

A SIMULATION-BASED ANALYSIS OF PRICE DYNAMICS IN A
REAL ESTATE MARKET INSPIRED FROM TURKEY

by

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ABSTRACT

A SIMULATION-BASED ANALYSIS OF PRICE DYNAMICS IN A REAL ESTATE MARKET INSPIRED FROM TURKEY

The real estate market in Turkey holds significant importance for the nation's economy and development. It serves as an important engine of economic growth, attracting both domestic and foreign investments through the years. Housing prices are an important concern for the government, homeowners, policymakers, and financial institutions. Numerous studies have been conducted regarding housing prices in literature. The primary objective of this study is to construct a system dynamics model based on Turkey's characteristics to mimic the basic structures of the Turkish real estate market and understand the reasons behind the cycles in sales and price through years. The developed model is tailored to reflect Turkey, using data related to the Turkish population, sales statistics, and price statistics for the initialization. System dynamics approach is utilized to simulate because it effectively represents the complex interactions and feedback loops inherent within the market. The created system dynamics model captures the long-term dynamics until the year 2050 partially and simulates how the market could evolve under various scenarios. Compared to the studies in relevant area, in this study, secondhand house market, actions of investors and the change of rental price are included to survey the market from various aspects. From 2010 to 2024, the developed model partially captures the real dynamics of Turkish housing market, however there are some external factors related to Turkey which cannot be included to the model. According to the findings, there are cycles caused by the imbalance of demand and supply in the market. Until 2050, rental prices of houses have increased exponentially, which has been reviewed and tried to be solved by the scenario and policies. Reducing interest rate to 20 % is found to be enough to prevent rental price increase through years. Moreover, by introducing around 200 000 more projects each year regularly, the average rental price of a house can be reduced by almost 60% in 2050.

ÖZET

TÜRKİYE'DEN İLHAM ALAN BİR GAYRİMENKUL PİYASASINDAKİ FİYAT DİNAMİKLERİNİN SİMÜLASYON TABANLI ANALİZİ

Türkiye'deki gayrimenkul piyasası, ülkenin ekonomisi ve gelişimi için bir öneme sahiptir. Gayrimenkul piyasası yıllar boyunca hem yerli hem de yabancı yatırımları çekerek ekonomik büyümenin önemli bir kaynağı olarak hizmet eder. Konut fiyatları; hükümet, ev sahipleri, politikacılar ve finans kuruluşları için önemli bir konudur. Literatürde konut fiyatlarıyla ilgili çok sayıda çalışma yapılmıştır. Bu çalışmanın temel amacı, Türkiye'nin özelliklerine dayalı bir sistem dinamikleri modeli oluşturarak Türk gayrimenkul piyasasının temel yapılarını taklit etmek ve yıllar boyunca satış ve fiyat döngülerinin arkasındaki nedenleri anlamaktır. Geliştirilen model, model başlangıcı için Türk nüfusu, satış istatistikleri ve fiyat istatistikleriyle ilgili verileri kullanarak Türkiye'yi yansıtacak şekilde uyarlanmıştır. Çalışmada, piyasada bulunan karmaşık etkileşimleri ve geri bildirim döngülerini etkili bir şekilde gösterdiği için Sistem Dinamikleri yaklaşımı kullanılır. Oluşturulan sistem dinamikleri modeli, 2050 yılına kadar olan uzun vadeli dinamikleri kısmen yakalar ve piyasanın çeşitli senaryolar altında nasıl gelişebileceğinin simülasyonunu yapar. İlgili alandaki çalışmalarla karşılaştırıldığında, bu çalışmada ikinci el konut piyasası, yatırımcıların eylemleri ve kira fiyatındaki değişim dahil edilerek piyasa çeşitli açılardan incelenmiştir. Geliştirilen model 2010-2024 yılları arasında Türkiye konut piyasasının gerçek dinamiklerini kısmen yakalamış olsa da modele dahil edilemeyen Türkiye ile ilgili bazı dış faktörler bulunmaktadır. Bulgulara göre piyasadaki talep ve arz dengesizliğinden kaynaklanan döngüler bulunmaktadır. 2050 yılına kadar ev kira fiyatları üstel olarak artmakta olup bu durum senaryo ve politikalar ile incelenerek çözülmeye çalışılmıştır. Faiz oranının %20'ye düşürülmesinin yıllar içinde kira fiyatı artışını önlemek için yeterli olduğu görülmüştür.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	iii
ABSTRACT	iv
ÖZET	v
LIST OF FIGURES.....	viii
LIST OF TABLES	xvii
1. INTRODUCTION	1
2. PROBLEM DESCRIPTION	3
3. RESEARCH OBJECTIVES	12
4. RESEARCH METHODOLOGY	14
5. MODEL DESCRIPTION	17
5.1. Overview of the Model	17
5.2. Causal Loop Diagram of the Model.....	26
5.3. Stock-Flow Diagram of the Sectors	36
5.3.1. Housing Supply Sector.....	36
5.3.2. Housing Demand Sector	51
5.3.3. Housing Price Sector.....	59
6. VALIDATION OF THE MODEL	69
6.1. Structural Validity	69
6.1.1. Test 1: No Sales Demand.....	70
6.1.2. Test 2: Extremely High Sales Price	80
6.2. Sensitivity Analysis.....	82
6.3. Behavioral Validity	86
7. THE BASE BEHAVIOR.....	95
7.1. 2024-2030 Behavior.....	95
7.2. 2030-2050 Behavior.....	107
8. SCENARIO AND POLICY ANALYSIS	111
8.1. Scenario Analysis.....	111

