as late as 2013. The following two arrows with grayer shades present prominent studies that respond to the findings of inefficiency while maintaining the neoclassical tenets. Finally, the last two darker shaded arrows present groups of behavioral studies that gained impetus after the 2006 housing bubble. As the figure intends to convey with its gradient shades, the behavioral literature on house prices has been evolving from its neoclassical origins. As such, contemporary house price theories with behavioral insights, do not categorically reject neoclassical tenets, but rather build on them.

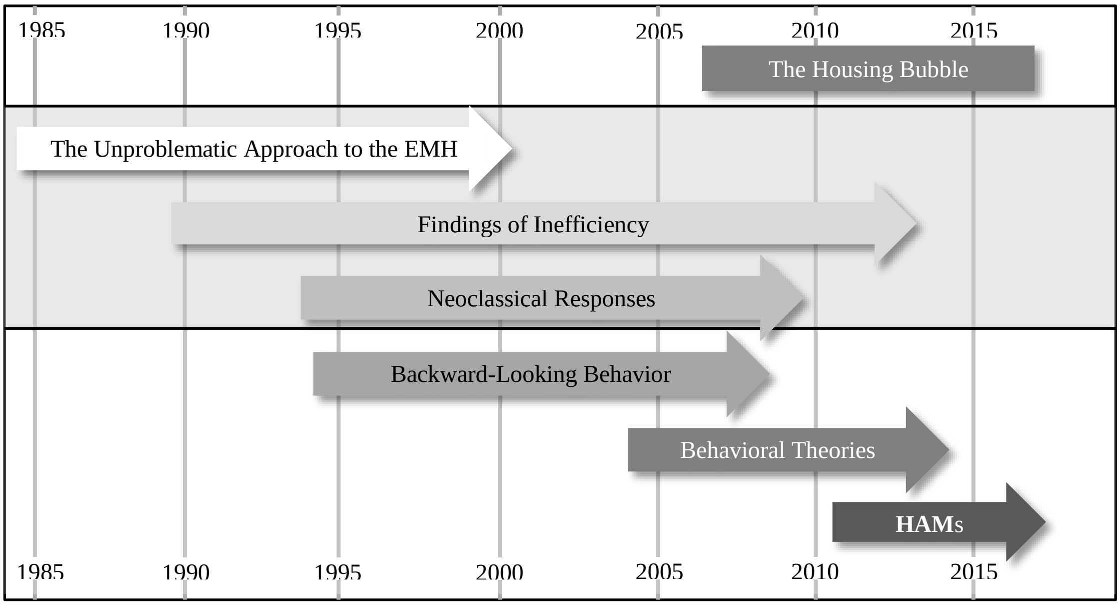

Figure 2.7 Timeline for the housing price theories after the EMH

2.3.2.1. Models Based on the EMH

This subsection presents prominent studies that conform to the neoclassical assumptions laid out in the earlier section 2.2.2. Accordingly, these studies readily assume that (1) individuals are fully rational; (2) fundamentals determine market prices; (3) economic agents are homogenous, and (4) markets are efficient. Characteristically, they explain movements in house prices as *equilibrium responses* to various shocks impinged upon economic fundamentals.

In this strand of research, the “capital-theoretic” study of Poterba (1984) made key contributions to the literature by defining “effective costs of ownership” and by positing the existence of a “rental equilibrium” in housing markets. The former refers to the utility associated with home ownership, recognizing that homeowners benefit from living in a house rent free, but also incur costs due to depreciation, repair costs, property taxes, foregone interest and capital gain or loss. The latter on the other hand, refers to the assumption of equilibrium in rental markets caused by the inelasticity of supply in the short run. The model’s underlying assumptions are explicitly neoclassical. Notably, homebuyers are rational individuals who equate the price of houses with the present discounted value of their effective costs of ownership. Hence, they are not only capable of identifying this cost accurately, but also possess perfect foresight, with expectations consistent with the long-term equilibrium of the market. The model’s conclusions confirmed the neoclassical belief in market fundamentals: The price surge in the real price of owner-occupied housing during the 1970s was a result of the substantial changes in the inflation rate. Ortalo-Magné and Rady’s (1999) research presented similar results for the UK market: House prices changed according to changes income and credit availability.

DiPasquale and Wheaton’s seminal study (1992) proposed an asset based model while considering the durable nature of the housing stock. In it, the authors presented a simple analytical framework referred to as the “Four-Quadrant Model” (FQM). The model is a general one, applicable to all types of real estate including commercial, industrial, and residential. As shown in Figure 2.8, it divides the real estate market into two interrelated markets: one for the “real estate assets” and the other for the “real estate space”, shown on the left and right sides of the diagram respectively. Quadrants II and III further divide the asset market by representing two interrelated processes separately: one for the valuation and the other for the production of housing assets. Similarly, quadrants I and IV represent the adjustment of stock levels and the determination of rent in the market for space. This diagrammatic layout enables tracing out the impacts of exogenous shocks in a nation’s economy on rents, discount factors, construction activity in the short run, and on building stock in the long run.

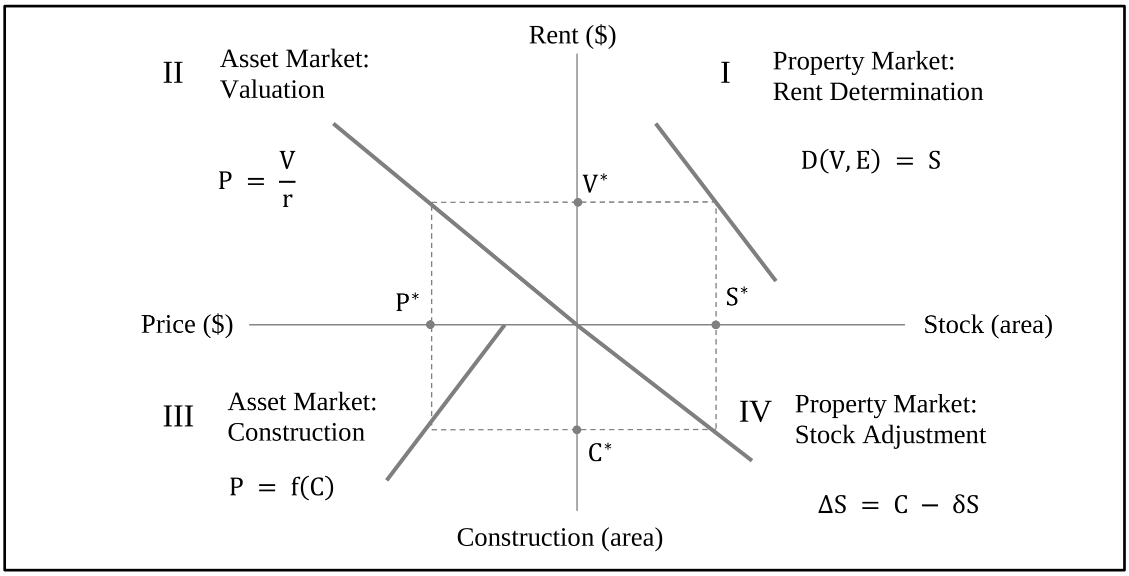

Figure 2.8 The Four-Quadrant Model of real estate
(Source: DiPasquale and Wheaton, 1992)

In line with the Marshallian theory of competitive equilibrium, the downward sloping curve in quadrant I represents demand for space (D) by relating rents (V) to the existing levels of stock (S) and to other exogenous economic factors (E) such as income or number of households. Assuming market clearing conditions for rented space, rents are determined at which the demand for space equaled the supply of space. When market fundamentals such as income or population increase, the demand for space use rises. Since stock is inelastic in the short run, a change in the exogenous economic factors causes rents to rise as well. Quadrant II represents the first part of the asset market that relates rents to prices (P). The slope of the line represents the exogenous capitalization rate (r) at which individuals discount future cash flow of rents to determine the present value of the asset. Next, quadrant III assumes the price of the asset and construction costs to be equal, both of which are functions of the quantity of newly built assets (C). Finally, quadrant IV converts the flow of new construction into a long-run stock level (S) by incrementing the existing stock with new flow minus the stock depreciated at a constant rate (δ).

As shown in the left panel of Figure 2.9, the model assumes market equilibrium in the long run, based on steady state levels of rents (V^*), prices (P^*), construction activity (C^*), and stock (S^*). When exogenous shocks influence market fundamentals, these levels adjust to their new positions at V^{**}, P^{**}, C^{**}, and S^{**} shown in the right panel. For example, when a demand shock shifts the demand curve right from D_0 to D_1, rents and prices initially increase up to their new levels shown as V_1 and P_1. This rapid increase in prices stimulates new construction activity, which in turn causes stock level increases in the long run, and eventually puts a downward pressure on rents. Consequently, rents and prices move back to their new steady states higher than the initial equilibrium levels but lower than their immediate levels right after the exogenous shock.

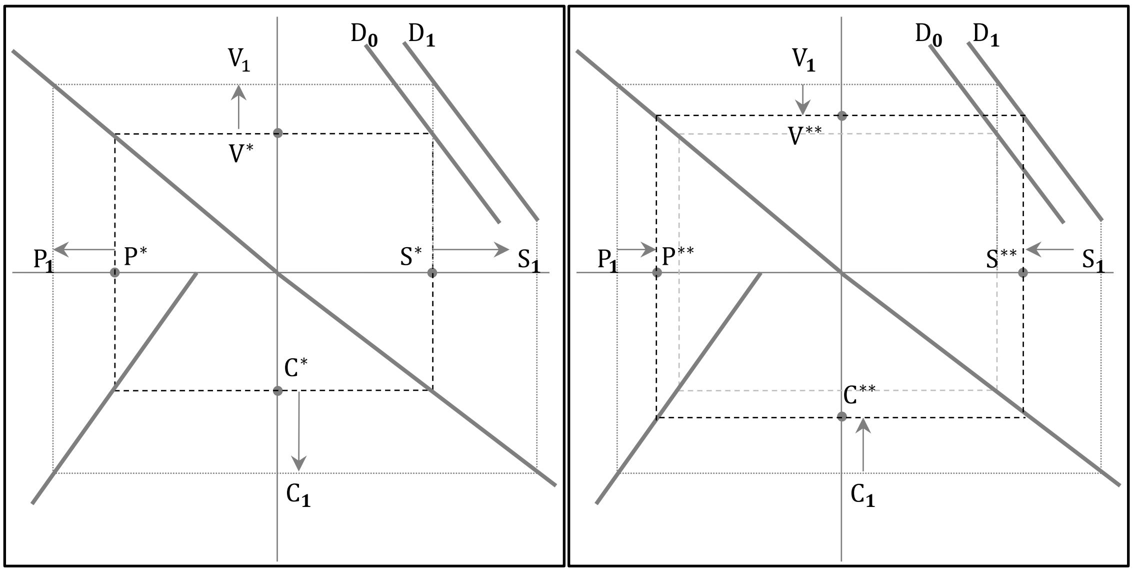

Figure 2.9 Comparative statics based on the Four-Quadrant Model
(Source: Wheaton, 2008)

2.3.2.2. Findings of Inefficiency

While studies based on the assumptions of the EMH were gaining prominence, another strand of research began to raise questions about these very assumptions. For example, in an early study Topel and Rosen (1988) drew attention to “some anomalies” in the expected present value theory of asset pricing for housing capital. Subsequently, a set of influential studies argued that house prices did *not* incorporate publicly available information such as interest rates (Case and Shiller, 1989) and fluctuations in demand (Mankiw and Weil, 1989) which was at odds with the EMH. Furthermore, several studies focused on findings of predictability and profit making opportunities in the housing markets, which violated the arbitrage assumptions associated with efficient markets (e.g., Case and Shiller, 1989; Case and Shiller, 1990). In addition, other studies showed that models based on market efficiency failed to capture the volatility of observed house price dynamics during times of booms and busts (See Cho, 1996 for an extended review; Clayton, 1996). Consequently, even Poterba (1991), the oft-cited pioneer of the asset based approach, highlighted “the possibility that investors may extrapolate” recent price trends, and thereby departed from the rational expectations/efficient markets framework. In a recent study, Ambrose, et al. (2013) estimated the deviation of house prices from fundamentals and found that these deviations can be persistent and long lasting.

2.3.2.3. Neoclassical Responses to Findings of Inefficiency

The above findings of inefficiency in housing markets triggered a set of responses from other economists. Some of them presented research findings in favor of the present value formulation and its “considerable power for explaining housing market phenomena” (Clark, 1995). Others highlighted the power of market fundamentals such as “rent-price ratio” (Gallin, 2008), “supply elasticity” (Glaeser, et al., 2008; Goodman and Thibodeau, 2008), “demographics” (Stevenson, 2008), “availability of risk-priced mortgage credits” (Wheaton and Nechayev, 2008) in determining house prices. In the same strand of research, others focused on fundamentals such as “interest rates, housing premia, and rent growth” (Campbell, et al., 2009) as well as “excess of mispriced mortgage finance” (Levitin and Wachter, 2010).

Regarding the concerns about mispricing in housing markets, proponents of the rational expectations/efficient markets framework published studies that refuted this possibility. While Malpezzi and Wachter (2005) referred to a theory of “rational bubbles” which justified overvaluation of asset prices while satisfying arbitrage conditions, others such as Himmelberg, et al. (2005) stated that their analysis revealed “little evidence of a housing bubble”.

2.3.2.3.1. Models with Backward-Looking Behavior

Given the mounting empirical evidence against the REH and the EMH, several studies began to explore backward looking expectation schemes within an asset-based framework in the 1990s. Allowing economic agents to extrapolate from past data, these studies recognized observed volatility in housing prices as “fluctuations” or “oscillations” caused by exogenous shocks in market fundamentals. Such movements were not necessarily "bubbles" *per se*, since the studies construed them similar to the deviations from equilibrium prices observed in the cobweb cycles. Despite this change in proposed models, this branch of literature carried forward the other neoclassical assumptions. Notably, they maintained the assumption of individual rationality based on utility maximizing behavior, emphasized a firm confidence in the market mechanism, and explained price outcomes based on market fundamentals (e.g., Abraham and Hendershott, 1994; Quigley, 1999).

One of the oft-cited applications of backward-looking expectations in the housing markets was a simulation model developed by Malpezzi and Wachter (2005). Similar to earlier studies (Malpezzi and Mayo, 1997; Malpezzi and Maclennan, 2001), the model proposed a stock-flow framework and assumed the presence of long-term equilibrium in housing markets. As shown in Figure 2.10, the model predicts that the effect of the elasticity of supply dominates the effects of speculative demand; and the effects of speculation increases with the increasing inelasticity of supply. Accordingly, when supply is elastic, prices without speculation and prices with speculation move in tandem. However, when supply is inelastic, prices with speculation become highly volatile. The policy implication of the simulation is characteristically neoclassical: Market regulation causes more speculation and hence, more volatility.

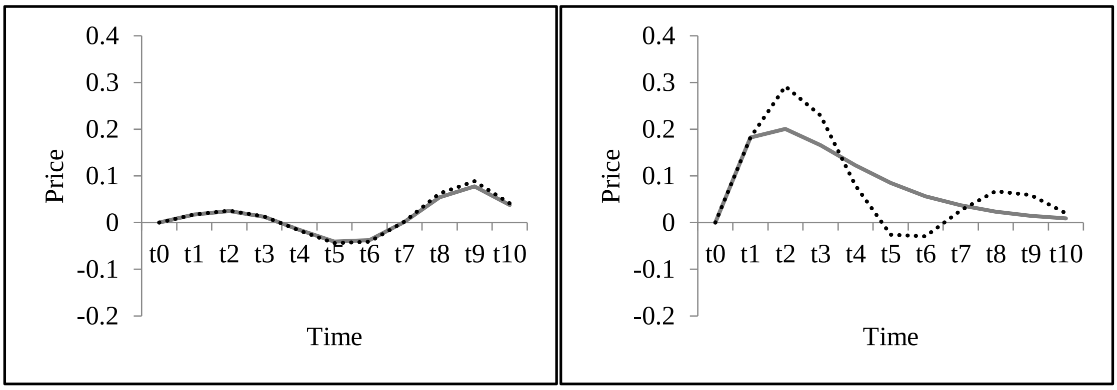

Figure 2.10 Time series of house prices (Source: Malpezzi and Wachter, 2005). The left panel and right panels show the effects of elastic (η = 10) and inelastic supply (η = 0.2) respectively; the dotted lines show speculative demand in both panels.

Although the model contributed to the understanding of price movements in the presence of backward-looking expectations and supply lag, it did not consider the interaction between rents and prices. In contrast, another model developed by Wheaton (1999) studied the durable nature of housing units and their asset-like qualities in a dynamic system of equations by simulating the effects of an exogenous demand shock on a real estate market in equilibrium. As shown in Figure 2.11, the results suggest that certain combinations of elasticity, supply lag (n) and depreciation parameters (δ) cause prices to converge smoothly to the previous steady state, while others generate fluctuations.