8.1.1. Decreased CBRT Interest Rate	111
8.2. Policy Analysis	123
8.2.1. First Home Campaign	123
8.2.2. Project Real Estate Fund	131
9. RESULTS AND CONCLUSIONS	135
REFERENCES.....	138
APPENDIX A: MODEL EQUATIONS	145



LIST OF FIGURES

Figure 2.1. House Prices in Turkey from 2010 to 2023 (TL/m ²) [23].	8
Figure 2.2. Nominal House Prices in Turkey from 2010 to 2023 (\$/m ²) [23].	8
Figure 4.1. Bathtub Stock-Flow Model [30].	15
Figure 5.1. Simplified stock-flow diagram of Turkish real estate market.	18
Figure 5.2. Causal Loop Diagram and Main Loops.	26
Figure 5.3. Sales Supply-New Houses Stock Loop.	27
Figure 5.4. Supply Shortage -Total Sales Demand Loop.	28
Figure 5.5. Sales Supply -Secondhand Houses Stock Loop.	29
Figure 5.6. Sales Price -Essential Housing Demand and Sales Price -Investment Oriented Housing Demand Loop	30
Figure 5.7. Rental Price -Total Demand for Rent Loop.	31
Figure 5.8. Average Rental Price -Rental Supply Loop by New Investment Demand.	32
Figure 5.9. Average Rental Price – Rental Supply Loop by New Vacant Houses.	33
Figure 5.10. Supply Shortage-Essential Housing Demand Loop.	34
Figure 5.11. Average Sales Price-Total Demand for Sale Loop.	35

Figure 5.12. Stock-flow diagram of housing supply.....	37
Figure 5.13. Effect of new vacant houses/project start rate by shortage.	38
Figure 5.14. Effect of supply shortage on project start rate.....	39
Figure 5.15. Demand creation within the model.	41
Figure 5.16. Sales Effect 1.....	43
Figure 5.17. Sales Effect 2.....	43
Figure 5.18. Points on sales effect graphs.	44
Figure 5.19. Effect of rent multiplier on owned house putting on sale fraction.....	46
Figure 5.20. Effect of rent multiplier on rented house putting on sale fraction.	47
Figure 5.21. Stocks for rental market.	48
Figure 5.22. Effect of rental demand on new renting.....	50
Figure 5.23. Stock flow diagram of housing demand.....	51
Figure 5.24. Effect of sales price on essential housing demand.....	53
Figure 5.25. Effect of rent multiplier on essential housing demand.....	53
Figure 5.26. Effect of Sales Price on Investment Oriented Demand.....	55
Figure 5.27. Effect of Rent Multiplier on Investment Oriented Demand.....	56

Figure 5.28. CBRT Interest Rates from 2010 to 2024 (%).....	57
Figure 5.29. Effect of CBRT Interest Rates on Investment-oriented Demand.....	58
Figure 5.30. Stock flow diagram of housing price sector.....	60
Figure 5.31. Effect of Demand-Supply Imbalance on Sales Price.....	61
Figure 5.32. Change of average sales price.....	62
Figure 5.33. Effect of Demand-Supply Imbalance on Rental Price.....	64
Figure 5.34. Change of average rental price.....	65
Figure 5.35. Rent multiplier.....	66
Figure 6.1. Normal essential demand ratio for test 1.....	71
Figure 6.2. Normal investment-oriented demand for test 1.....	71
Figure 6.3. Essential housing demand for test 1.....	72
Figure 6.4. Perceived investment-oriented housing demand for test 1.....	72
Figure 6.5. Investment-oriented housing demand for test 1.....	73
Figure 6.6. New investment oriented demand for test 1.....	73
Figure 6.7. Total demand for sale and total supply for sale for test 1.....	74
Figure 6.8. Supply shortage for test 1.....	74

Figure 6.9. Construction finish rate for test 1.....	75
Figure 6.10. Total new (a) and second (b) sales for test 1.....	75
Figure 6.11. New vacant houses (a) and houses on secondhand market (b) for test 1.....	76
Figure 6.12. Sales supply to sales demand ratio for test 1.....	76
Figure 6.13. Average sales price for test 1.....	77
Figure 6.14. Total occupied houses for test 1.....	77
Figure 6.15. Occupied house stocks for test 1.....	78
Figure 6.16. Rental demand and supply for test 1.....	79
Figure 6.17. Perceived average rental price for test 1.....	79
Figure 6.18. Nominal house prices in Turkey from 2010 to 2023 (\$/m ²).....	80
Figure 6.19. Essential housing demand for test 2.....	81
Figure 6.20. Perceived investment-oriented housing demand for test 2.....	81
Figure 6.21. Total sales for test 2.....	81
Figure 6.22. Gross Rent Multiplier for test 2.....	82
Figure 6.23. Average Sales Price in sensitivity test-1.....	83
Figure 6.24. Perceived Average Rental Price in sensitivity test-1.....	84

Figure 6.25. Average Sales Price in sensitivity test-2.....	85
Figure 6.26. Perceived Average Rental Price in sensitivity test-2.....	85
Figure 6.27. Nominal House Prices in Turkey from 2010 to 2023 (\$/m ²) [23]	86
Figure 6.28. Average sales price between 2010 and 2023.....	87
Figure 6.29. Total sales between 2010 and 2024.....	88
Figure 6.30. Total new sales between 2014 and 2023.....	88
Figure 6.31. Total second sales between 2014 and 2023.....	89
Figure 6.32. Demands between 2010 and 2024.....	90
Figure 6.33. Sales supply between 2010 and 2024.....	90
Figure 6.34. Construction finish rate and new sales between 2010 and 2024.....	91
Figure 6.35. Project start between 2010 and 2024.....	91
Figure 6.36. Construction finish rate between 2010 and 2024.....	92
Figure 6.37. Owner Occupied Houses between 2010 and 2024.....	93
Figure 6.38. Total Occupied Houses between 2010 and 2024.....	94
Figure 7.1. Supply shortage for the base run.....	96
Figure 7.2. Sales supply and sales demand for the base run.....	96

Figure 7.3. Project start rate for the base run.....	97
Figure 7.4. New constructions for the base run.	97
Figure 7.5. Sales supply for the base run.....	98
Figure 7.6. Essential and perceived investment-oriented housing demand for the base run....	99
Figure 7.7. Average sales price for the base run.	100
Figure 7.8 Perceived average rental price for the base run.	100
Figure 7.9 Perceived gross rent multiplier for the base run.	101
Figure 7.10 Sales supply to sales demand ratio for the base run.	101
Figure 7.11. Construction in progress for the base run.....	102
Figure 7.12. New vacant houses for the base run.....	102
Figure 7.13. Change of houses on secondhand market for the base run.	103
Figure 7.14. Houses available for rent for the base run.....	104
Figure 7.15. Rental supply and demand for the base run.	104
Figure 7.16. Total new and second sales for the base run.	105
Figure 7.17. House owning rate for the base run.....	105
Figure 7.18. New and secondhand essential sales for the base run.	106

Figure 7.19. B1 causal loop diagram.	108
Figure 7.20. B5 causal loop diagram.	110
Figure 8.1. Change of CBRT Interest Rate.	112
Figure 8.2. Perceived Investment Oriented Housing Demand for Scenario 1.	112
Figure 8.3. Essential Housing Demand for Scenario 1.	113
Figure 8.4. Total Demand for Sale for Scenario 1.	114
Figure 8.5. Supply Shortage/Initial Supply Shortage for Scenario 1.	114
Figure 8.6. Effect of Supply Shortage on Project Start Rate.	115
Figure 8.7. Project Start Rate for Scenario 1.	115
Figure 8.8. New Vacant Houses for Scenario 1.	116
Figure 8.9. New Investment Sales for Scenario 1.	116
Figure 8.10. New Investment Demand for Scenario 1.	117
Figure 8.11. New Houses for Sale Fraction for Scenario 1.	117
Figure 8.12. Houses Available for Rent for Scenario 1.	118
Figure 8.13. Rental Supply/Rental Demand for Scenario 1.	118
Figure 8.14. Perceived Average Rental Price for Scenario 1.	119

Figure 8.15. Sales Supply/Sales Demand for Scenario 1.	120
Figure 8.16. Average Sales Price for Scenario 1.	120
Figure 8.17. Gross Rent Multiplier for Scenario 1.	121
Figure 8.18. Change of normal essential demand ratio for policy 1.	123
Figure 8.19. Essential housing demand for policy 1.	124
Figure 8.20. Total demand for sale for policy 1.....	124
Figure 8.21. Supply shortage for policy 1.	125
Figure 8.22. Project start rate for policy 1.	125
Figure 8.23. Perceived investment-oriented housing demand for policy 1.....	126
Figure 8.24. Owner occupied houses for policy 1.	126
Figure 8.25. Gross Rent Multiplier for policy 1.	127
Figure 8.26. Perceived average rental price for policy 1.....	127
Figure 8.27. Houses on secondhand market for policy 1.	128
Figure 8.28. Total second sales for policy 1.	129
Figure 8.29. Perceived Average Rental Price for policy 1.....	129
Figure 8.30. Total demand for rent for policy 1.....	130

Figure 8.31. Effect of Project Real Estate Fund for policy 2.	131
Figure 8.32. Project Start Rate for policy 2.	132
Figure 8.33. New Vacant Houses for policy 2.	132
Figure 8.34. Perceived Average Rental Price for policy 2.....	133
Figure 8.35. New Vacant Houses for policy 2.	133

LIST OF TABLES

Table 2.1. Provinces with the highest and lowest annual rent rise – December 2023 ([10]).	3
Table 5.1. Initial values of stocks for base behavior.....	24
Table 5.2. Constant parameters for the base model.	25
Table 6.1. Selected parameters for sensitivity analysis.	83



1. INTRODUCTION

Real estate markets are among the most unsteady and dynamic markets which show large amplitude cycles lasting 10 to 20 years. Real estate markets account for a large portion of the total wealth of an economy and constitute an important part of the banking activity and debt, as well as having a strong impact on the labor market [1]. Housing markets demonstrate oscillatory behavior with 10-20 years of cycle periods and cyclic properties vary between different types of real estate. Real estate cycles create instability in the market, allowing an economic shock to prompt fluctuations around the market's equilibrium. [2]. According to research and analyses, endogenous dynamics of the housing sector can be responsible for the occurrence of cycles [3].