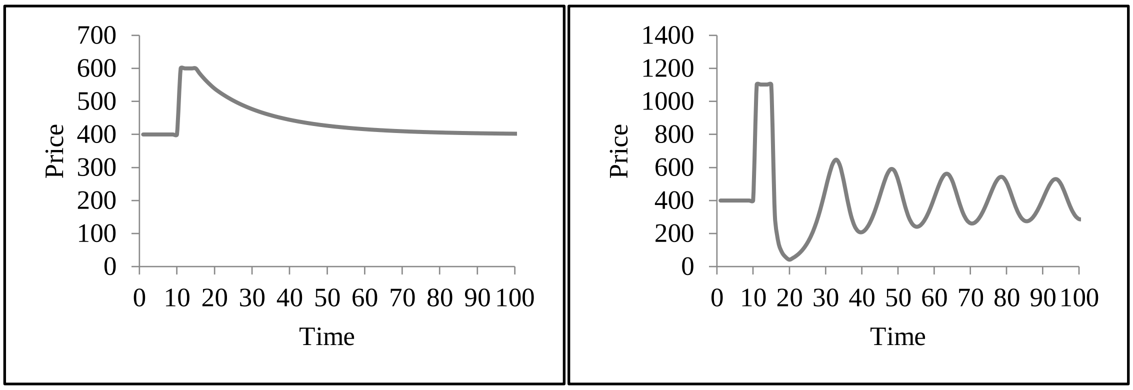

Figure 2.11 Time series prices of housing prices (Source: Wheaton, 1999). The left and right panels show stable ($\varepsilon = 1$, $\eta = 1$, and $\delta = 0.05$) and unstable parameters ($\varepsilon = 0.4$, $\eta = 2$, and $\delta = 0.1$) respectively. In both simulations a demand shock of 50% is introduced in the 10th period with $n = 5$ and $r = 0.05$.

2.3.2.4. Behavioral Models

As depicted in Figure 2.7, the mid-2000s marked the early stages of behavioral theory development on house prices. Case and Shiller (2004) pioneered this effort in a remarkable study which showed that elements of a speculative bubble (i.e., “the strong investment motive, the high expectations of future price increases, and the strong influence of word-of-mouth discussion”) existed in the US housing market. Later, Black et al. (2006) found that “momentum behavior” drove the house prices in the UK; and Fraser, et al. (2008) published similar findings for the New Zealand market. Recently, several researchers argued in favor of a “behavioral agenda” in housing economics while others began to publish studies based on psychological biases such as mental accounting or anchoring (e.g., Paraschiv and Chenavaz, 2011; Leung and Tsang, 2013).

The common denominator across these studies was the suggestion to relax the individual rationality assumption. In fact, even researchers who have been long-time proponents of the neoclassical tenets began to publish results favoring this change (Glaeser, et al., 2014):

> [For future studies] a second extension is to relax the assumption of perfect rationality for homebuyers, and perhaps builders as well. Can this volatility be the result of real shocks to housing markets or must it reflect bubbles or animal spirits?

2.3.2.4.1. Heterogeneous Agent Models (HAMs)

In the recent finance and economics literature, there is a strand of studies that utilize Heterogeneous Agent Models (HAMs) which are analytically tractable tools used in exploring the behavior of markets composed of interacting heterogeneous participants. This subsection presents a number of HAMs that studies the behavior of housing markets.

Burnside, et al., (2011) developed an early application of a HAM for the housing markets. The agents in the model have heterogeneous beliefs about fundamentals, i.e., some agents believe that these fundamentals will improve while others do not. Furthermore, although agents can update their prior beliefs in a Bayesian fashion, they have limited access to data. Another key feature of the model is an element that the authors refer to as social dynamics. Thus, agents meet randomly with each other and some of them change their prior beliefs about long-run fundamentals after these meetings. These features of the model generate market behavior with home sales and prices displaying a sharp positive correlation.

Next, Dieci and Westerhoff (2012) published a HAM which attempted to account for the "forces of human psychology that drive international financial markets" in the context of housing markets. Notably, some agents in the model believe that housing prices will revert to a long-run fundamental steady state, while others believe that the recent trends will continue. Furthermore, both groups of agents dynamically switch their beliefs based on the market sentiment. Specifically, these behavioral changes in agent strategies occur according to how far housing prices deviate from a long-run fundamental steady state.

In the same year, a master thesis (Bijman, 2012) included a model with similar characteristics. The model modifies Wheaton's (1999) aforementioned study to include heterogeneous expectations and a natural vacancy rate. Similar to other HAMs, the agents in the model switch behaviors dynamically, but this time between rational expectations and naive expectations.

Within the next year, Bolt, et al. (2013) published a housing market model with heterogeneous expectations that links rental levels to prices via imputed rents. The results display nonlinear aggregate price fluctuations around the fundamental value with two non-fundamental equilibrium prices on either side of the fundamental price. Using quarterly data on rents and house prices, the authors estimate the model parameters for five different countries, namely the US, the UK, the Netherlands, Japan, and Switzerland. The study concludes that the data support heterogeneity in expectations, with temporary switching between trend extrapolation and mean-reversion beliefs.

More recently, Eichholtz, et al., (2015) published an article with interacting heterogeneous agents with a focus on whether a fundamental factor or a trend explains house prices in the Netherlands. The authors find that agents in the housing market switch their expectations about future changes in house prices between fundamental and momentum strategies. Furthermore, the results of the study imply that neither fundamental variables nor recent trends explain housing price dynamics alone. Instead, both contribute to the variation in house prices and the importance of both factors varies over time.

2.3.3. Summary

As Table 2.2 shows, early asset based studies of the housing markets dating back to the mid-1980s relied on a representative, perfectly rational agent operating in efficient markets. These studies explained house price dynamics using “market fundamentals” such as inflation rate, supply and demand elasticities, construction costs, income levels, and ownership costs. However, motivated by research output that challenged market efficiency assumptions by the early 1990s, house price studies gradually began to relax the efficiency assumptions by utilizing backward-looking expectation schemes. About a decade later around mid-2000s, behavioral studies began to gain impetus. In contrast to their predecessors, these studies incorporated psychological and epidemiological research findings into the existing literature.

Table 2.2 Summary of house price studies after the EMH. The first column in the table identifies the section that presented individual studies, filled with the same shade as in Figure 2.7. The fourth, fifth, sixth and seventh columns match the key differences between neoclassical and behavioral studies identified in section 2.2.2.

Section	No	Author, Year	Individual Rationality	Determinants of Market Price	Individual Interactions	Market Efficiency
2.3.2.1	1	Poterba, 1984	✓	u, Ei	None	✓
	2	DiPasquale and Wheaton, 1992	✓	η, ε, δ, C^c, r	None	✓
	3	Ortalo-Magné and Rady, 1999	✓	y, m	None	✓
2.3.2.2	1	Topel and Rosen, 1988	✓	η	None	✗
	2	Mankiw and Weil, 1989	✓	N	None	✗
	3	Case and Shiller, 1989	✓	i + Lagged Appreciation	None	✗
	4	Case and Shiller, 1990	✓	y, N, C^c + Lagged Appreciation	None	✗
	5	Poterba, 1991	✓	u + Extrapolative Behavior	None	✗
	6	Cho, 1996	NA	NA	NA	✗
	7	Clayton, 1996	✓	u + Psychological Factors	None	✗
	8	Ambrose, et al., 2013	✓	r^{rf}, i + Extrapolative Behavior	None	✗
2.3.2.3	1	Clark, 1995	✓	V/P	None	✓
	2	Himmelberg, et al., 2005	✓	u	None	✓
	3	Glaeser, et al., 2008	✓	η	None	✓
	4	Gallin, 2008	✓	V/P	None	✓
	5	Goodman and Thibodeau, 2008	✓	η	None	✓
	6	Stevenson, 2008	✓	y, N, Er^{rf}	None	✓
	7	Wheaton and Nechayev, 2008	✓	m	None	✓
	8	Campbell, et al., 2009	✓	EV, $E\gamma$, Er^{rf}	None	✓
	9	Levitin and Wachter, 2010	✓	m	None	✓

(cont. on next page)

Table 2.2 (Cont.)

2.3.2.3.1	1	Abraham and Hendershott, 1994	✓	y, C^c, r^{rf} + Lagged Appreciation	None	✗
	2	Wheaton, 1999	✓	η, ε, δ, C^c, n, r + Extrapolative Behavior	None	✗
	3	Quigley, 1999	✓	y, N + Lagged Appreciation	None	✗
	4	Malpezzi and Wachter, 2004	✓	η + Extrapolative Behavior	None	✗
0	1	Case and Shiller, 2004	✗	y, N, $\exists r^{rf}$ + Market Sentiment	None	✗
	2	Black, et al., 2006	✗	y + Momentum Behavior	None	✗
	3	Fraser, et al., 2008	✗	y + Momentum Behavior	None	✗
	4	Paraschiv and Chenavaz, 2011	✗	+ Prospect Theory	N/A	✗
	5	Leung and Tsang, 2013	✗	r^{rf} + Mental Accounting	None	✗
	6	Glaeser, et al., 2014	✗	y, N, S + "Animal Spirits"	None	✗
2.3.2.4.1	1	Burnside, et al., 2011	✗	+ Social Dynamics	✓	✗
	2	Dieci and Westerhoff, 2012	✗	η, ε + Market Sentiment	✓	✗
	3	Bijman, 2012	✗	η, ε, δ, C^c, n + Social Dynamics	✓	✗
	4	Bolt, et al., 2013	✗	u + Mean Reversion	✓	✗
	5	Eichholtz, et al., 2015	✗	i + Performance Strategy	✓	✗

CHAPTER 3

THE PROPOSED MODEL

The previous chapter presented a theoretical framework that encapsulates theories on house price dynamics. This framework rests on two main pillars of thought. On one hand, the neoclassical perspective maintains that housing markets are efficient mechanisms in which participants make rational pricing decisions by utilizing all available information on market fundamentals. Accordingly, the perspective argues that prices reflect the fundamental value of the housing units, i.e., there is no long-term mispricing. On the other hand, the behavioral perspective raises questions about the efficiency of housing markets as well as the rationality of their participants; and thereby argues that house prices may deviate from their fundamental values.

In this chapter, this dissertation proposes a model founded on a neoclassical precedent but with behavioral extensions. The chapter begins with a methodological discussion. Next, it explicates the research problem, provides further implementation details, and presents the verification of the model. The chapter concludes with validating the model in an empirical context, namely Istanbul's housing market.

3.1. Method

The proposed model is a simulation. As a research method for the social sciences, simulation has a long-established history dating back to the first use of computers in university research in the early 1960s (Troitzsch, 1997; Gilbert and Troitzsch, 2006, p. 6). Since then, many social scientists from a variety of disciplines such as psychology and sociology (See Suleiman, et al., 2000), economics and econometrics (See Fontana, 2006), operations research (See Vertinsky, 2008), and organization sciences (See Davis, et al., 2007) have used computer simulations to study a wide range of phenomena. While simulation models can use a variety of techniques including system dynamics, cellular automata, agent-based modelling, multilevel simulation and genetic algorithms (For various classifications see Davis, et al., 2007; Fontana, 2006; Gilbert and Troitzsch, 2006), they all serve similar uses. In broad terms, these include (1) *theory development* either by facilitating "generative explanations" (Epstein, 2006) or by extending a "simple theory" (Davis, et al., 2007), (2) *theory testing* by exploring the robustness of standard theory (Epstein, 1999; Davis, et al., 2007) and (3) *prediction* (Axelrod, 1997; Gilbert and Troitzsch, 2006, p. 4).

The model proposed in this dissertation utilizes simulation in parallel to the first use above, i.e., as an explanatory tool that provides insight into an observed social phenomenon. This is consistent with the following definition of simulation (Davis, et al., 2007):

> as a method for using computer software to model the operation of "real-world" processes, systems, or events…In particular, simulation involves creating a computational representation of the underlying theoretical logic that links constructs together within these simplified worlds. These representations are then coded into software that is run repeatedly under varying experimental conditions (e.g., alternative assumptions, varied construct values) in order to obtain results.

As depicted in Figure 3.1, Gilbert and Troitzsch use the term *target* for the observed "real-world" processes and suggest that simulation aims to "create a model of this target that is simpler to study than the target itself". Furthermore, the authors suggest that simulation allows researchers, "to draw conclusions about the model that will also apply to the target" by way of assessing the similarity of simulated data to the data collected from the target (Gilbert and Troitzsch, 2006, p. 15).

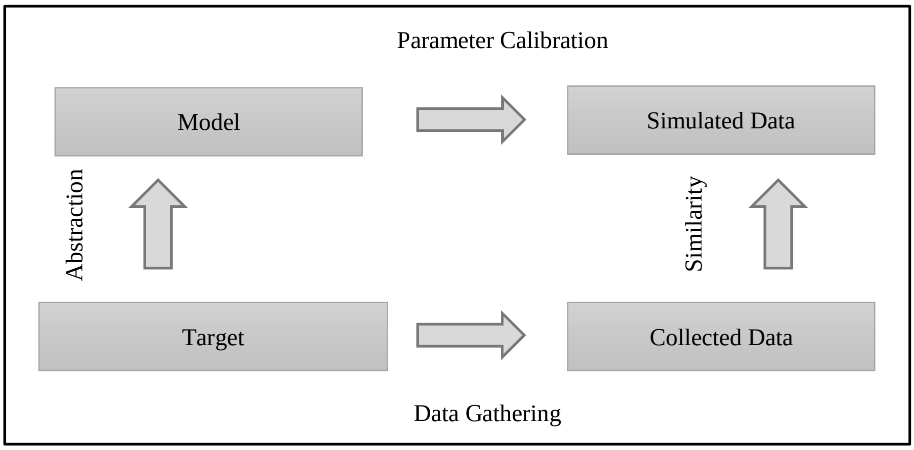

Figure 3.1 The basic "logic" of simulation methods
(Adapted from Gilbert and Troitzsch, 2006, pp. 16-18)

Epstein (1999; 2006) elaborates on the epistemological underpinnings of such a research effort in social sciences, for which the author suggests the term “generative” in order to distinguish it from both inductive and deductive approaches. According to the author, “The scientific enterprise is, first and foremost, explanatory” and to explain an observed macroscopic regularity is “to furnish a suitable micro-specification that suffices to generate it” (2006). For this specific purpose, the author suggests Agent-Based Modeling (ABM) as a simulation method and identifies the following six distinctive features of it:

First, in contrast to models consisting of a representative agent, ABM allows researchers to incorporate heterogeneity into their models, i.e., individuals may differ from one another in their state and in their behavior; and these may change endogenously over time. Second, agent-based models support autonomy, meaning that there is no central authority over individual behavior except feedback mechanisms between macrostructures and microstructures. Third, events occur in explicit space, which may be a physical landscape or an abstract Cartesian construct. Fourth, agents communicate via local interactions in this space, which allows modelling effects of proximity. Fifth, agents act with bounded rationality meaning that they are limited in information and computing power. Although their actions are purposeful, they are not “global optimizers” i.e., they use simple heuristics to aid their decision-making. Sixth, non-equilibrium dynamics allows researchers to step outside the equilibrium existence theorems, thereby aids in modelling emergence of macro level regularities out of micro level interactions.

Over the recent years, ABM applications have spread across a wide range of social science disciplines (See Gilbert, 2008 for a general treatment; Page, 2008 for applications in economics). In the meantime, several studies addressed the use of the method in financial markets. LeBaron argued that ABM was “beginning to show promise as a research methodology that will greatly impact how we think about interactions in economic models” (2000), and subsequently published a guide for building agent-based models of financial markets (2001). Later, in two related studies, LeBaron (2006) surveyed recent research on agent-models used in finance, and Hommes (2006) focused on Heterogeneous Agent Models (HAMs) as an analytically tractable class of agent-based models for which theoretical research supported numerical simulation results. Regarding the housing markets, a number of recent studies advocated the use of the method in order to explain the recent price formations (e.g., Burnside, et al., 2011; Dieci and Westerhoff, 2012; Bijman, 2012; Geanakoplos, et al., 2012; Bolt, et al., 2013; Eichholtz, et al., 2015).

Like other research methods, ABM has weaknesses. Some of these apply not just to ABM but also to other simulation based research methods. First, due to the necessity to eliminate complexity, simulation methods may lead to "an overly simplistic and distant model that fails to capture critical aspects of reality" (Davis, et al., 2007). Second, because of the different ways of assigning numerical values to structural simulation parameters, some of the most relevant statistical properties of a theoretical model may be conditioned (Novales, 2000). Third, as a related limitation, many simulation models utilize specific functional forms and even specific parameter values. Without this specificity, the complex dynamics of simulations are often very difficult to determine, which brings the risk that the conclusions of the model do not generalize (Wheaton, 1999). Finally, the lack of clarity and consensus about the nature of simulation methods often compromises the value of their use (Davis, et al., 2007; Fontana, 2006). To avoid this last pitfall, the rest of this subsection presents a "roadmap" drawing from studies that propose stepwise instructions for utilizing simulation methods (Davis, et al., 2007) and in particular for utilizing ABM (LeBaron, 2001; Gilbert, 2008).

(1) As presented in Figure 3.2, the first step in simulation based research is the *identification of the research problem* that reflects an "understanding of the extant literature and relates to a substantial theoretical issue" (Davis, et al., 2007). Such a problem may originate from various sources, including observed social phenomena, theoretical conundrums, inductive case studies, and formal theoretical models. Since it is often necessary to reduce the observed complexity, this stage also involves explicating the underlying assumptions regarding the nature of the problem.

(2) The second step is the *computational representation*. At this stage, it is important to balance the parsimony and accuracy of the model by capturing the key properties of the observed process while leaving out its nonessential properties. Although there are no hard rules for determining what these properties are, "it is often effective to err on the side of simplicity in simulation research" (Davis, et al., 2007). Next, the step involves implementation of the model, which comprises selection of a development platform and translating the design decisions into computer code.

(3) Once the simulation model is operational, the next critical step is *verification*. In effect, this is a debugging step to ensure that the model works as intended (Gilbert and Troitzsch, 2006, p. 19). Such a task is relatively straightforward if the simulation produces identical behavior to that of a benchmark model with the same parameters. In addition, the verification step involves sensitivity analysis where researchers discover the

parameter boundaries for which the computational representation is stable (Davis, et al., 2007). For example, to verify an agent-based simulation, researchers can deploy parameter values that are supposed to converge into a representative agent equilibrium and observe the simulation results accordingly. In addition, via sensitivity analysis they can demonstrate exactly where the parameter boundaries are between simple and complex behaviors (LeBaron, 2001).

(4) Following the verification step, researchers can benefit from *experimentation* by varying constructs or assumptions, and by adding new features to the computational presentation. This allows researchers to build a theoretical understanding of the target phenomenon in a stepwise fashion (Davis, et al., 2007). In practice, verification and experimentation comprise an iterative sequence of steps, as new experiments typically require the repetition of the verification procedure.

(5) The final step is *validation*, which primarily focuses on "whether the simulation is a good model of the target" (Gilbert and Troitzsch, 2006, p. 23). One possible way to this is to use the simulation to "predict" some well-known data set and to compare the results to the actual data (Davis, et al., 2007).

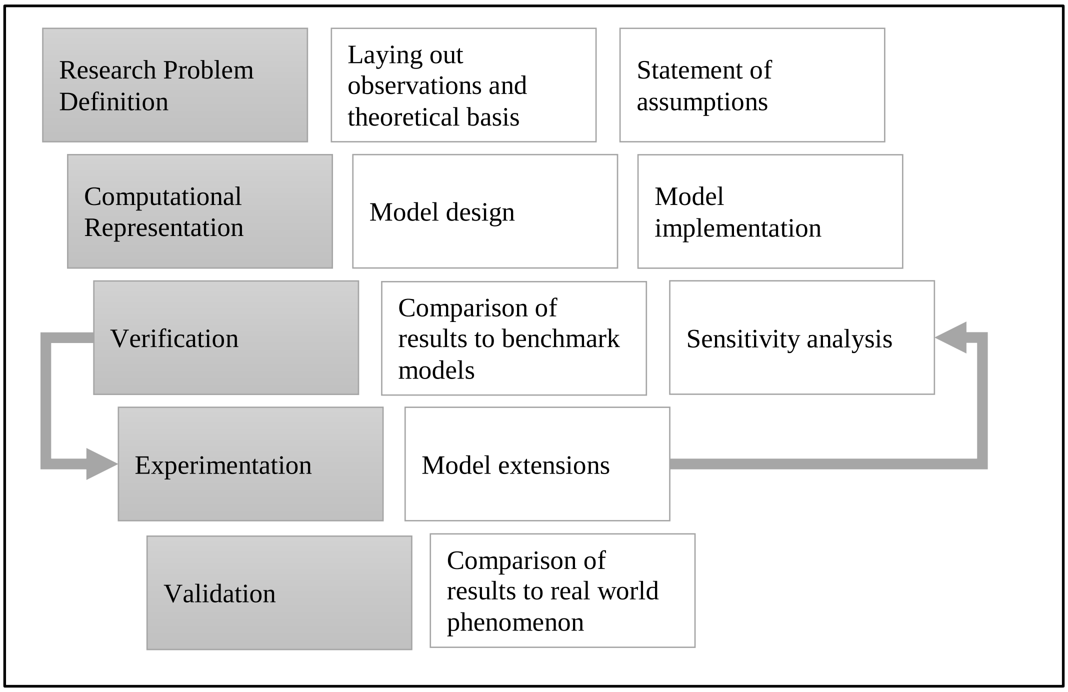

Figure 3.2 The roadmap followed in the proposed model
(Based on LeBaron, 2006; Gilbert and Troitzsch, 2006; Davis, et al., 2007)

The following sections will present the development of the proposed model in the order charted above.

3.2. Research Problem Definition

As stated previously, this dissertation seeks to contribute to the understanding of price formations in housing markets. For this purpose, it extends a prominent real estate market model (Wheaton, 1999), henceforth the benchmark model, to include contemporary insights from behavioral economics.

The benchmark model explains real estate prices with market fundamentals such as price elasticity of supply, price elasticity of rental demand, depreciation rate, construction cost, supply lag, and a constant discount rate. While maintaining the neoclassical individual rationality assumptions, it also includes backward-looking behavior where market participants extrapolate future prices based on current levels of rent. As such, it assumes neither efficiency of real estate markets (EMH), nor the presence of a rational expectations equilibrium (REH). However, it does assume that a single representative agent reacts to market behavior, which brings about aggregate changes in prices and in quantities of the building stock. Accordingly, interactions between a heterogeneous set of individuals are nonexistent in the benchmark model.

Like the benchmark model and other prominent neoclassical real estate market models (e.g., Poterba, 1991; Poterba, 1984; DiPasquale and Wheaton, 1992), this dissertation establishes an analytical base that rests on market fundamentals. Then, by referring to a growing body of contemporary literature (e.g., Case and Shiller, 2004; Bolt, et al., 2013; Dieci and Westerhoff, 2012; Eichholtz, et al., 2015), the proposed model builds on this base by allowing heterogeneous behavior among market participants. It does so by replacing the representative agent by *chartists* who believe that the recent trends will continue and *fundamentalists* who believe that the market will follow an economic variable instead of trends (Harrison and Kreps, 1978; Allen and Taylor, 1990; Frankel and Froot, 1987; Frankel and Froot, 1990). Furthermore, the proposed model allows these agents to change their behavior dynamically based on a well-known epidemic model (Kirman, 1993) and by comparing their performance with others' in the markets (Brock and Hommes, 1997). This implies that, in agreement with behavioral studies expounded earlier (e.g., Simon, 1955; Tversky and Kahneman, 1974; Kahneman and Tversky, 1979; Kahneman and Tversky, 1984), market participants in the proposed model are not fully rational. Precisely stated, households, individuals, or firms may update their existing beliefs correctly when new information becomes available, but fail to make deliberate decisions based on expectations of utility only (Barberis and Thaler, 2003; Hommes, 2006).

Therefore, the proposed model seeks to answer the following two interrelated questions: To what extent does the inclusion of (1) behavioral heterogeneity and (2) dynamic market behavior affect the benchmark model?

3.3. Computational Representation

In search of these answers, the proposed model extends the benchmark model by progressively adding (I) estimation of ownership costs, (II) heterogeneous expectations, and (III) dynamic behavior as shown in Table 3.1.

Table 3.1 Development stages of the proposed model

Model ID	Key Extension	Individual Rationality	Determinants of Market Price	Individual Interactions	Market Efficiency
Benchmark	N/A	✓	η, ε, δ, C^c, n, r + Extrapolative Behavior	None	×
I	Estimation of ownership costs	✓	Benchmark + u_t, $\mathbb{E}\pi$	None	×
II	Heterogeneous expectations	✓	I + ψ	None	×
III	Dynamic behavior	×	II + ζ, ρ, θ	Social Dynamics Epidemics	×

3.3.1. The Benchmark Model

The benchmark model represents rental demand as a dynamic function (D_t) that depends on an exogenous economic "demand instrument" (E_t), a demand constant (A), and the rent amount (V_t) with a constant elasticity (ε) as shown below:

$$D_t = AE_tV_t^{-\varepsilon}. \quad (3.1)$$

In so doing, it assumes market-clearing conditions, i.e., rents adjust until demand equals the current stock of space (S_t), which leads to the following short run relationship:

$$V_t = \left(\frac{S_t}{AE_t}\right)^{\frac{1}{-\varepsilon}}. \tag{3.2}$$

On the supply side, the stock of real estate evolves according to the following difference equation, where δ represents the constant depreciation rate of stocks as suppliers deliver a flow of new units (C_t) with a lag of n periods after construction begins:

$$\frac{S_t}{S_{t-1}} = 1 - \delta + \left(\frac{C_{t-n}}{S_{t-1}}\right). \tag{3.3}$$

Therefore, the difference in stock between two time periods increases with the depreciation rate and decreases with the ratio of new construction to the existing stock. This ratio, in turn, is a function of the asset price itself. In other words, as prices go up, the ratio of new construction to the existing stock increases:

$$\left(\frac{C_{t-n}}{S_{t-1}}\right) = BP_t^{\eta}. \tag{3.4}$$

In the above formulation, the elasticity of supply determines the *ratio* of new construction to the existing stock levels. More importantly, by relating future prices of n periods ahead to the current rents V_t and a constant capitalization rate (r) the benchmark model allows economic agents to use a backward looking expectation scheme:

$$P_t = \frac{V_{t-n}}{r}. \tag{3.5}$$

In the proposed implementation of the benchmark model, housing markets evolve according to the algorithm shown in Figure 3.3. This exact sequence of market activities takes place in each of the discrete time steps of the simulation for a specified number of iterations. For the first step, the values of stock, rent, price, and construction activity are simply equal to their initial values. For the subsequent ones, following Equation (3.3), current stock levels increase or decrease depending on the quantity of depreciated stock and on the quantity of delivered housing. With this new stock level, rents adjust according to the market clearing conditions assumed in Equation (3.2). Then, prices of housing units reflect the changes in rents using Equation (3.5); and this stimulates further construction activity delivered in the future, following Equation (3.4). While this sequence mainly describes the benchmark model, the proposed model differs by allowing agent heterogeneity in the portion of the diagram shaded with gray. This involves implementing the following three extensions.

3.3.2. Extension I: Estimation of Ownership Costs

The first extension modifies the benchmark model by replacing the constant discount rate (r) with an exogenous and dynamic cost of ownership parameter (u_t) in order to link expectations into asset pricing. Based on a formulation described in earlier studies (e.g., Poterba, 1984; Himmelberg, et al., 2005), the model estimates the annual cost of ownership as a function of the house price (P), annual maintenance rate (ω), mortgage rate (r^m), price depreciation rate (δ^p), risk premium (γ) and a constant expectation of capital gain ($\sqsubseteq\pi$) as shown below:

$$u_t = P_t {r^{rf}}_t(1-\mu) + P_t {r^m}_t \mu + P_t\omega + P_t\delta^p + P_t\gamma - P_t \sqsubseteq \pi. \quad (3.6)$$

Assuming rental market clearing conditions and factoring out the price parameter, the equation reduces to:

$$u_t = \frac{V_t}{P_t}\ , \quad (3.7)$$

where u_t represents the cost of ownership proposed as an alternative to the “conventional” rent-to-price ratio.

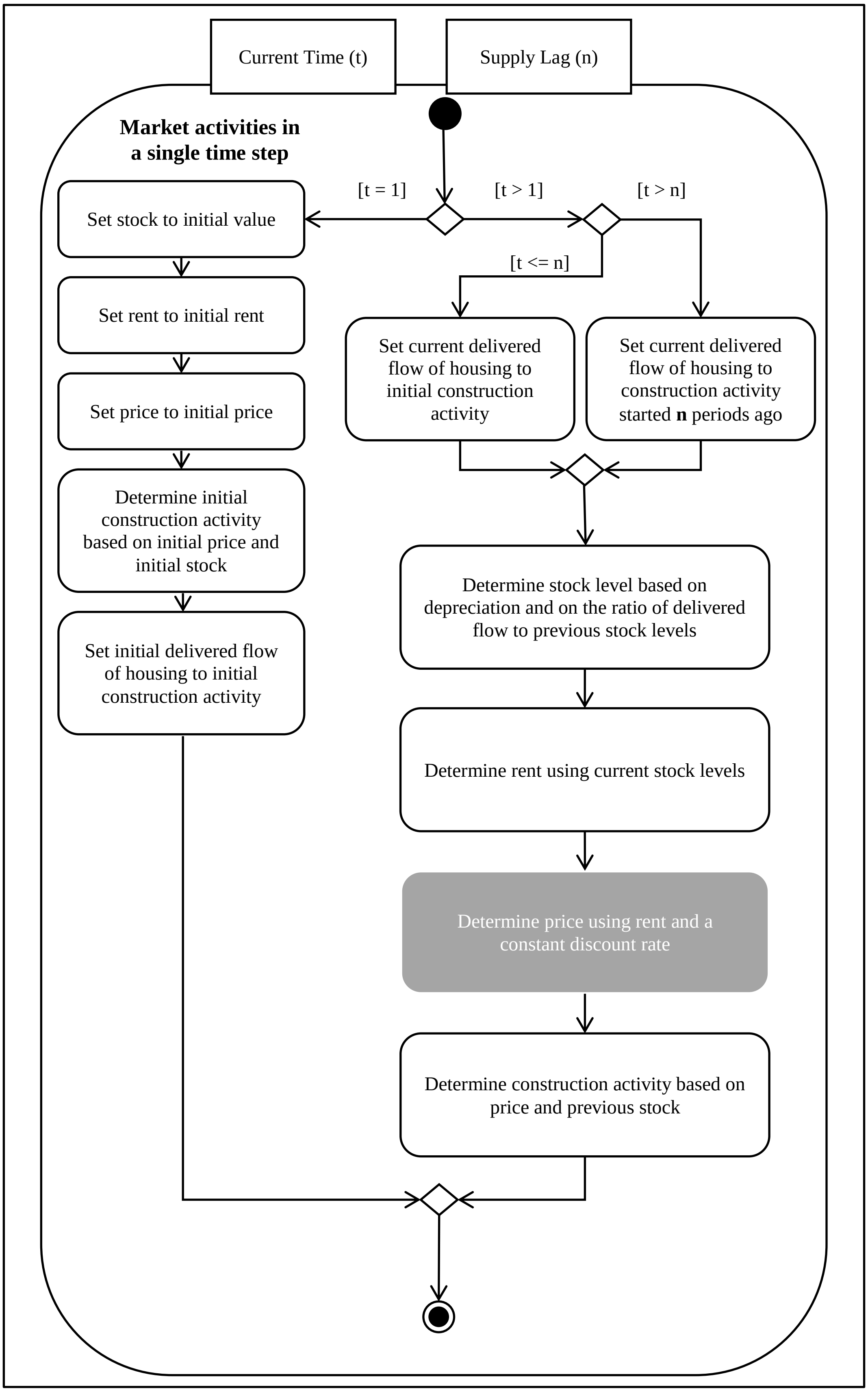

Figure 3.3 Housing market activities in each time step of the simulation shown with an activity diagram in UML (Unified Modeling Language)

3.3.3. Extension II: Heterogeneous Expectations

In the second extension, the model allows market participants to have heterogeneous expectations. Accordingly, individuals can follow chartist and fundamentalist strategies in the estimation of the ownership cost. Chartists, who make up a constant percentage of the agent population (ψ), expect the recent trends in the housing markets to continue based on the n^m periods moving average of house price changes.

$$\mathbb{E}_t^c\ \pi = \frac{1}{n^m}\sum_{i=1}^{n^m} \Delta P_{t-i}\ . \tag{3.8}$$

On the other hand, fundamentalists, who make up the rest of the agent population (1-ψ), base their expectations of the risk-free interest rate:

$$\mathbb{E}_t^f\ \pi = \ {r^{rf}}_t\ . \tag{3.9}$$

Hence, the market expectation for capital gain or loss resulting from housing assets in a given period equals:

$$\mathbb{E}_t\ \pi = \ \psi\left(\frac{1}{n^m}\sum_{i=1}^{n^m} \Delta P_{t-i}\right) + (1-\psi){r^{rf}}_t\ . \tag{3.10}$$

With this important extension, market expectation of capital gain is no longer an exogenous input to the simulation; on the contrary, it is an endogenous component of the simulation estimated at each discrete time step.

3.3.4. Extension III: Dynamic Agent Behavior

Finally, the third extension allows chartists and fundamentals to switch their behaviors dynamically. The behavior-switching regime either follows Kirman's (1993) epidemiological model or Eichholtz et al.'s fitness model (2015).

In the epidemiological behavior-switching regime, there are k individuals among a population of N who subscribe to a certain strategy:

$$k \in (0, 1, 2, \dots, N). \tag{3.11}$$

The system evolves as individuals meet in random where one of them recruits the other with a probability of ρ. In addition, individuals can change their behavior independently before meeting anyone with a small probability of θ, which connotes possible self-conversion due to arrival of exogenous news. The system dynamically evolves according to a simple Markov chain based on two probabilities. The first one represents the probability of an increment from k to k + 1 after an interaction:

$$p_1 = \left(1 - \frac{k}{N}\right)\left(\theta + \rho\,\frac{k}{N-1}\right). \tag{3.12}$$

Similarly, the second one represents the probability of a decrement by 1:

$$p_2 = \frac{k}{N}\left(\theta + \rho\,\frac{N-k}{N-1}\right). \tag{3.13}$$

On the other hand, in the performance based behavior-switching regime, the following multinomial logit probability describes the percentage of agents that apply the chartist strategy:

$$\psi_t = \frac{e^{\zeta f^c{}_t}}{e^{\zeta f^c{}_t} + e^{\zeta f^f{}_t}}. \tag{3.14}$$

Above, the parameter ζ represents the agents' intensity of choice. At ζ = 0, agents do not switch their behavior, hence ψ follows the initial population composition for all periods. At the other extreme, when ζ = +∞, all agents choose the strategy determined by the fitness function. Using a simpler version of the fitness measure suggested by Eichholtz, et al (2015), the proposed model assumes that agents assess the fitness of a given strategy based on the gains or losses they would incur over the n^u periods, if they had adopted a specific strategy.