The housing market is an important sector that reflects a country's economic performance. Housing prices are a significant concern for real estate developers, homeowners, policy makers, and banks. Examining the internal dynamics of housing prices and managing their rapid growth is very important for the healthy development of the housing industry. Several factors can influence real estate prices, and the relationships between them are complex [4]. There are several studies conducted on housing prices. The relationship between housing characteristics and house prices has been displayed by hedonic-based models over the past three decades [5]. Hedonic price models are frequently used in housing markets, and they are used to analyze the factors on the price of the goods while supporting the idea that the price of the good relates to some internal and external factors. The price of housing is affected by some physical features of the house such as the size and appearance. Moreover, external factors like the neighborhood, access to public transport, security of the place, proximity to school, etc. are also other determinants of the price of housing [5,6].

Housing is one of the fundamental investment methods for investors and households in Turkey. The housing sector in Turkey has played a crucial role among traditional investment tools, maintaining its significance over time. Starting in 2002, a significant growth rate was observed in this sector following a global financial expansion, leading to fast growth worldwide. Various factors, such as housing shortages, enhanced access to housing loans, and the enduring

appeal of real estate as an investment, contributed to a substantial rise in housing investments. This period of monetary expansion continued until the onset of the global crisis in 2008 [7].

Housing is one of the primary investment options for both investors and households in Turkey. In countries experiencing high population growth and lacking sufficiently developed capital markets, housing investments are preferred by individual investors. Thus, the demand for housing remains strong in these countries, while housing prices can increase faster compared to developed nations. Since housing is a common investment method in Turkey, the potential demand for housing remains robust [8].

According to the research, there has been a rising trend in the prices of housing in Turkey in recent years. Two determinant sectors affect housing prices significantly. The first sector consists of the people that buy and rent houses while the second sector consists of house suppliers. The relationship between these two sectors in terms of the behaviors of households and suppliers (construction companies) can change across the years due to the factors such as increasing inflation, volatility of the Turkish lira and high interest rates. Moreover, the construction companies act to maximize their profit, and their decisions play a crucial role in the housing market. The reaction of the housing market to the economic and political developments creates confusion, and it needs to be analyzed and studied under different scenarios.

The purpose of the study is to analyze the real estate price, supply and demand dynamics of a hypothetical real estate system that shares key characteristics with the Turkish real estate market. A system dynamics model is constructed which is inspired by price, supply and demand dynamics of Turkey between 2010 and 2023. This simplified Turkey-inspired housing model is not an exact Turkey model, but it is constructed such that main components of the Turkish real estate market are included however not all the variables and concepts that constitute the market dynamics in Turkey are included such as income levels of households, construction costs, government policies, employment rates, urbanization and foreign investment.

2. PROBLEM DESCRIPTION

Increase in the prices of real estates in big cities has been one of the most crucial concerns of Turkey in recent years. The increase in house prices is caused by several factors. Main determinants of housing prices are supply and demand. It was specifically demonstrated that housing prices increase when there is excess demand for homes [9]. The other important factors that affect the housing prices can be summarized as location, accessibility to transportation, construction costs, security and the quality of the building elements [10].

The prices of rental properties have been gradually increasing compared to the previous years in Turkey. According to the Bahçeşehir University Economic and Social Research Center (BETAM), average rental price of a flat was 12.9 TL/m² in December 2019. The average rental prices noted in the following years were 15.4 TL/m² in December 2020, 25 TL/m² in December 2021, 71 TL/m² in December 2022, and 132.7 TL/m² in December 2023 [10, 11, 12, 13].

Table 2.1. Provinces with the highest and lowest annual rent rise – December 2023 ([10]).

City	December 2022 Price (TL/ m ²)	December 2023 Price (TL/ m ²)	Annual Rent Increase (%)
Mean (Turkey)	71,0	132,7	87,0
Ordu	30,9	90,6	193,5
Kahramanmaraş	25,0	72,5	190,1
Diyarbakır	30,0	84,1	180,3
Van	28,6	79,4	177,9
Erzurum	20,4	55,0	169,7
Adana	45,0	83,3	85,2
Mersin	61,5	108,3	76,0
İstanbul	100,0	173,3	73,3
Muğla	111,1	176,5	58,8
Antalya	117,7	144,4	22,8

There is a significant difference between the cities of Turkey regarding the annual rate of rental price increases. According to the table above, the cities with the highest annual rate of increase in average rental prices are Ordu (193.5 %), Kahramanmaraş (190.1 %), Diyarbakır (180.3 %), Van (177.9 %) and Erzurum (169.7 %). On the other hand, the cities with the lowest annual rate of increase in average rental prices are Adana (85.2 %), Mersin (76 %), İstanbul (73.3 %), Muğla (58.8 %) and Antalya (22.8 %).

There are several studies conducted on real estate markets that use modeling. The article "A 3-Dimensional Discrete Model of Housing Price and Its Inherent Complexity Analysis" reviews a theoretical framework for understanding housing prices by a three-dimensional model. The authors develop a discrete model that combines various factors affecting housing prices, such as location, size, and socio-economic variables. After analyses, the study reveals how these interrelated factors contribute to fluctuations in housing markets. The findings emphasize non-linear relationships and dynamic interactions among variables, suggesting that housing prices are influenced by both local conditions and economic trends. The model serves as a tool for policymakers and researchers to analyze housing market behaviors more effectively and make informed decisions [14].

The authors of the article "Are International Real Estate Markets Integrated: Evidence from Chaotic Dynamics" apply chaos theory and dynamic systems analysis to evaluate whether market behaviors are affected by complex, nonlinear interactions. This study discovers chaotic dynamic behaviors in real estate markets, suggesting that these markets are not fully integrated and can exhibit unpredictable behavior. Authors also point out that factors affecting real estate prices, such as local economic conditions and policy interventions, play significant roles in shaping market trends. As a result of the findings, investors and policymakers should take into account the risks associated with global real estate investments. To summarize the findings of this research, it can be concluded that real estate market behaviors are generally unpredictable [15].

In the paper of Ebru, Ç., & Eban, A. (2009) [6], the relationship between house prices and housing characteristics is studied in Istanbul. The survey data used in the study contains

housing characteristics such as the number of the bathrooms, house location, heating system and room numbers. The data is used to analyze the effects of these factors on housing prices with the help of the hedonic price model in Istanbul. Quantile regression methods are used to discriminate the attributes of housing characteristics along with the distribution of housing prices. According to the findings, security, age of the house, heating system, higher number of rooms and additional bathrooms raise the price of the houses.

In the study of Özbaş, Özgün and Barlas, the dynamics of oscillations that arise endogenously in real estate (housing) prices are studied by System Dynamics approach. The simulation model has been developed to explore some of the structural causes of cycles in key housing market variables, specifically from the viewpoint of construction companies. This model emphasizes the economic balance dynamics between supply and demand. Due to inherent delays in recognizing real estate market conditions, prices and other related market variables display significant oscillations [16]. In our model, the mechanisms and loops that cause price increases and decreases will be investigated in detail and appropriate policies will be discussed. In this model, we also include housing investment decisions and secondhand house market in the model to obtain a broader analysis on a Turkey-inspired model. Investment-oriented demand of households and the supply of secondhand houses significantly influence the rental market in Turkey, and these concepts are not studied in detail in [16]. We will include the effect of interest rates on housing demand by examining the changes in demand more effectively.

The core factors that create this dynamic problem are the relationships between price, demand and supply itself. Each factor interacts with and affects the overall market. Generally, as prices rise, the demand for housing tends to decrease, as fewer buyers can afford homes. Conversely, when prices drop, more buyers enter the market, increasing demand. On the supply side, higher prices can encourage developers to build more homes, thus increasing supply. Conversely, if prices fall significantly, developers may delay or halt new projects, decreasing future supply [16, 17]. Demand and supply market shifts affect prices significantly. If demand increases, this will typically drive prices up until supply catches up, unless supply can be increased quickly. Conversely, if supply increases substantially without a matching increase in demand, prices may fall until a new equilibrium is achieved [18]. Speculation can also play a

role; if investors believe prices will continue to rise, they may purchase houses as investment, affecting demand and ultimately pushing prices up [19].

In Turkey, there are some principal factors that increase the level of housing demand and prices in a region. These factors are population growth rate, income growth and immigration into the region. The population growth rate is high as well as millions of immigrants have entered Turkey in the last eight years. As a result, housing demand has increased. Moreover, land and construction costs have risen rapidly so housing prices have dramatically increased. Consequently, the rent multiplier and payback period of housing investments have risen quickly in Turkey in recent years [8].

The demand for housing can be divided into two components: essential demand and investment-oriented demand. Essential demand stands for the demand of a house for residing purposes where investment means purchasing a house just for investing purposes. Housing investment is a common investment method among individual investors in Turkey. Due to high inflation, people desire to protect their savings and invest in real estate. Moreover, construction costs of the newly built houses may increase the sales prices of those houses. Since some people cannot afford to buy these newly built houses, the demand for secondhand properties emerges. Secondhand home sales constitute almost 70% of all home sales in Turkey [20]. Additionally, the production of new houses cannot meet the demand in Turkey which induces a supply shortage problem. This supply shortage brings about both higher rental and sales prices in Turkey.

Since the 1990s, housing prices have been increasing in developed countries around the world, especially in the United States (excluding Japan). From the end of 1990 to the second quarter of 2007, real housing prices increased by approximately 60% in the United States, 40% in the Euro Area, 55% in Canada, and 135% in the United Kingdom. Since the 1990s, the increase in the housing prices in Turkey has been much greater than in the United States, the Euro Area, Canada, the United Kingdom, and many other industrialized countries. According to the REIDIN Housing Price Index, housing prices in Turkey increased by 160% between 2009 and 2016, and by over 230% since 2003 [21, 22]. The Central Bank of the Republic of Turkey

(CBRT) indicates that the value of residential properties has increased in all regions of the country from April 2022 to April 2023. Thus, in the major cities there has been a considerable increase in the housing prices. There is also a significant supply-demand gap in these cities, particularly in Istanbul, Ankara, and Izmir. Additionally, in the recent inflationary environment, the uncertainty caused by sharp fluctuations in the value of the Turkish lira has led to a substantial demand for affordable housing [21].