The following equations show the estimation of the two fitness measures, where the fitness of the chartist strategy (f_t^c) depends on the change in the log of the chartist price between two consecutive time periods:

$$f_t^c = \frac{1}{n^u} \sum_{i=1}^{n^u} \Delta P_{t-i} \, , \tag{3.15}$$

whereas, the fitness of the fundamentalist strategy (f_t^f) depends on the change in the log of the fundamentalist price:

$$f_t^f = \frac{1}{n^u} \sum_{i=1}^{n^u} \Delta P_{t-i} \, . \tag{3.16}$$

3.3.5. Summary of the Proposed Model

As shown in the left hand side branch in Figure 3.4, in a housing market consisting of a representative agent, prices depend on ownership costs estimated with a constant expectation of capital gain. In contrast, in a housing market consisting of heterogeneous agents, prices have a fundamental component and a chartist component. The estimation of the fundamental component is straightforward: fundamentalist agents simply determine the price based on current ownership costs estimated with expectations that match the risk-free interest rate. On the other hand, if there are at least two past observations that chartists can extrapolate from, chartist expectations affect prices too. Furthermore, in this case, depending on the simulation parameters, agents may update their behavior dynamically based on a behavior-switching regime. As a result, market prices reflect the fundamentalist and chartist components weighted by their respective percentages in the agent population.

APPENDIX A presents further implementation details, including the computational design pattern and the user interface of the proposed model.

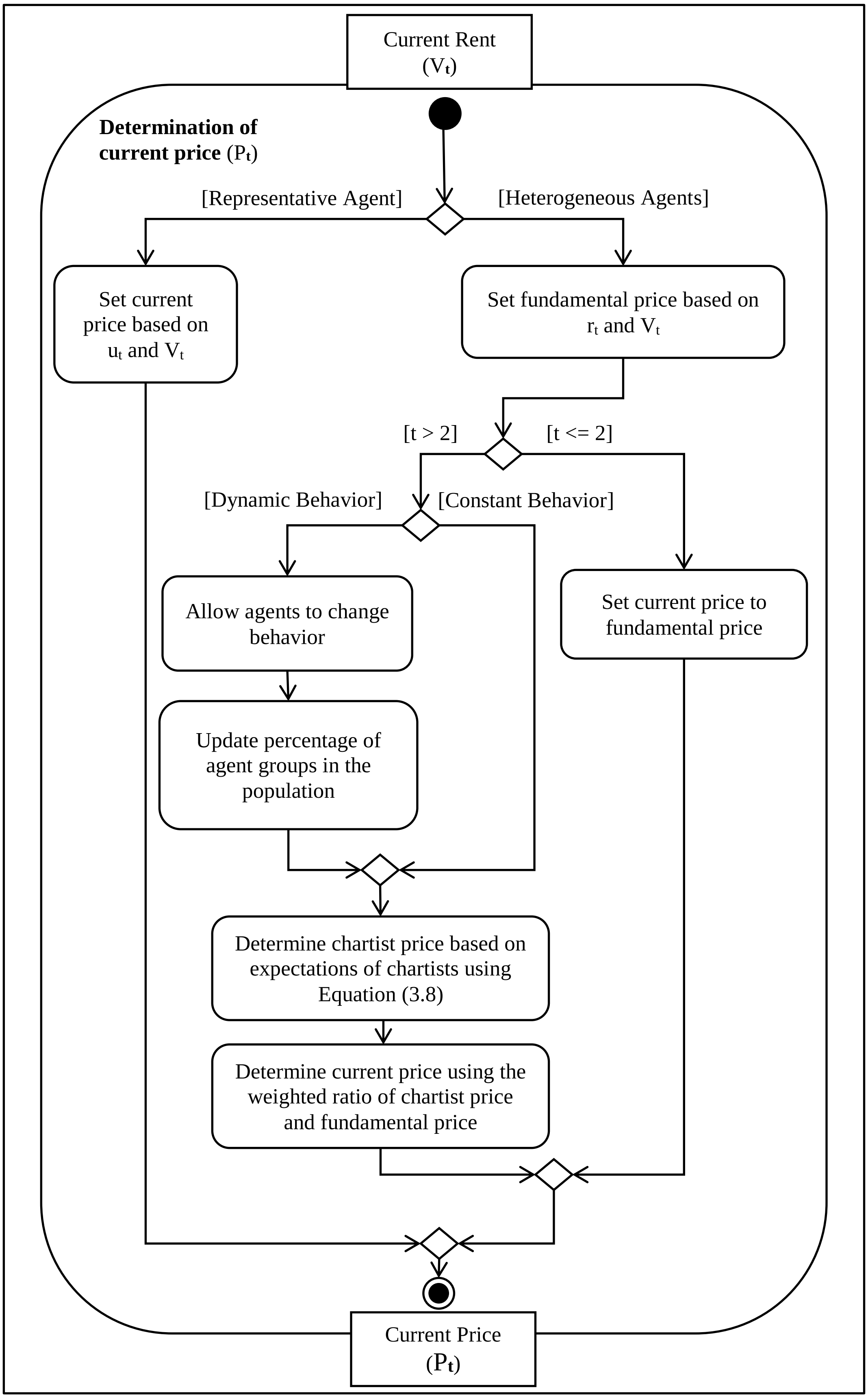

Figure 3.4 Price determination algorithm of the proposed model shown with an activity diagram in UML (Unified Modeling Language)

3.4. Verification and Experimentation

This section presents the verification of the proposed model. As suggested by LeBaron (2001), the verification starts with a comparison of the simulation results to the known behavior of the benchmark model. It then proceeds to experiment with model extensions presented in the previous section.

3.4.1. The Benchmark Model

Before examining the dynamic behavior of the proposed model, it is helpful to observe that the demand, supply, valuation, and stock growth curves reflect their functional specifications correctly. Figure 3.5 shows an example. The proposed simulation also allows performing this verification dynamically with changes in demand and discount rates, as shown in Figure A.3 of APPENDIX A.

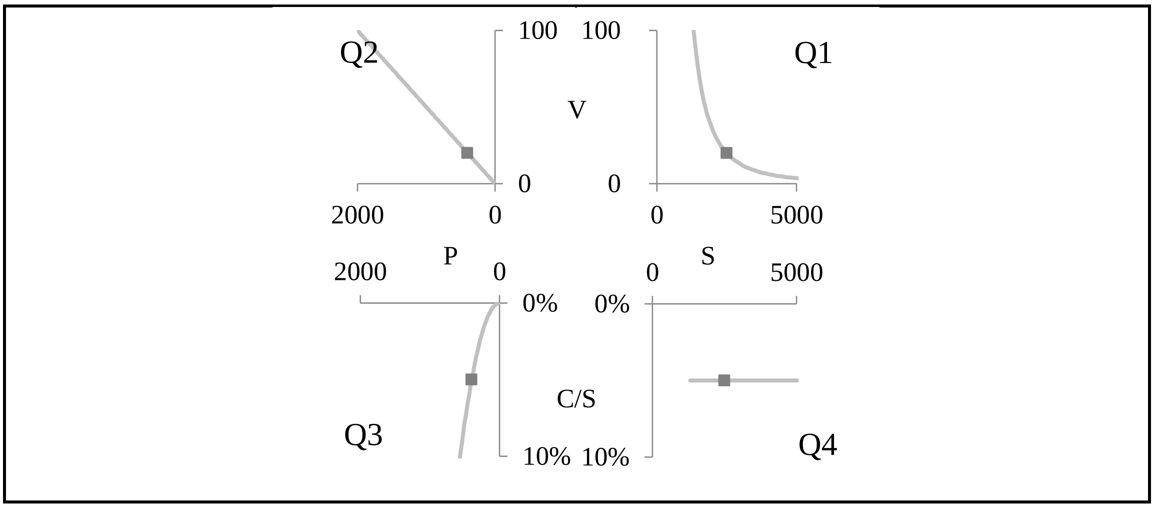

Figure 3.5 Verification of the model graphically. The diagrams are generated with parameters $\varepsilon = 0.4$, $\eta = 2$, $\delta = 0.05$ and $r = 0.05$.

As shown in Figure 3.6, running the simulation dynamically yielded patterns that are identical to published results (Wheaton, 1999). In the specific example below, an increase of 50% in the demand instrument (E) shocks the housing market. This generated an immediate response in prices followed by fluctuations in both prices and stock. Since the discount rate is constant, prices moved in tandem with rents.

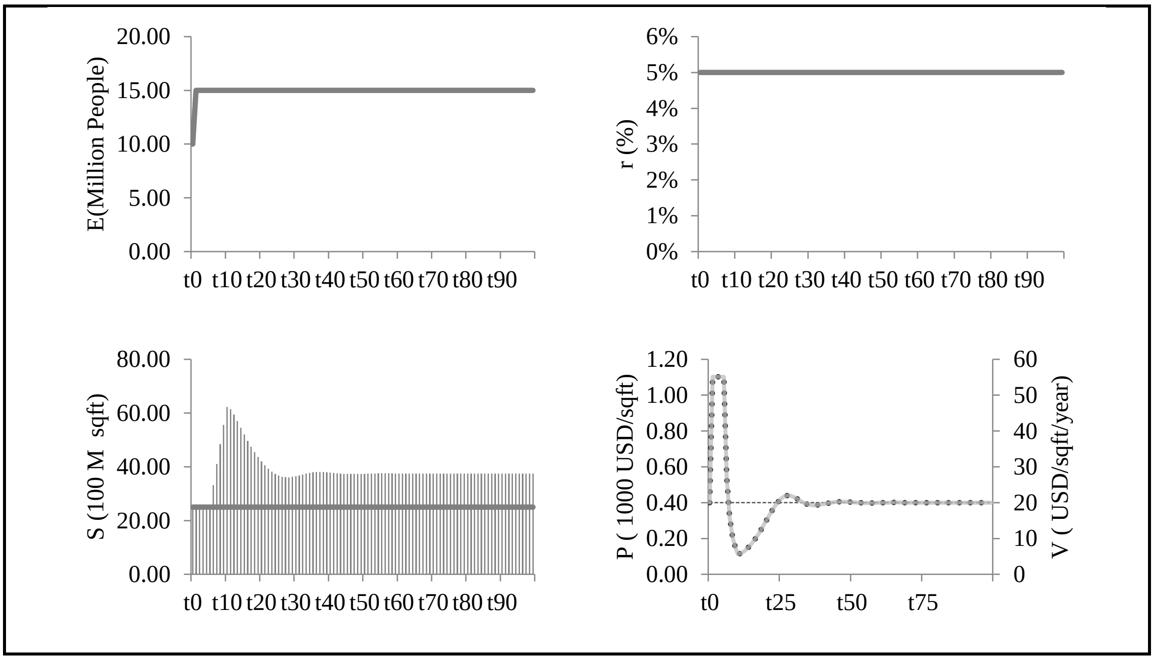

Figure 3.6 Verification of the model's dynamic behavior. The diagrams show parameters ε = 0.4, η = 2, δ = 0.05 and r = 0.05. A demand shock of 50% takes place in the 2nd period. Results match previously published quantities. Rents moved in tandem with the prices shown in the dotted line.

At this point, it is possible to use the model for experimentation. For example, an interesting question is to ask how housing prices and stock evolve over time when demand does not increase abruptly, but increases steadily to the post-shock levels over time. As shown in Figure 3.7, in this case, price fluctuations were much milder and the increase did not dissipate as early as the former case. Furthermore, stock formation did not display any fluctuations, but increased in parallel to increasing demand. Similar to the previous case, changes in rents and changes in prices moved in tandem.

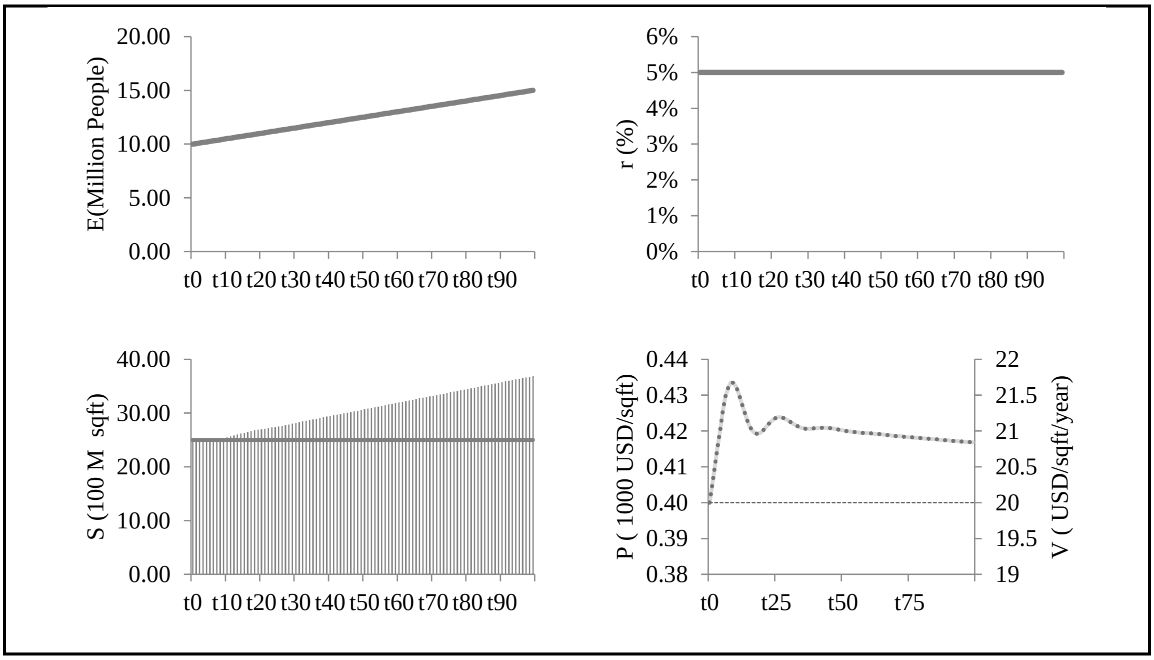

Figure 3.7 Effects of demand increase spread over time. In comparison to the previous figure, price and rent did not dissipate to its steady state as fast as the former case. Stock displayed steady growth. Again, prices and rents moved in tandem.

3.4.2. Extension I: Effects of Dynamic Ownership Costs

As stated earlier, the proposed model modifies the benchmark model by replacing the constant discount rate (r) with an exogenous and dynamic cost of ownership parameter (u_t) in order to link expectations to asset pricing. The next set of simulations holds the demand for rental space (E) constant while experimenting with gradual declines in ownership costs (Δu). As shown in Figure 3.8, housing markets are quite sensitive to such a change. Notably, the same fluctuations created by the changes in demand are visible with changes in ownership costs. As expected, with a decline in ownership costs, rents and prices did not move in tandem anymore; on the contrary, they moved in opposite directions. Especially for changes that exceed 2%, the price model exploded, leading to excessive stock formation and sharp declines in rents.

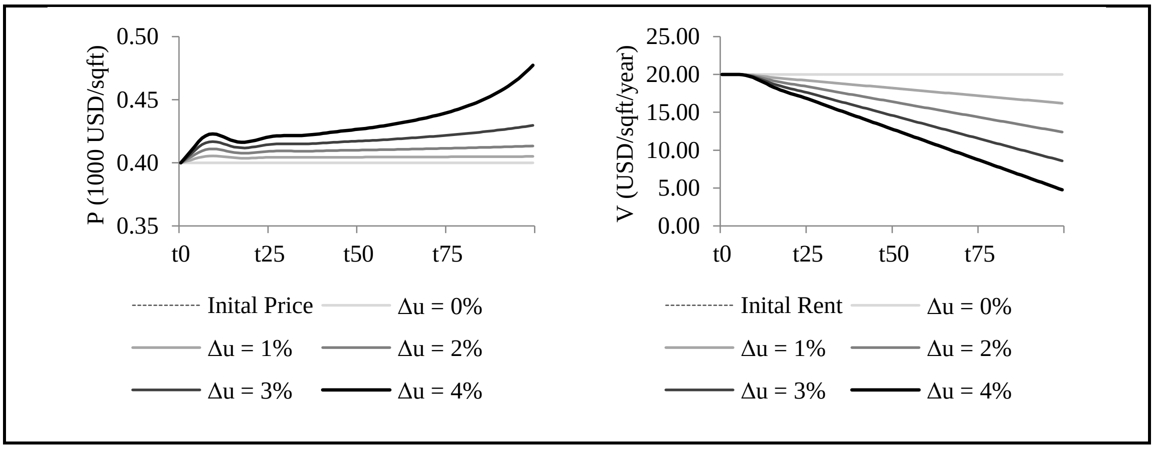

Figure 3.8 Sensitivity analysis of changing ownership costs. The demand instrument is constant, i.e., $\Delta E = 0$.

Next, it is instructive to see how sensitive the model is to declines in ownership costs while there is an accompanying increase in demand for rental space. As the next figure shows, although there was an immediate increase in rents, changes in ownership costs prevented the continuation of such an increase. Furthermore, the price and rent oscillations became more pronounced.

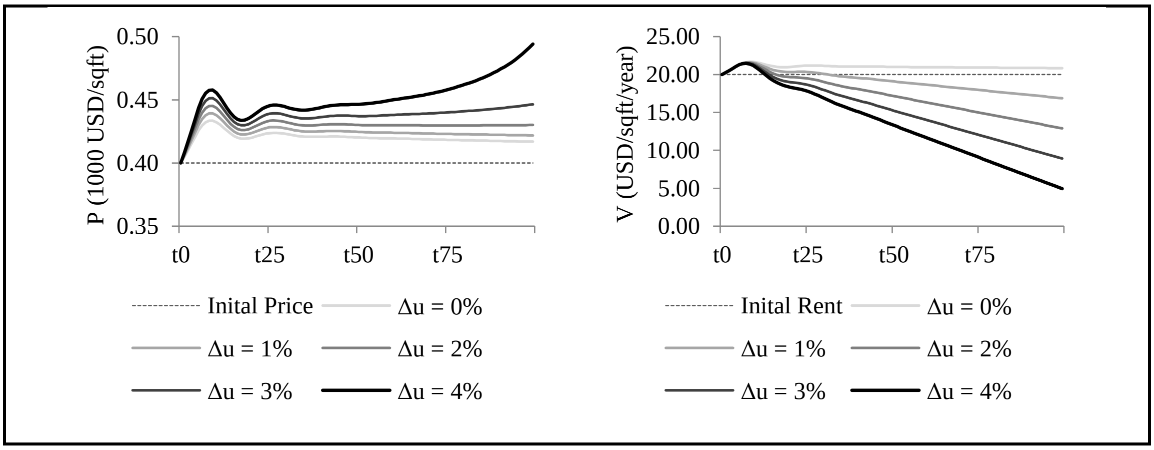

Figure 3.9 Sensitivity analysis of changing ownership costs and demand. The demand instrument gradually increases by half over the simulation run, i.e., $\Delta E = 50\%$.

Because the underlying model displays distinct patterns with different elasticity parameters, it is also instructive to observe the effects of changes in ownership costs against such market fundamentals. For this purpose, Figure 3.10 charts the output from several combinations of price elasticity of rental demand (ε) and price elasticity and supply (η).

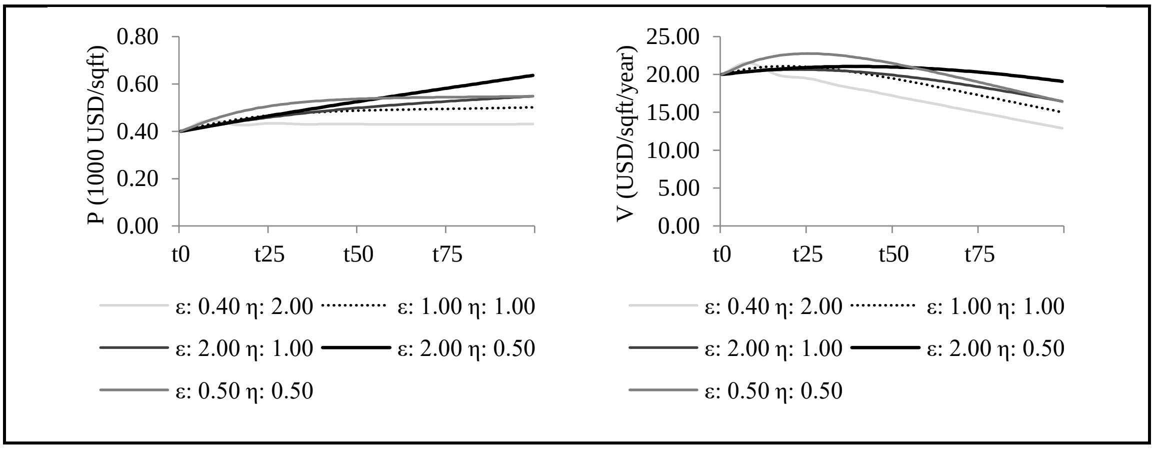

Figure 3.10 Sensitivity analysis of changing ownership costs and elasticities. The change in rental demand (ΔE) is 50% and the change in ownership costs (Δu) is 2%.

The results were in line with neoclassic theory. In markets with inelastic supply and elastic demand (i.e., ε = 2.00, η = 0.50), gradual changes in discount rates caused price increases that are explosive; at the opposite end, with elastic supply (ε = 0.40, η = 2.00), prices followed a stable pattern. Further analysis revealed that both the increase in prices and the corresponding decline in rents are quite sensitive to depreciation rates (δ). As shown Figure 3.11, in markets with low depreciation rates, changes in discount rates triggered steady price increases, while rents remained relatively flat. On the other hand, in markets with high depreciation rates, prices did not deviate from a steady state but rents declined significantly.

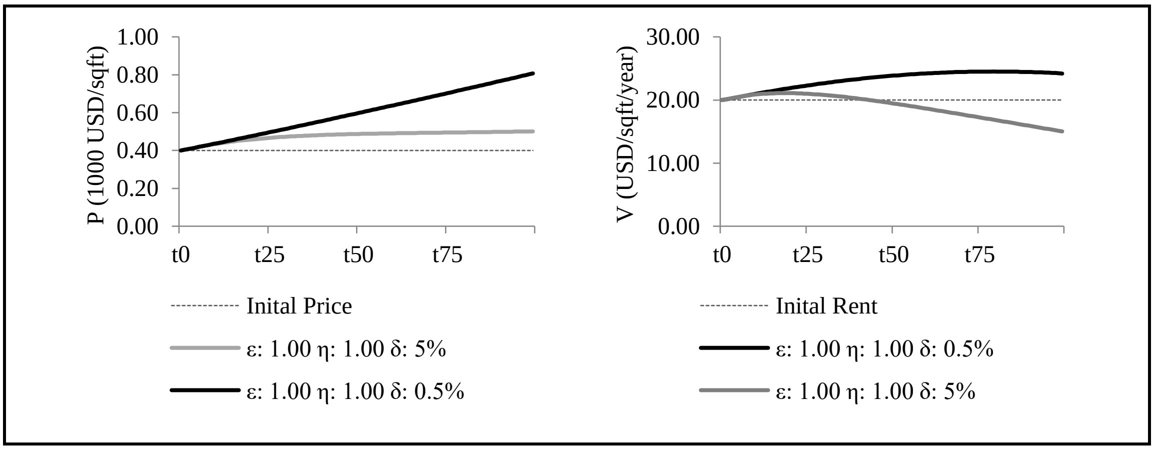

Figure 3.11 Sensitivity analysis for changing ownership costs and depreciation

During the verification of the other extensions to the model, the parameters above will remain constant. This will allow analyzing the effects of further modifications *ceteris paribus* while focusing on the effects of endogenously changing ownership costs.

Table 3.2 Parameters that remain constant in subsequent model extensions

Parameter	**Symbol**	**Value**
Change in demand instrument	ΔE	0%
Change in user costs	Δu	2%
Price elasticity of rental demand	ε	1
Price elasticity of supply	η	1
Stock depreciation rate	δ	1%
Memory for price extrapolation	n^m	2
Memory for strategy comparison	n^u	2
Supply lag	n	5

3.4.3. Extension II: Effects of Heterogeneous Expectations

The second extension allows market participants to have heterogeneous expectations. Accordingly, individuals in the following experiments can follow chartist and fundamentalist strategies in determining the housing prices. In order to gauge this effect, experiments I, II and III in Figure 3.12 simulate a market where ownership costs decrease gradually for 2%. In this setting, market behavior followed the fundamentals strictly, with the maximum price reaching up to 561.70 USD/sqft. Similarly, experiments IV, V, and VI simulate a market where ownership costs decrease for 2%, but this time abruptly. In a fundamentalist only market simulated in experiment IV, the maximum price reached 666.66 USD/sqft. Noticeably, such an increase in prices did not occur in experiment V where chartists made up the entire population of the market, i.e., ψ = 100%. However, when the market comprised both groups, the price went as high as 771.78 USD/sqft, “overshooting” the fundamental price as expected.

Two observations summarize these experiments. First, the presence of chartists affects the market outcome dramatically when the exogenous shock is sudden. More importantly, the presence of chartists alone does not lead to elevated prices; their impact is only visible when there are fundamentalists who react to the exogenous changes on market fundamentals.

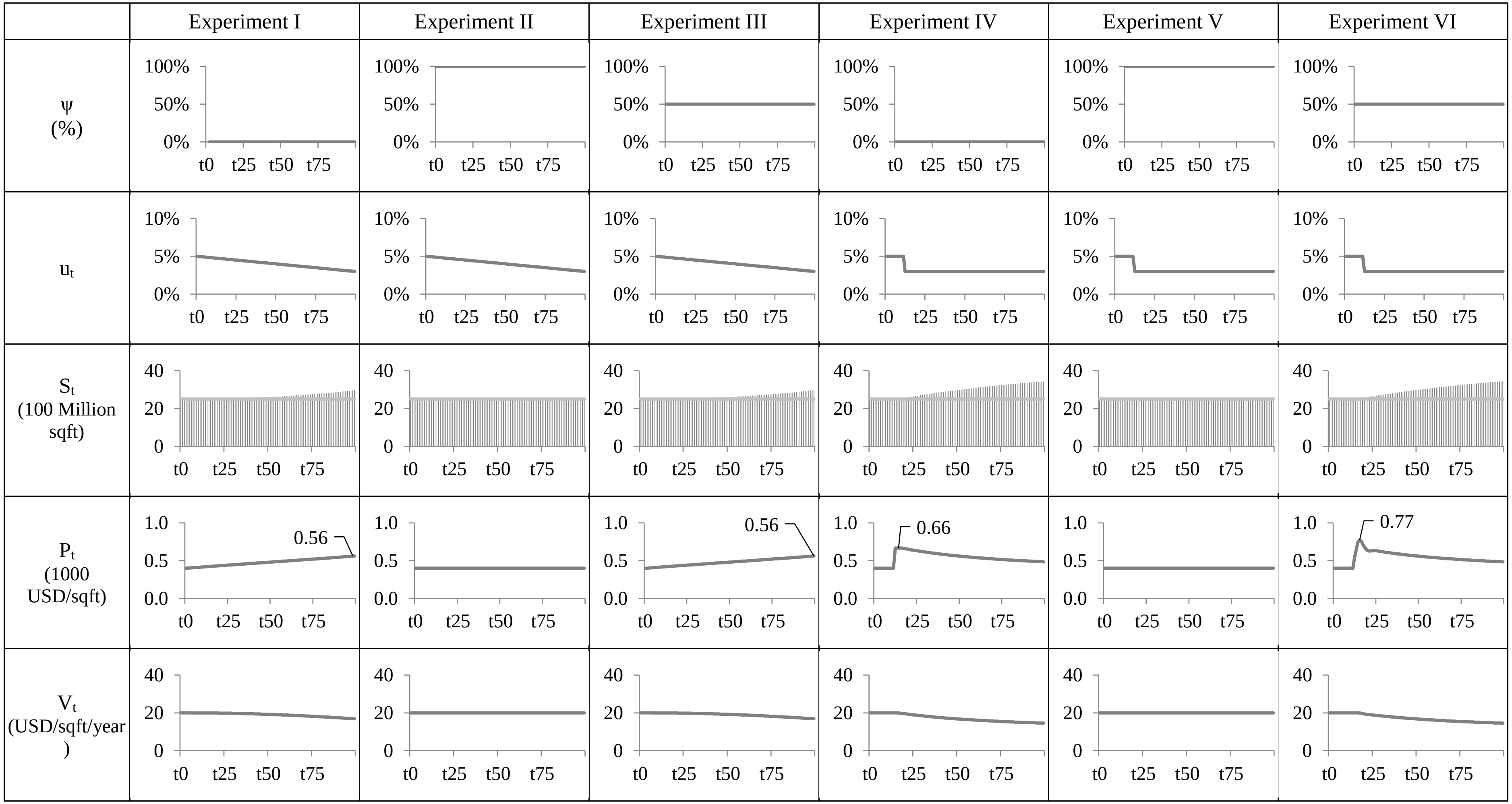

Figure 3.12 Sensitivity analysis of agent heterogeneity. The price change was dramatic in the last experiment, in which chartists and fundamentalists coexist in a market setting that has a sudden change in ownership costs.

3.4.4. Extension III: Effects of Dynamic Agent Behavior

In the third extension, the proposed model allows heterogeneous agents to interact with each other. It does so by implementing (1) Kirman's (1993) epidemiological model and (2) Eichholtz et al.'s (2015) fitness model as two distinct behavioral switching regimes.

3.4.4.1. Behavior Switching Regime Based on Epidemics

In the epidemiological behavioral switching regime, house prices evolve as one of the fundamentalist or chartist individuals recruits others with a probability of ρ. In addition, prices reflect self-initiated changes in behavior, which occur with a probability of θ. As discussed earlier, the model produces three noteworthy frequency distributions depending on the values of ρ and θ. In the first case, the percentage of chartists and fundamentalists remain around one half of the population. In the second one, the percentages of agents are uniformly distributed. Finally, in the third case, both groups take either very high or very low values, simulating the presence of a "large majority" in the population.

Table 3.3 Descriptive statistics of maximum price in the epidemiological model

Experiment							
ID	Parameters	*N*	*Mean*	*SD*	*Min*	*Max*
I	$\theta = 0.15$ $\rho = 0.7$	30	775.10	21.18	731.78	829.07
II	$\theta = 0.01$ $\rho = 0.98$	30	830.87	87.77	692.84	1018.28
III	$\theta = 0.005$ $\rho = 0.99$	30	940.00	292.52	702.39	2128.66

Because the model is stochastic, it is necessary to observe market behavior after a number of simulation runs. As shown in Table 3.3, in markets where agents do not readily change their behavior based on their interactions with others, the variation in the maximum prices was relatively small. In contrast, in markets where agent composition follows a uniform distribution, the mean of maximum prices increased modestly. However, with the presence of large majority groups, average prices not only observably increased, but also exhibited a high standard of deviation.

The characteristics of these different cases are also visible in Figure 3.13, which shows specific instances out of the multiple simulation runs. In Experiment I, where chartist and fundamentalists consistently make up around one-half of the population, prices fell steadily after the initial price rise. In Experiment II, agents recruit each other with relative ease and their distribution in the population was uniform over time. In such an experimental setting, prices began to fluctuate, but the change in magnitude was not extreme. In contrast to the previous experiments, when majority groups dominate the market, the price behavior changed drastically. For example, in the specific run shown in the figure, fluctuations had magnitudes that are unmatched in previous experiments; furthermore, the frequency of fluctuations was higher, causing the price instability to persist until later periods.

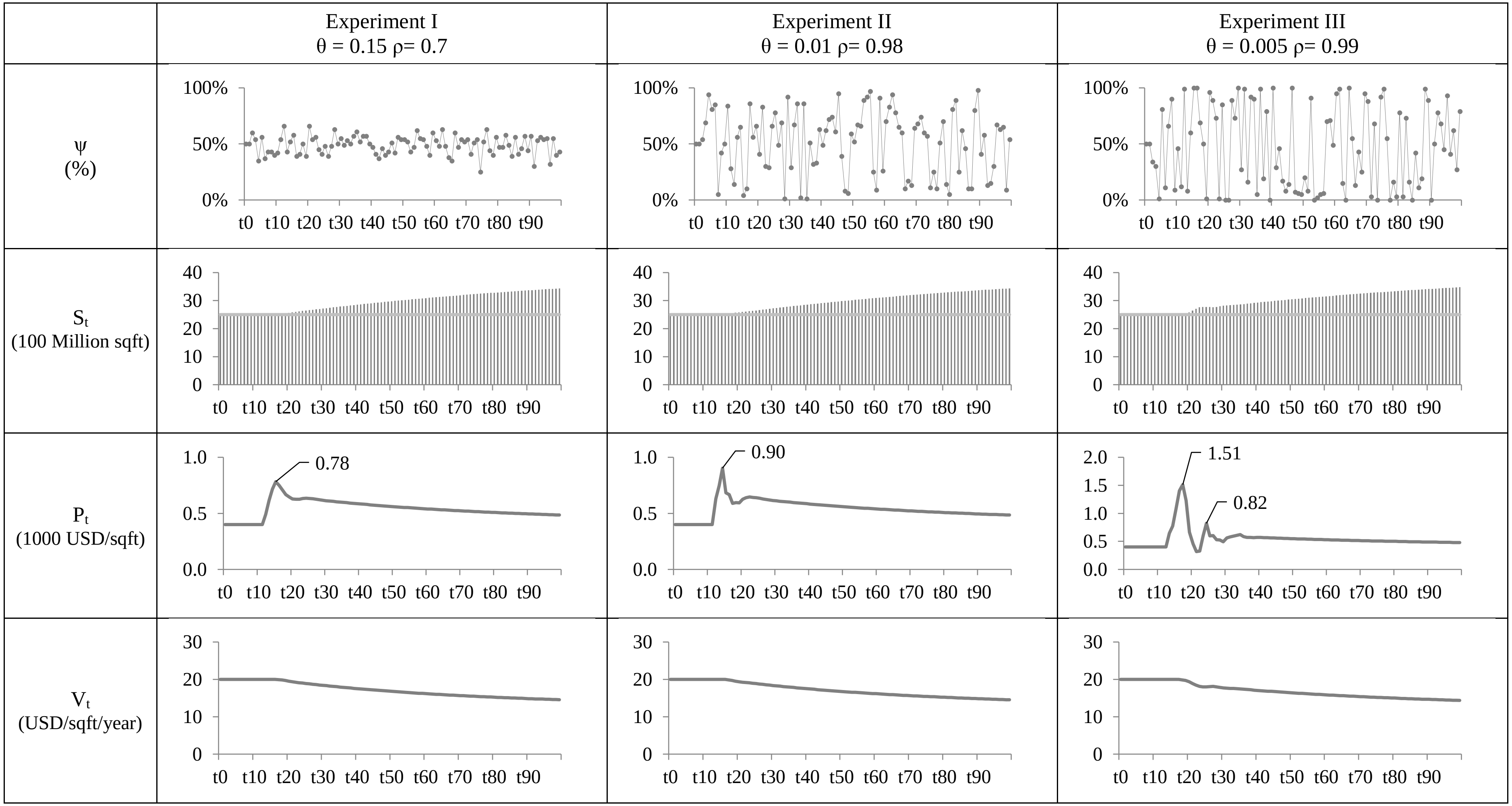

Figure 3.13 Sensitivity analysis of epidemic behavior-switching. In the presence of a majority group simulated in Experiment III, fluctuations had magnitudes that are unmatched in previous experiments and/or their frequency was observably higher.