There are numerous studies conducted on the housing market worldwide. In Turkey, there has been a prevailing trend of rising prices in the housing market since the early 2000s. As can be seen in the figure 2.1, from the beginning of 2010 there has been a long-lasting price increase trend in Turkey's housing sector [8]. There are several studies that investigate the factors which affect housing prices. Some of these factors include supply, demand, population growth, economic conditions and interest rates. In this study, it will be explored if those factors also play a role in a Turkey-inspired housing market. In other words, key housing sector variables such as demand, supply and price will be included in the model as in the literature and initialization of the model will be made according to Turkish housing market conditions. In this study, Turkey's housing market is chosen as a base model. Consumers' behaviors of purchasing a house affects the market considerably. When considered on a sectoral basis, the housing sector is the second largest sector after transportation sector in Turkey. Real estate is not just a need for shelter in Turkey; it is also a means of long-term investment and considered as a rental income for investors. Moreover, economic conditions are highly influenced by political decisions. Thus, Turkey has some important social, economic and political aspects which remarkably affect housing market dynamics. [21].

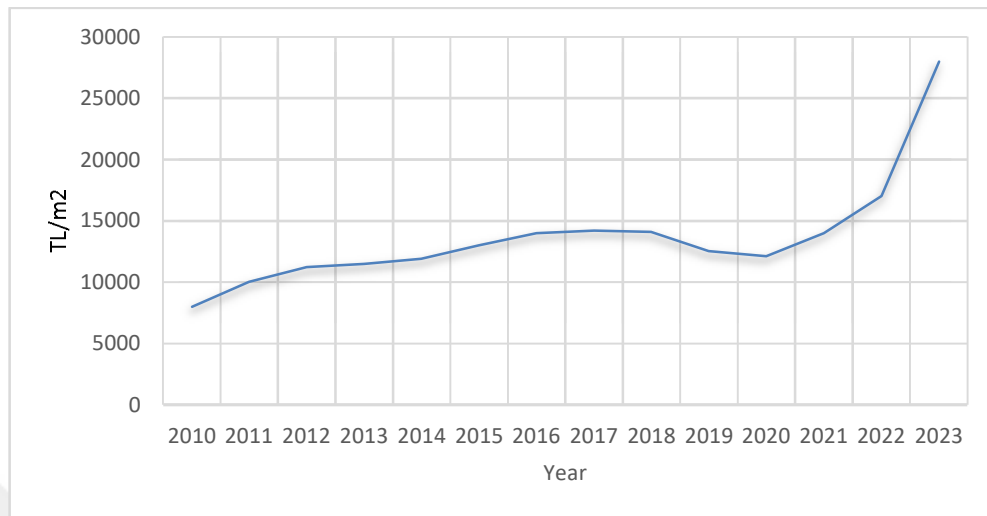


Figure 2.1. House Prices in Turkey from 2010 to 2023 (TL/m²) [23].

According to Figure 2.1, on average, purchasing a house has become three times more expensive in 2023 compared to 2010.

In figure 2.2, inflation adjusted house prices are shown between the years 2010 and 2023:

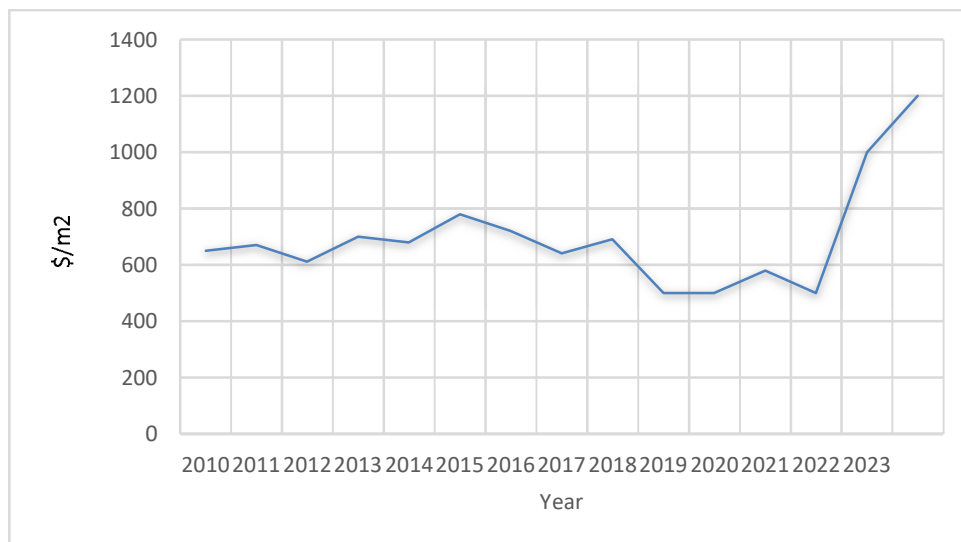


Figure 2.2. Nominal House Prices in Turkey from 2010 to 2023 (\$/m²) [23].