3.4.4.2. Behavior Switching Regime Based on Fitness

The last extension to the benchmark model presents a behavior-switching regime in which agents consider the past performance of alternative strategies in determining their current behavior. In order to compare the effects of this behavior-switching regime, the parameter values remain the same as the previous set of experiments presented earlier in Table 3.2.

As shown in Experiment I in Figure 3.14, when the intensity of choice parameter ζ is zero, agents maintained their initial positions no matter what happens in the housing markets. In this scenario, following the shock in the 12th period, prices went up only modestly and gradually fell back to its steady state. In Experiment II, agents are mildly sensitive to the capital gains and losses of others. As such, only a small group of chartists changed their behavior when they observed the gains that the fundamentalist strategy would have produced with the fall in ownership costs. Again, the change in prices was relatively low. In Experiment III, market participants began to switch to the alternative strategies *en masse*. For example, in the 16th period, the percentage of chartists went as high as 90%, fell down to 10% by the 21st period, and price swings became noticeable. More importantly, the price changes in the final experiment dwarfed the previous results. With successive swings in the market sentiment, the maximum price level went up as high as 500%, to as high 7403.43 USD/sqft.

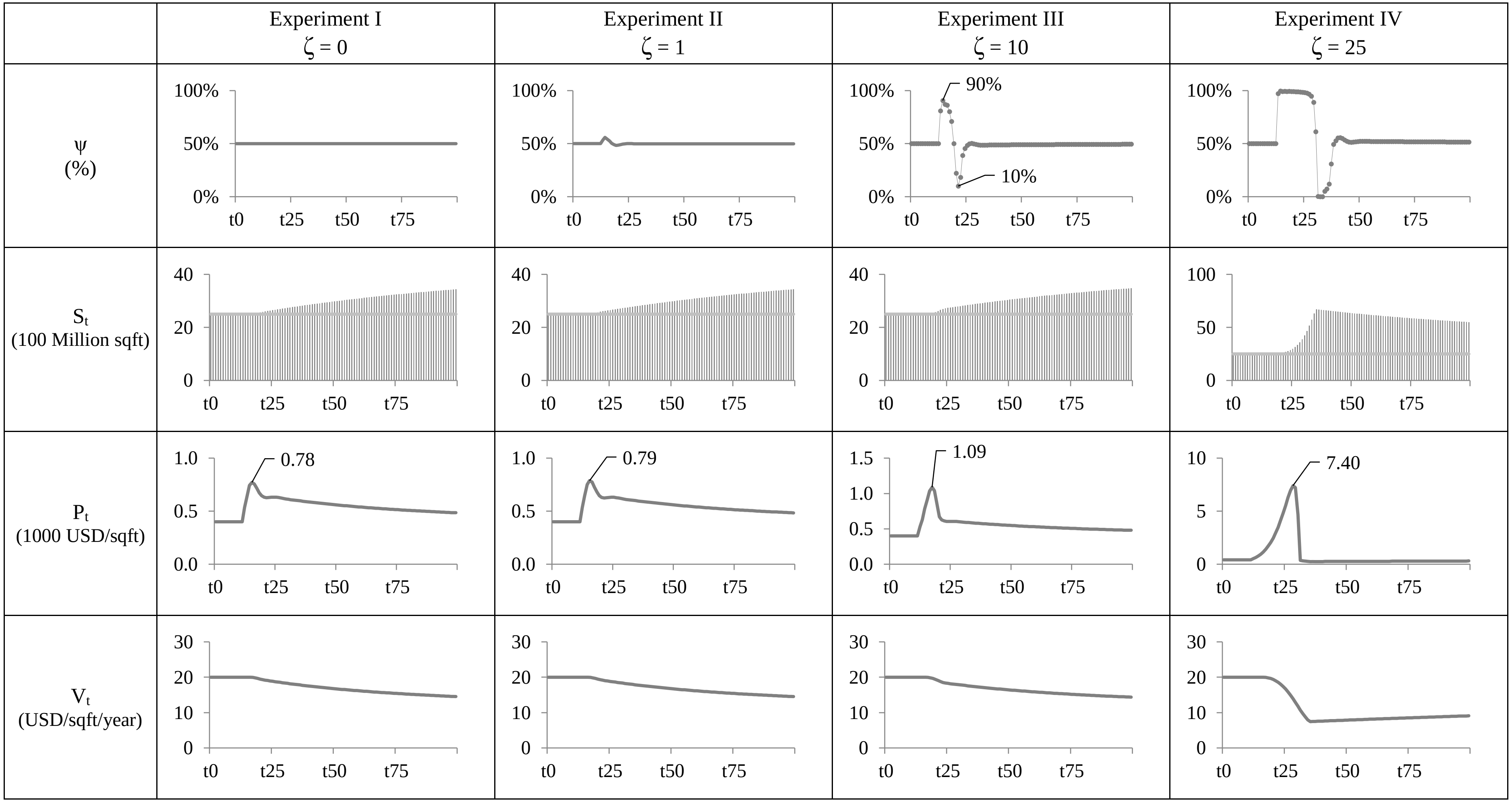

Figure 3.14 Sensitivity analysis of fitness based behavior-switching. In Experiment I, agents never change their behaviors. In contrast, in Experiments II-III and IV, they react to the market sentiment to the extent determined by the intensity of choice parameter ζ.

3.5. Validation

This final subsection presents the validation of the proposed model by comparing the simulation results to the actual data collected from Istanbul's housing market between January 2010 and September 2015. During this period, as shown in Figure 3.15, inflation adjusted real house prices increased dramatically in the city. As of the time of this writing, the price increase continues on a steady basis. APPENDIX B presents further observations about this remarkable market.

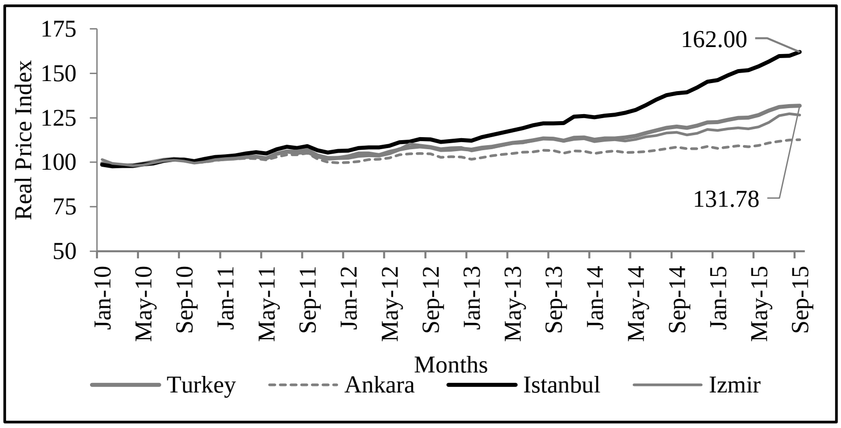

Figure 3.15 Comparison of the real house prices in Istanbul to other national markets. The index is deflated by the CPI of each market and rescaled to 2010 = 100. (Sources: "House Price Index", CBRT; "Consumer Price Indices", TURKSTAT)

The validation consists of three sets of experiments. The first set utilizes parameter values that generate unstable market behavior in the benchmark model, whereas the second set utilizes parameter values that converge to a steady state. Based on these observations, the third set of experiments specially focus on three parameters which seem to affect model substantially, namely the memory of chartist agents (n^m, n^u) and the intensity of choice parameter (ζ). For comparison purposes, the presentation includes a simple statistic known as Mean Absolute Percentage Error (MAPE), which expresses accuracy of the simulation model as a percentage error:

$$\left(\frac{1}{n}\sum_{t=1}^{n}\left|\frac{e_t}{A_t}\right|\right) * 100 \quad . \tag{3.17}$$

where A_t is the actual price, rent, or stock levels; and $e_t$is the difference between A_t and the simulated price, rent or stock level for a given period. It is important to note that the intention here is not to minimize this metric but to use it as a tool in observing the model's aggregate behavior.

Table 3.4 and Table 3.5 tabulate the first and second set of experiments. Although the two sets differ in terms of the underlying price elasticities, they exhibited similar patterns regarding the gradual introduction of behavioral parameters. In both sets, Experiment I provides the benchmark conditions with a constant discount rate, and Experiments II and III introduce the dynamic ownership costs as described in detail in APPENDIX B.II. As it is noticeable in the tables, the results were quite sensitive to the expected rates of capital gain, since a difference of 0.5% in expectations (i.e., from 10% to 10.5%) changed the MAPE for prices around 5%. Next, experiments IV, V and VI demonstrate the effects of introducing heterogeneity into the market. In both sets of experiments (i.e., with unstable elasticity parameters and stable elasticity parameters), allowing heterogeneous behavior among market participants improved the performance of the price model marginally. It is also interesting to note that the variation of the chartists' percentage from 25% to 50% and 75% did not seem to have an observable effect on the performance of the model. Furthermore, utilizing a behavior-switching regime based on epidemics did not improve the performance of the model. As experiments VII, VIII, and IX demonstrate, various combinations of recruitment and self-conversion brought about almost identical results to those obtained from the previous versions of the model.

Although the experiments summarized so far converged on a similar set of values, experiments X, XI, and particularly XII and XIII began to exhibit divergence. As Figure 3.16 shows, this was because the gradual increase in the intensity of choice parameter changed market behavior observably. Especially when the parameter took values as high as 1000, market price began to deviate from the fundamentalist price and followed a steadily increasing trend.

Table 3.4 Simulation results with unstable parameters(i.e., $\varepsilon = 0.4$, $\eta = 2$, $\delta = 0.25\%$)

Experiment ID	Description	Market Fundamentals	Behavioral Factors	MAPE (P)	MAPE (V)	MAPE (S)
I	Benchmark	r = 5%	-	31.84%	7.37%	6.53%
II	Extension I – Dynamic ownership costs	$\in\pi = 10\%$	-	35.60%	7.09%	6.38%
III	Extension I – Dynamic ownership costs	$\in\pi = 10.5\%$	-	31.98%	4.51%	5.24%
IV	Extension II – Heterogeneous Expectations	-	$\psi = 50\%$	28.55%	6.73%	6.36%
V	Extension II – Heterogeneous Expectations	-	$\psi = 25\%$	28.65%	6.75%	6.36%
VI	Extension II – Heterogeneous Expectations	-	$\psi = 75\%$	28.33%	6.68%	6.35%
VII	Extension III – Behavior Switching Regime Based on Epidemics	-	$\theta = 0.15$ $\rho = 0.7$	28.54%	6.74%	6.36%
VIII	Extension III – Behavior Switching Regime Based on Epidemics	-	$\theta = 0.01$ $\rho = 0.98$	28.58%	6.75%	6.36%
IX	Extension III – Behavior Switching Regime Based on Epidemics	-	$\theta = 0.005$ $\rho = 0.99$	28.50%	6.72%	6.35%
X	Extension III – Behavior Switching Regime Based on Fitness	-	$\zeta = 0$	28.55%	6.73%	6.36%
XI	Extension III – Behavior Switching Regime Based on Fitness	-	$\zeta = 10$	28.48%	6.72%	6.35%
XII	Extension III – Behavior Switching Regime Based on Fitness	-	$\zeta = 100$	27.29%	6.56%	6.29%
XIII	Extension III – Behavior Switching Regime Based on Fitness	-	$\zeta = 1000$	26.10%	7.19%	6.49%

Table 3.5 Simulation results with stable parameters(i.e., $\varepsilon = 1$, $\eta = 1$, $\delta = 0.25\%$)

Experiment ID	Description	Market Fundamentals	Behavioral Factors	MAPE (P)	MAPE (V)	MAPE (S)
I	Benchmark	r = 5%	-	39.03%	5.18%	6.15%
II	Extension I – Dynamic ownership costs	∈π = 10%	-	41.72%	5.16%	6.10%
III	Extension I – Dynamic ownership costs	∈π = 10.5%	-	36.75%	5.73%	5.48%
IV	Extension II – Heterogeneous Expectations	-	ψ = 50%	35.87%	5.32%	6.08%
V	Extension II – Heterogeneous Expectations	-	ψ = 25%	35.95%	5.31%	6.08%
VI	Extension II – Heterogeneous Expectations	-	ψ = 75%	35.67%	5.32%	6.08%
VII	Extension III – Behavior Switching Regime Based on Epidemics	-	θ = 0.15 ρ= 0.7	35.86%	5.32%	6.08%
VIII	Extension III – Behavior Switching Regime Based on Epidemics	-	θ = 0.01 ρ= 0.98	35.91%	5.31%	6.08%
IX	Extension III – Behavior Switching Regime Based on Epidemics	-	θ = 0.005 ρ= 0.99	35.83%	5.32%	6.08%
X	Extension III – Behavior Switching Regime Based on Fitness	-	ζ = 0	35.87%	5.32%	6.08%
XI	Extension III – Behavior Switching Regime Based on Fitness	-	ζ = 10	35.81%	5.32%	6.08%
XII	Extension III – Behavior Switching Regime Based on Fitness	-	ζ = 100	34.85%	5.34%	6.06%
XIII	Extension III – Behavior Switching Regime Based on Fitness	-	ζ = 1000	32.55%	5.44%	6.04%

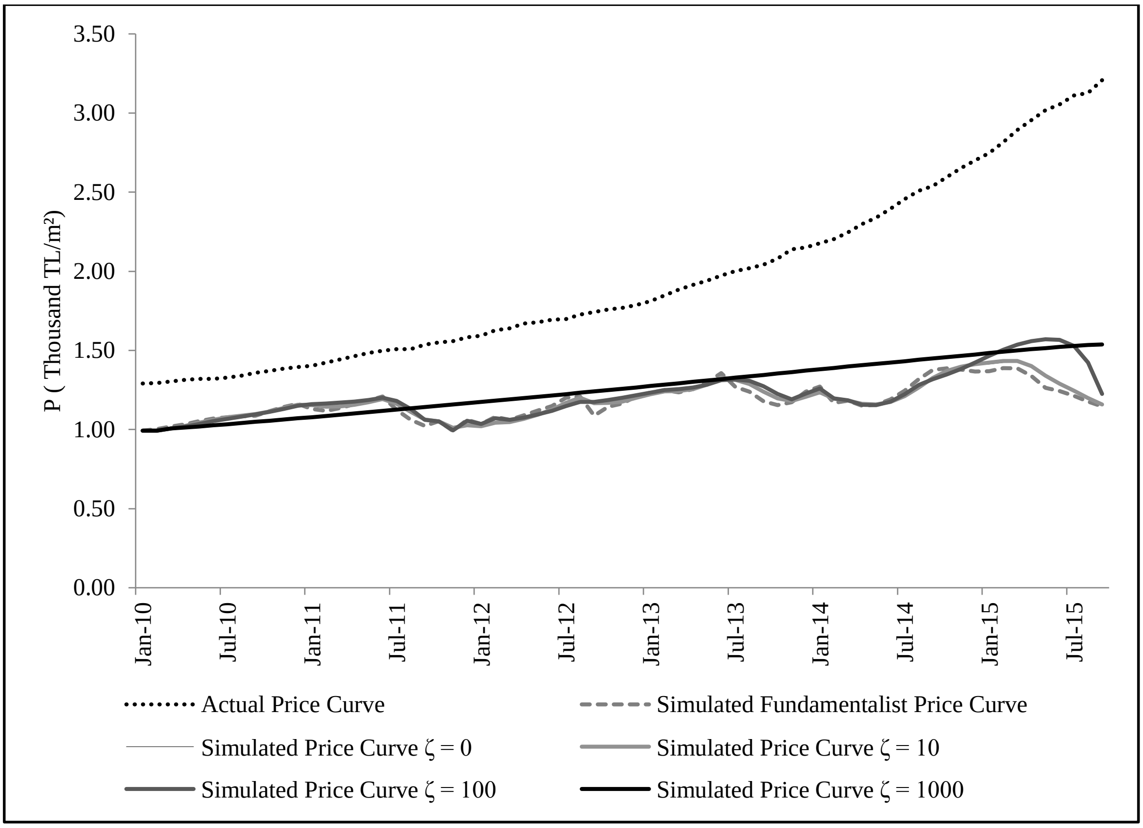

Figure 3.16 The effects of the intensity of the choice parameter on price dynamics. The figure depicts experiments X, XI, XII and XIII tabulated Table 3.5 with parameter values ε = 1, η = 1 and δ = 0.25%.

In order to understand this trend formation, it is instructive to see how the percentage of chartists changes with respect to ζ. As the following figure depicts, increasing this parameter from 100 to 1000 allowed chartists tendencies to take over the market entirely. As a result, the market disconnected from the underlying fundamentals and prices increased on a steady basis.

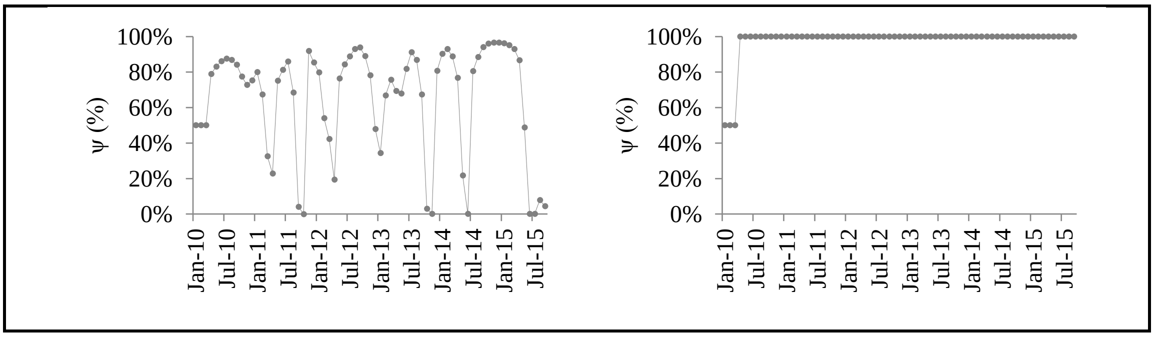

Figure 3.17 The effects of the intensity of the choice parameter on heterogeneity. (Left figure ζ = 100, right figure ζ = 1000)

Further analysis of the model revealed that the market trend is highly sensitive to the time frame that participants use in extrapolating future prices (n^m) as well as the time frame they use (n^u) in comparing the competing strategies. Precisely stated, as the memory of the market participants got shorter, the price trend became steeper; and the model's MAPE improved drastically as Table 3.6 below shows.

Table 3.6 Simulation with changes in months used in backward-looking behavior (i.e., $\varepsilon = 1$, $\eta = 1$, $\delta = 0.25\%$, $\zeta = 1000$)

Experiment ID	$n^m = n^u$ (Months)	MAPE (P)	MAPE (V)	MAPE (S)
I	24	32.91%	5.41%	6.05%
II	12	32.87%	5.42%	6.05%
III	6	32.55%	5.44%	6.04%
IV	3	31.14%	5.51%	5.99%
V	2	28.69%	5.62%	5.91%
VI	1	17.95%	6.10%	5.58%

Figure 3.18 conveys the same information visually. As investor myopia increased (i.e., as the number of months used in extrapolation and strategizing decrease), simulated prices deviated from the fundamentals and began to mimic the actual trend.

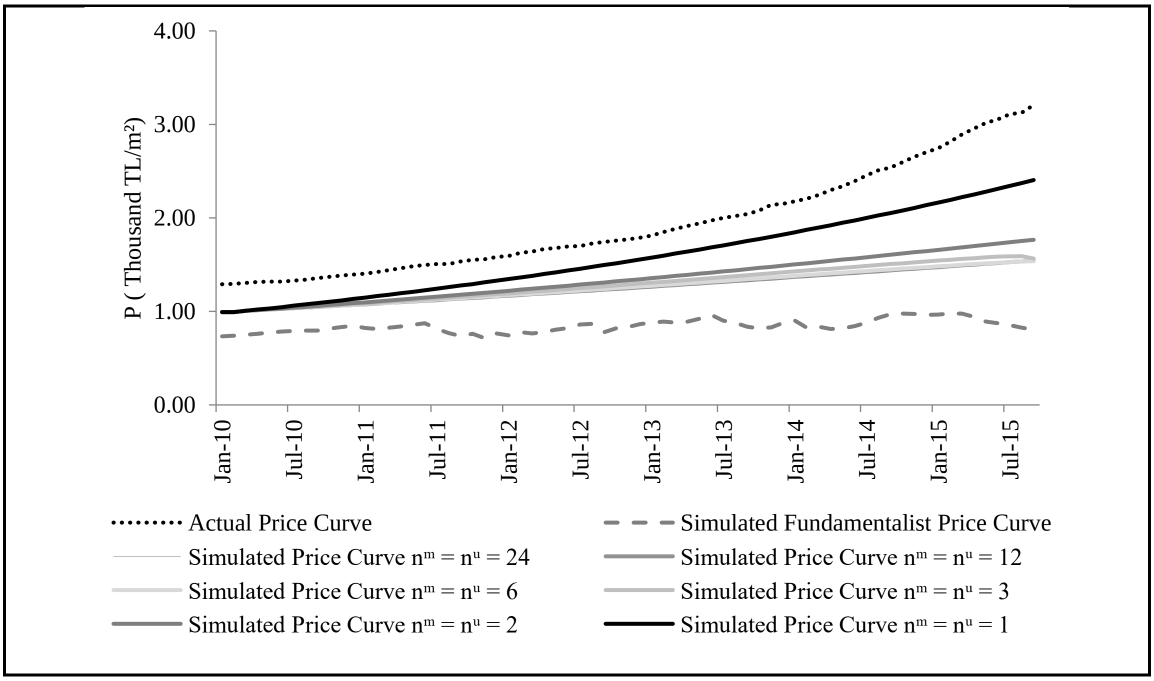

Figure 3.18 The effects of the market participants' memory on price formation

CHAPTER 4

CONCLUSIONS

This dissertation has sought to contribute to the body of knowledge on the pricing of the built environment on two principal counts. First, by drawing from a contemporary debate in the asset pricing literature, it extended a prominent real estate model (Wheaton, 1999). Second, by bringing the recent developments in the price dynamics of global housing markets to the attention of researchers within the architecture, construction, and engineering domain, it paved the way for a multi-disciplinary effort to study this important phenomenon.

Recent history taught us that booms and busts in house prices can have disastrous consequences for individuals, firms, industries, nationwide economies, and for the global economy. As this dissertation laid out in its theoretical framework, there are no hard and fast rules that explain what determines house prices and how we can read price changes over time. In contemporary capitalist economies, housing does not only provide the utility of shelter for households, but also functions as a commodity produced for exchange in the markets and as an asset for storing and enhancing wealth. The theories that intend to explain the price of this complex economic entity conflict with each other, demonstrating the diversity of the methodological, epistemological, and ideological commitments of the theorists involved in the effort.

Given the vast range of competing views, this dissertation presented a theoretical framework that rests on a recent debate that has been developing over the last four decades. On the two sides of this debate are neoclassical economists and behavioral economists who have different takes on the determinants of house prices as well as on the interpretation of price changes. The former perspective maintains that housing markets are efficient mechanisms in which participants make rational pricing decisions by utilizing all available information on fundamentals. Accordingly, the perspective argues that prices reflect the fundamental value of the housing units, i.e., there is no long-term mispricing. On the other hand, the behavioral perspective raises questions about the efficiency of housing markets as well as the rationality of their participants, and argues that house prices may deviate from their fundamental values.

In agreement with a growing body of literature, this dissertation echoed the view that incorporating insights from behavioral economics can enhance the exploration of price formations in housing markets. The support this statement, it extended Wheaton's model (1999) and experimented with behavioral heterogeneity among market participants. Specifically, it sought to answer the following two interrelated questions: To what extent does the inclusion of (1) behavioral heterogeneity and (2) dynamic market behavior enhance the benchmark model? For this purpose, the dissertation used empirical data obtained from Istanbul's housing market between January 2010 and September 2015.

4.1. Key Findings

(1) A model based on market fundamentals (i.e., price elasticity of rental demand, population growth, discount rate, supply lags, price elasticity of supply, and depreciation rate) did not generate the observed price pattern in the empirical context of the study. Moreover, extending the model to include dynamic ownership costs based on changes in interest rates did not improve the model's performance.

(2) On the other hand, extending the model to allow heterogeneous expectations brought about some improvement. However, this was a modest quantitative improvement only as the model still failed to display the recent upward trend observed in the market.

(3) Similarly, extending the model with behavior-switching regime based on an epidemiological approach provided a minor improvement only.

(4) In contrast to the previous three findings, extending the model with a behavior-switching regime based on the fitness of competing market strategies mimicked the observed behavior. The performance of such a model was quite sensitive to the length of the past observations that market participants consider in making pricing decisions.

4.2. Theoretical Implications

The first finding above adds weight to the arguments that house prices may deviate from market fundamentals (Mankiw and Weil, 1989; Case and Shiller, 1989; Poterba, 1991) and that such deviations may be long term (Shiller, 2005; Ambrose, et al., 2013; Shiller, 2014). However, this finding does not imply that we can reject the role of market fundamentals in price determination since the proposed model relies on the changes in fundamentals to provide the initial momentum for the subsequent price dynamics. As such, the finding supports the view that neoclassical and behavioral approaches are not mutually exclusive, but are rather complementary (Shefrin, 2008, p. xix; Watkins and McMaster, 2011).

The second finding that market models with heterogeneity compares favorably to models with a singular representative agent supports studies that call for an agent based approach in exploring house price dynamics (e.g., Geanakoplos, et al., 2012). However, it is important to note that the potential of heterogeneous models lies in allowing market participants to interact with each other and the market. In other words, heterogeneity in and of itself does not seem to make a substantial difference unless the agents can update or switch their behavior dynamically.

With that said, it is important to note that the two behavior-switching regimes used in the proposed model yielded quite different results. The lack of success of the epidemiological regime supports Shiller's (2005, pp. 165-166) view that basic parameters of these types of models are not "constant in the social sciences as in biological applications" and the "rate of transmission errors" is much higher in a contagion of ideas than for disease or other natural processes.

On the other hand, the behavior-switching regime based on past performances of competing market strategies did improve the results significantly. First, this supports the arguments of researchers who highlight the possibility that housing market participants may extrapolate recent price trends while maintaining the individual rationality assumptions (e.g., Poterba, 1991; Abraham and Hendershott, 1994; Quigley, 1999; Wheaton, 1999; Malpezzi and Wachter, 2005). More importantly, it reinforces the argument proposed in a recent group of studies that housing market participants switch their expectations between fundamental and momentum strategies when making pricing decisions (e.g., Dieci and Westerhoff, 2012; Bolt, et al., 2013; Eichholtz, et al., 2015).

Finally, the results seem to support the view that "investor myopia" plays an important role in the observed house price dynamics, implying that market participants calculate prices "over limited time and space horizons" (Smith, 2011) rather than considering the full set of information at their disposal.

4.3. Policy Implications

If the factors that influence house prices go beyond the rational demand for and supply of housing to include social and psychological phenomena, then this calls for action on the part of policy makers, researchers and members of civic and professional organizations.

First, there should be an ongoing and organized effort to monitor housing markets. Such an organization could be similar to institutions that continuously develop earthquake early warning systems and issue public warnings when needed. Given the disastrous results that societies have suffered from the recent turmoil in housing markets, such an analogy is not far-stretched. As the preceding chapters demonstrate, the presence of price anomalies in competitive markets is a controversial topic on its own, let alone the difficulty of detecting such a price formation with certainty. Nevertheless, such an organization can offer the public the alternative opinions on the matter while maintaining impartiality. For that to be possible, the organization should be autonomous, i.e., be immune from the potential pressures of political and economic entities that seek to use the housing market as an economic apparatus to meet their own objectives. Such an organized effort would offer "stabilizing opinions" when markets begin exhibiting signs of an irrational exuberance or when a wave of pessimism takes over the market sentiment. In either case, the focus would be disclosing the *en masse* deviations from the market's fundamental value. In a free society, there will always be speculative behavior despite the disclosed risks, but that does not have to spread across the entire market.

Second, there should be legally specified limits that govern the production and dissemination of knowledge claims made by housing market "experts". Given the complexity of housing markets, people often turn to "perceived wisdom of experts" and accept their opinions at face value (Shiller, 2005, p. 228). However, these opinions may be simply false. Alternatively, even when an expert makes a factually true knowledge claim, that claim may not be sincere or "socially right" as the underlying intention may be to steer the market behavior strategically. This is not simply a problem of ethics or professional standards, but a problem of liability that needs a legal framework.

4.4. Recommendations for Future Research

This dissertation can pave the way for future studies in a variety of ways depending on the interests and the background of researchers. Real estate economists with strong mathematical backgrounds can focus on the proposed model's stability analysis and dynamics by utilizing state of the art tools such as bifurcation diagrams and phase plots. Similarly, researches interested in the micro foundations of economic modelling can introduce further heterogeneity to the model and experiment with a variety of techniques ranging from game-theoretical approaches to the evolutionary selection of expectation rules. Another direction would be to extend the research by focusing on some of the parameters that currently lack empirical basis. These especially include the price elasticity of rental demand, elasticity of supply, and stock depreciation rate, which influence the model's behavior significantly. Construction management and economics researchers can utilize the theoretical framework proposed in this dissertation to tackle other problems from a behavioral perspective. Alternatively, they can provide input from construction firms' perspective in order to enhance the supply side of the model.

4.5. Closing Remarks

With their limited understanding of the inner workings of housing markets, individuals tend to use their instincts or follow others in making pricing decisions. These decisions can be simply wrong. Housing markets are not omnipotent mechanisms that can automatically correct miscalculations. On the contrary, they are quite vulnerable in the presence of speculative forces. All social entities ranging from global coalitions, states, industries, communities, households, and individuals have a part in exacerbating speculation in housing markets. Even when individuals are not in a position to change all of these, they can still act by questioning their own behavior. This modest effort may not only bring about changes in aggregate house prices, but may also trigger structural changes in the social environment.

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APPENDIX A

DETAILS OF MODEL IMPLEMENTATION

The simulation proposed in this study implements The Microsoft Office Excel© Visual Basic for Applications (VBA) object model using a computational design pattern known as Model-View-Controller (MVC). Following this pattern, the “Model” module encapsulates the underlying logic of the simulation; the “View” module handles user interface and charting functions; and the “Control” module coordinates the program flow. As shown in Figure A.1, the model module primarily consists of a singleton object that encapsulates simulation parameters and several markets. As part of the view module, each of the markets has a corresponding dashboard used in “stepping through” the evolution of price and stock formation during the simulation runs.

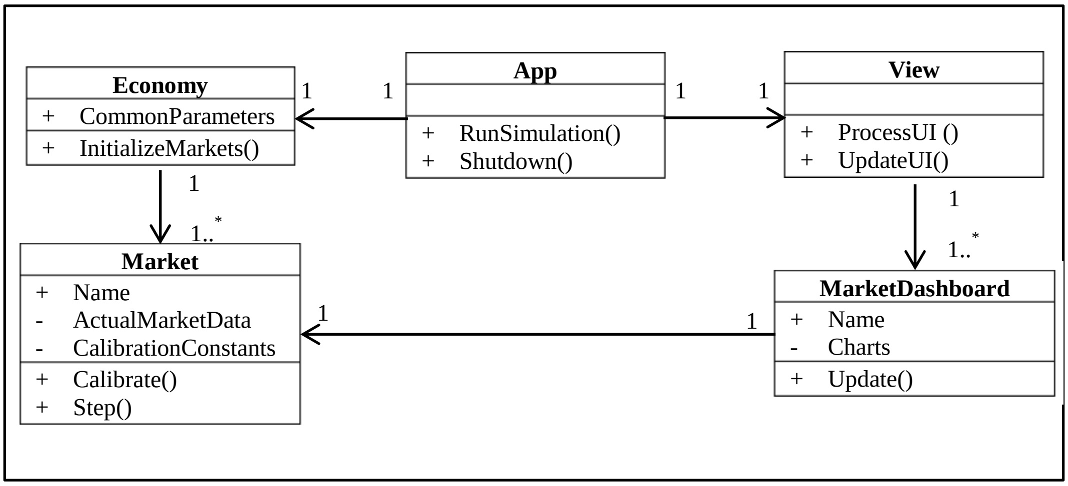

Figure A.1 Class relationships in the simulationshown in a class diagram in UML

The view module contains user interface dialogs, which facilitate model initialization and monitoring.

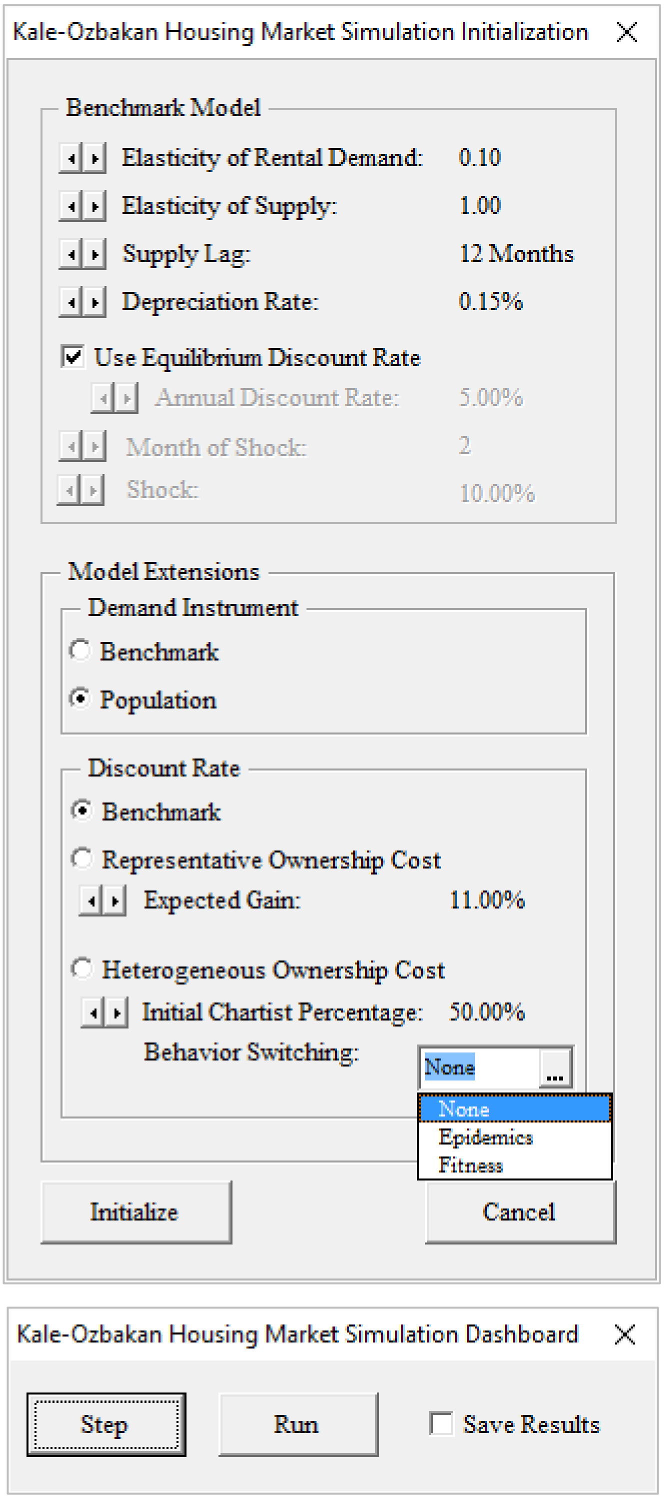

Figure A.2 The user interface dialogs of the simulation used in initialization (top figure) and monitoring (bottom figure)

Users of this interface can observe the evolution of market phenomena in a stepwise fashion with the dashboard shown below.