According to the literature, average sales prices of houses from 2010 to 2023 are given in the figure 2.2 in terms of dollars per meter square [23]. Since 2010, small cycles with two-year have been observed. A price decline that started in 2018 continued until 2022, followed by a significant price increase after 2022. In 2010, the average sales price of a house was 650 \$/m² and prices increased slightly until 2016-2017. While the residential square meter price in Turkey was \$ 650 in January 2010, it increased by 23.7% to \$ 803 in September 2016. A decline started after September 2016, and by September 2018, housing prices in Turkey decreased by 45.2% in dollar terms, falling to \$ 440. Turkey's housing prices, which were \$ 471 in December 2021, started to rise and increased by 154% in May 2023, reaching \$ 1197, the highest value since January 2010. In November 2023, it decreased by 11.4% compared to May 2023, falling to \$ 1061. All in all, according to figure 2.2, from 2010 to 2023, nominal house prices showed oscillatory behavior. There is also a considerable decrease in nominal house prices in 2018. The Turkish economy experienced a slowdown in the third quarter of 2018. In that year, interest rates in Turkey were increased to 24 % to combat increasing inflation and stabilize the Turkish lira. The Central Bank of the Republic of Turkey (CBRT) raised interest rates in response to a considerable depreciation of the currency and to address concerns about economic instability. Since interest rates were raised to combat inflation, borrowing costs rose. This situation made mortgages more expensive, making it difficult to afford housing. As a result, nominal housing prices fell significantly in 2018 [24, 25].

Due to the imbalance between housing demand and supply, the prices in the real estate market display booms and busts [26, 27]. From figure 2.2, we observe these booms and busts in Turkey through years. Between 2016 and 2018, there was a bust period while after 2022 we observe a boom that continues until 2023. The occurrence of boom-and-bust cycles in real estate markets is influenced by a variety of factors. Causes of boom periods include economic growth, low interest rates, population growth and urbanization, and speculation. When the economy is strong, households have higher incomes which leads to increased demand for housing. When interest rates are low, the cost of borrowing falls, making mortgages more affordable. This situation encourages more people to purchase homes, driving prices up. The number of households is increasing because the population is growing, in this case, extra houses are required. Lastly, speculations create booms in the market such that investors may anticipate

rising prices and purchase properties with the objective of selling later at a profit. Reasons for bust periods include economic recession, rising interest rates, excess supply and speculative bubbles. A downturn in the economy can lead to job losses and reduced income, thus housing demand decreases. Rising interest rates affect demand for mortgages. When the central bank raises interest rates to control inflation, borrowing becomes more expensive, leading to decreased demand for new mortgages. During boom periods, developers may build excessively, as a result oversupply occurs. When demand drops, this oversupply can initiate falling prices. [1, 28].

According to the given problem description and literature review above, the endogenous relations between the demand, supply and prices in Turkish real estate market have been an important concern for researchers and investors. The main motivation of this study is to create a Turkey-inspired system dynamics model to mimic the main structures of Turkish real estate market. The created model roughly resembles Turkey such that the initialization of the model is made based on the Turkish population, sales and price statistics. Investment side of the demand and the secondhand market is also included to obtain a model that reflects the conditions in Turkey. However, this model is just a conceptual model which mimics the key Turkish housing market structures, not all concepts that affect Turkish housing market are included. Thus, the outcomes of the model can reveal some key insights about Turkey, but we do not aim to forecast what will happen in Turkish housing market in the future exactly. All in all, the boom and busts periods, their magnitudes, real estate price fluctuations in a country where supply and demand dynamics are similar to Turkey will be examined in this study.

Understanding the endogenous dynamic behavior of house sales prices and rental prices is possible if the determinants of prices in the market are modeled using a stock flow system. Because the given literature reveals that housing markets are dynamic systems which require the simultaneous evaluation of several interactions in the market variables. This research will investigate the endogenous dynamics that may be responsible for creating such an oscillating housing price behavior (Figure 2.2) over the years on a Turkey-inspired conceptual model. Because several variables interact with each other, this system has a dynamic complexity, and each variable has an influence on the other. Consequently, the nature of the system is suitable

to model with stock-flow models.



3. RESEARCH OBJECTIVES

In the introduction and problem description sections, the basic properties of the Turkish real estate market are explained. Researchers investigating the dynamics of the Turkish housing market concentrate on a variety of areas, including price dynamics, demand and supply factors, market cycles and oscillations, and investment dynamics. Problem description section specifically focuses on price dynamics of Turkish housing market. According to the findings, housing prices fluctuate due to factors like supply and demand imbalance, inflation, and economic conditions. Many studies have revealed that rising housing prices cause limited housing affordability for a big segment of the population. In Turkey, house sales and rental prices can exhibit different dynamics at different times, and each creates a separate dynamic. However, rental prices and sales prices influence each other such that there is always a relation between them. Understanding the relationship between rental and sales prices and analyzing what influences them in the sector is quite important in a country like Turkey, where the housing sector constitutes a significant portion of the wealth.