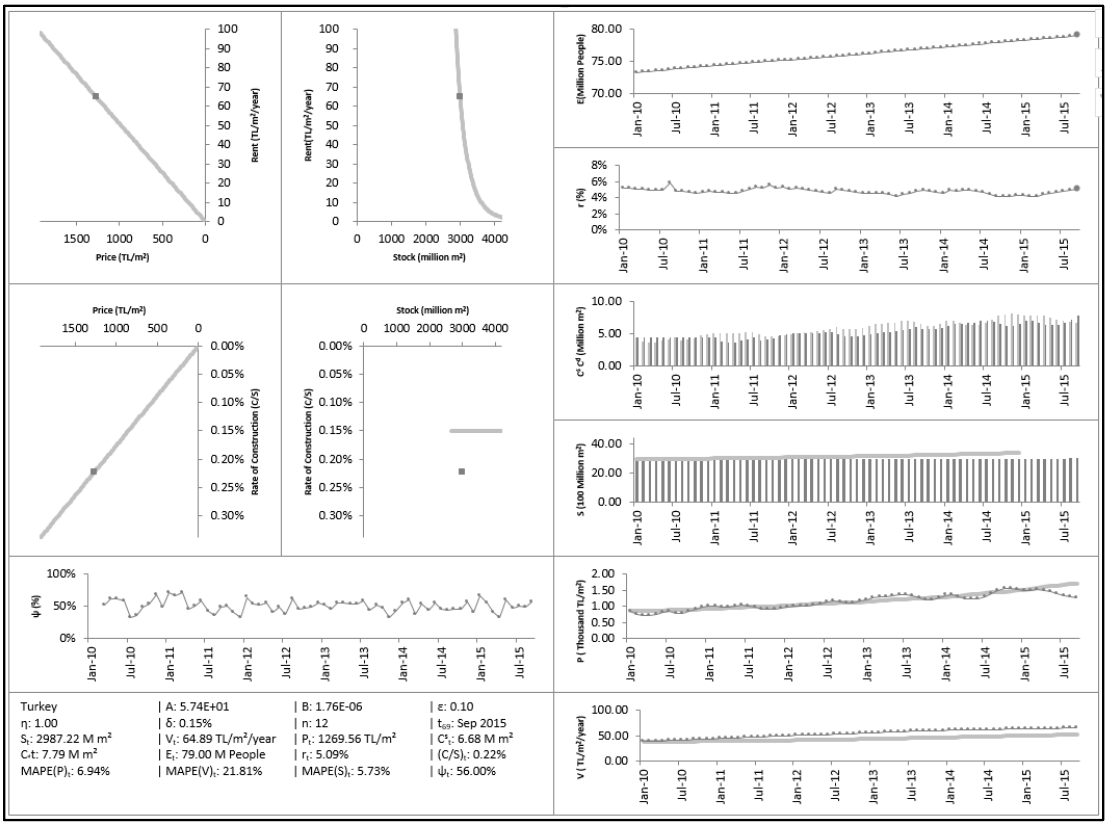

Figure A.3 The simulation dashboard showing the four quadrants of the benchmark model and time series charts of population, discount rates, started and delivered flow, stock, price, rents and percentage of chartist agents.

APPENDIX B

OBSERVATIONS AND DATA

B.I. Istanbul's Housing Market

While prices kept increasing in Istanbul's housing market between 2010 and 2015, no other financial instrument in the country followed a similar trend. As shown in Figure B.1, while housing provided annual real gains as high as 18.42%, returns from deposit accounts barely covered the inflation rate, whereas investments in the stock market (BIST), USD, and gold experienced severe fluctuations.

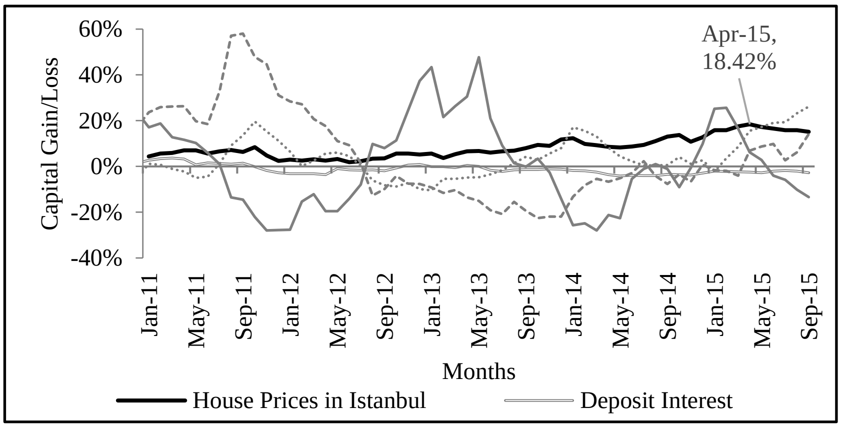

Figure B.1 Comparison of real annual capital gains/losses in various instruments. The nominal new house price index is deflated by the CPI of Istanbul to estimate real price changes shown in bold. (Sources: "The New House Price Index", CBRT; "The Consumer Price Indices" and "The Rates of Profits Created by Means of Financial Investment", TURKSTAT)

As Figure B.2 depicts, supply and demand side pressures offer some insight to the observed price increases in Istanbul. As the comparison of changes in population and building stock during the 2010-16 period reveals, Istanbul falls behind other markets in terms of construction activity. In Ankara for instance, a population increase of 11.93% accompanied a stock growth of 24.58%, while in Istanbul a similar population increase of 11.73% matched a stock increase of only 12.54%. Put in a broader context, the ratio of stock change (14.83%) to population change (7.87%) in the country was around 2; while in Istanbul this ratio was merely half as much.

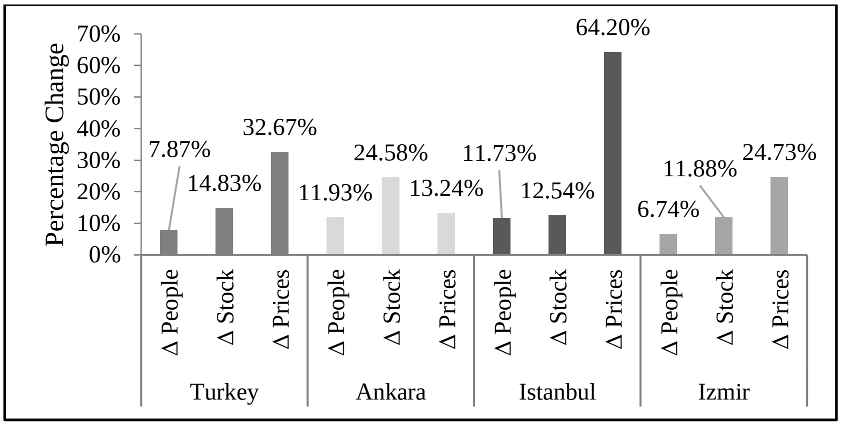

Figure B.2 Comparison real house price index in Istanbul to population growth. (Sources: "The New House Price Index", CBRT; "The Consumer Price Indices", "Address Based Population Registration System, ABPRS, 2007-2014", "Building Permits Statistics" and "Building Census 2000", TURKSTAT)

This observation, however, does not necessarily address why prices began to surge after 2010, and in particular after 2012, since similar demand and supply pressures arguably existed prior to the period. Furthermore, important questions remain about the relationship between market fundamentals and housing prices in Istanbul. For example, as shown in Figure B.3, inflation adjusted construction costs have remained relatively stable since the prices in Istanbul took off in early 2012.

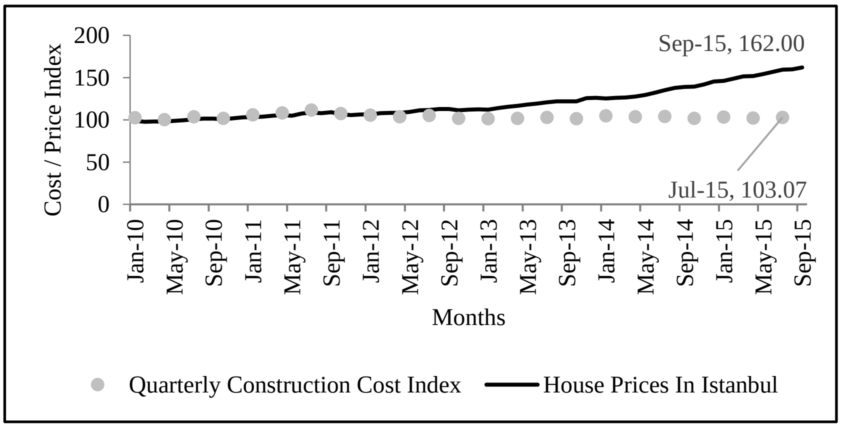

Figure B.3 Comparison real house price index in Istanbul to construction costs. Both indices are rescaled to 2010 = 100. (Sources: "The New House Price Index", CBRT; "The Consumer Price Indices" and "Building Construction Cost Index 2005-2015", TURKSTAT)

Moreover, as shown in Figure B.4 the real household income in Istanbul actually *declined* while the prices kept increasing in real terms.

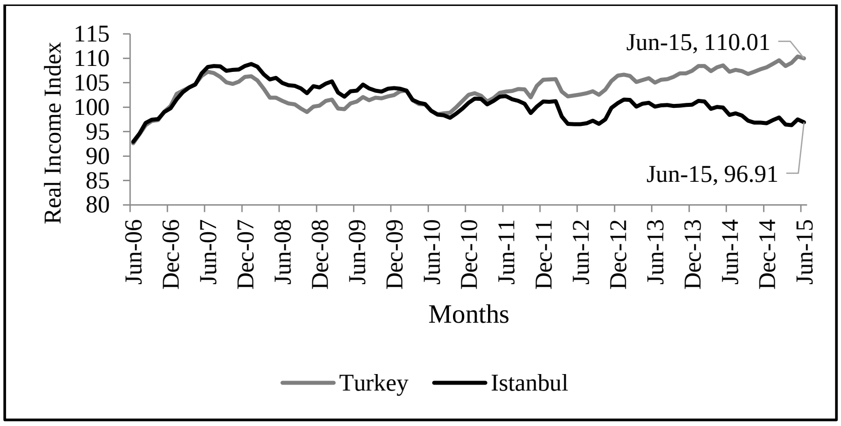

Figure B.4 Comparison real house price index in Istanbul to real income. Both indices are rescaled to 2006 = 100. (Sources: “The New House Price Index”, CBRT; “The Consumer Price Indices”, “Income and Living Conditions Survey, 2006-2014”, TURKSTAT)

Finally, the peculiar change in the price-to-rent ratio in the observed period, adds weight to the argument that housing prices in Istanbul do not follow the changes in market fundamentals alone. As the following figure shows, in January 2010, the ratio was nearly the same in Istanbul and in the rest of the country, at 25.03 and 22.33 respectively. The ratio grew at a faster rate in Istanbul and reached 45.40, far surpassing the country average of 32.48.

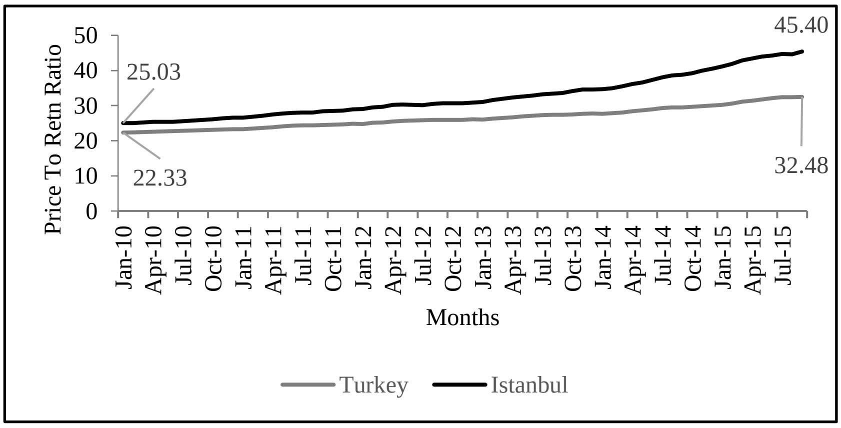

Figure B.5 Comparison of price-to-rent ratio Istanbul to country average. Rent index is constructed by using the monthly household expenditure on rents. The expenditure is converted to TL/m²/year based on assumption of average housing unit to be 150 m². Both indices are rescaled to 2010 = 100. (Sources: “The New House Price Index”, CBRT; “The Consumer Price Indices”, “Consumer Price Index Item: 0410001”, TURKSTAT)

B.II. Ownership Cost Data and Assumptions

As formulated in Equation (3.6), the proposed model uses an estimation of the ownership costs in Turkey based on the amount of foregone interest rate ($r^{rf}{}_{t}$), mortgage rate ($r^{m}{}_{t}$), required capital for mortgage credit (μ), annual maintenance rate (ω), annual price depreciation rate (δ^{p}) and risk premium rate (γ). Table B.1 tabulates the assumed constants and Figure B.6 charts the trends in interest rates.

Table B.1 Assumed constants used in the estimation of ownership costs

Parameter	**Symbol**	**Value**
Required capital for mortgage credit	μ	25%
Annual maintenance cost rate	ω	0.10%
Annual price depreciation rate	δ^{p}	2.50%
Risk premium rate	γ	2.00%

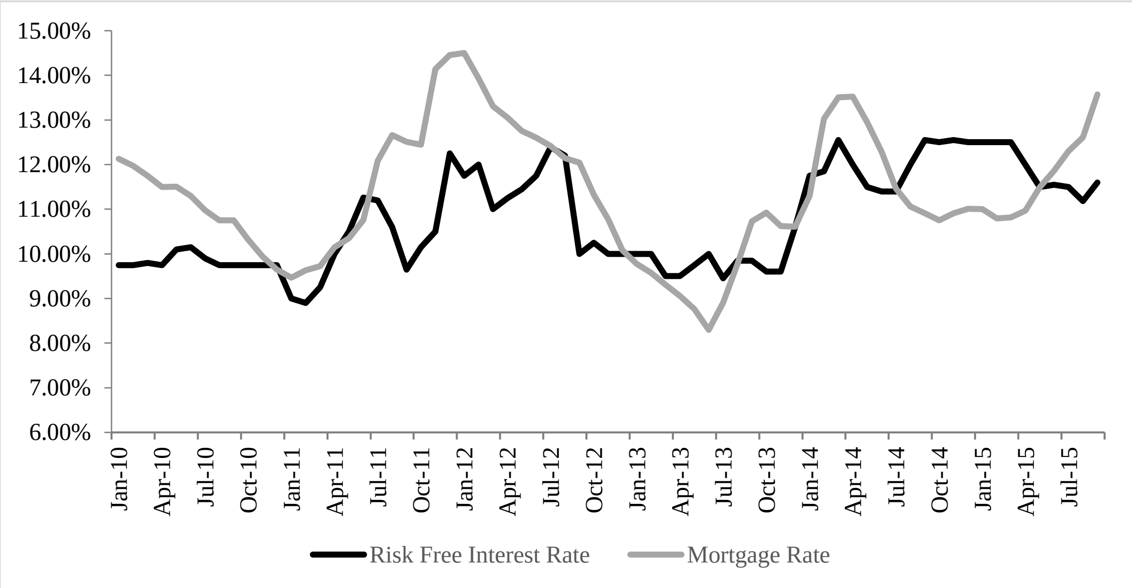

Figure B.6 Dynamic variables used in the estimation of ownership costs. (Sources: “Deposit interest rate”, TURKSTAT; “Mortgage interest rates”, TURKSTAT)

VITA

Ahmet Tolga Özbakan was born in 1972. Upon completion of his undergraduate studies in architecture with cum laude in the Middle East Technical University in 1995, he received a scholarship from Georgia Institute of Technology for his graduate studies. During these studies, he fulfilled the degree requirements of Master of Science in Civil Engineering in 1998 and completed all of the graduate level course work in the Faculty of Economics. In both faculties, he took various research and teaching assistantship responsibilities. In the years that followed, he professionally participated in and managed various large-scale IT and construction projects in the US, Turkey and India.

In 2010, Tolga joined the Department of Architecture as a lecturer at the University of Economics in İzmir, Turkey. That year, he also commenced his PhD level research work at the İzmir Institute of Technology under Prof. Serdar Kale's supervision. In 2013, he joined the Department of Architecture of Yaşar University in İzmir, where he presently teaches courses in construction technology and in construction management. He co-authored several national and international conference proceedings with a focus on pricing decisions in the built environment.