Housing market models created for academic and research purposes mainly investigate the sales price dynamics, urbanization, land availability, construction costs and socioeconomic impacts such as income level and access to housing. In our model, houses on the secondhand market are included, which are not part of most studies in literature. An increase in secondhand homes on the market can enhance housing affordability, depending on demand levels. Additionally, secondhand homes contribute to the total housing supply, which affects sales and rental prices. Thus, it is better to take secondhand homes into account to understand market dynamics clearly. Moreover, investors may prefer to invest in secondhand houses, since those houses meet the low-cost housing needs of tenants, creating consistent demand and rental income. So, rental price dynamics and investors' demand are considered in the model to create a realistic conceptual Turkey-inspired housing model [29]. In this study, current economic conditions are included since the effect of inflation on housing prices is substantially high. It is very important to take into account economic conditions to be able to speak about the housing prices by forward-looking policies.

In this study, a Turkey-inspired real estate market will be inspected by taking into account new constructions, secondhand market, sales demand, rental demand and actions of investors. Policies and scenarios are implemented to gain insight into the future of the market. The outcomes of the policies and scenarios can be important for the future of Turkish real estate market, but we cannot make exact inference for Turkey because there are some external factors related to Turkey which cannot be included to the system dynamics model since these factors incorporate additional interactions and concepts which are not suitable to model with a stock flow system. These external factors include income levels of households, construction costs, government policies, employment rates, urbanization and foreign investment. A stock-flow representation which is similar to Turkey's housing market is constructed.

To sum up, the aim of this study is to analyze the sales and rental price dynamics of a real estate market using a system dynamics model, for this purpose Turkey has been chosen as a reference country to observe the trend in housing prices and see what happens when we further simulate the model until 2050. What will be the average sales and rental prices of a conceptual housing market if the inflation will persist a couple of years in a country where economic conditions are similar to Turkey? What if the government applies policies to relieve inflation? What are the main causes of booms and busts in prices and how can we prevent them? Those research questions will be answered when we conduct experiments on the base model.

4. RESEARCH METHODOLOGY

In this study, System Dynamics Methodology is used to model a Turkey-inspired housing market dynamics. The created system dynamics model inspects the dynamics of real estate demand and supply and the resulting effect on the rental and sales price of houses is evaluated.

System dynamics methodology is a way of understanding and modeling complex systems over time. It focuses on the relationships between different elements within a system and how changes in one element can affect the entire system. By feedback loops, non-linear relations and computer simulation, system dynamics method helps in observing how a system could behave in the future and detecting points of intervention to improve its performance. To be able to conduct those experiments and demonstrate a long-time trajectory, system dynamics method is used.

System dynamics models investigate problems that we do not fully understand. These models typically exhibit specific properties. One of them is feedback loops. The system contains interconnected components where the output of one component affects another in a circular way. Time delays are another common property of system dynamics models. Changes in one part of the system may not immediately affect other parts, resulting in delays in the system's response. Moreover, the relationships between components are often nonlinear, like small changes can lead to disproportionate effects. There is also accumulation, some system components accumulate in stocks over time, affecting the behavior of the system. Lastly, those systems show typical dynamic behaviors such as growth, collapse, or oscillation due to the interplay of various elements over time.

The primary elements of a system dynamics model are stocks and flows. Main accumulated variables are demonstrated by stocks and their change rates are shown by flows. One basic example of a system dynamics stock-flow model is “Bathtub Model”. It is a basic and powerful way to illustrate the dynamics of stock accumulation and outflow in a system. A bathtub is the system where water level represents the stock (e.g., population, price, inventory,

weight, money) within the system. The faucet pouring water into the tub represents the inflow, in other words, accumulation of the stock, while the drain opening represents the outflow or depletion rate of the stock. As water flows in (inflow), the stock level in the bathtub rises over time. At the same time, water flows out (outflow) through the drain, depleting the stock. The stock level at any given time is the result of the balance between inflow and outflow rates.

By adjusting the inflow and outflow rates, we can observe how the stock level changes over time and comprehend the dynamics of stock accumulation and depletion within the system. The stock-flow model representation of this system is given below:

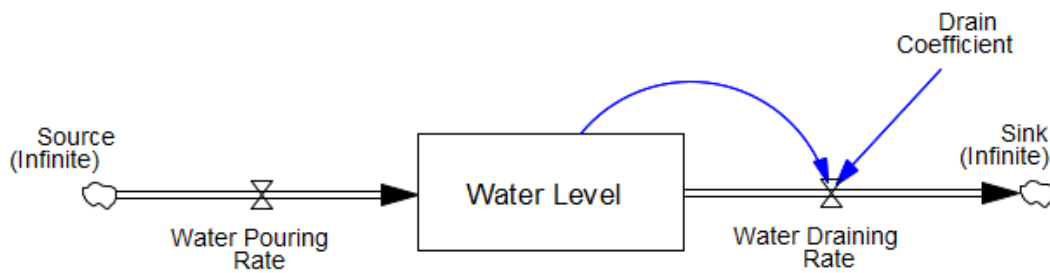


Figure 4.1. Bathtub Stock-Flow Model [30].

An initial value for stock is given to the model. In this representation, the water pouring rate is constant but the water draining rate depends on the water level in bathtub. Here in this representation, outflow depends on the stock. The water draining rate demonstrates a nonlinear relationship, as it depends on the water level; thus, the higher the water level, the faster the flow out. The change of stock depends on the inflow and outflow and the differential equation for stock is given below:

$$\frac{d(\text{Water Level})}{dt} = \text{Water Pouring Rate} - \text{Water Draining Rate}. \quad (4.1)$$

$$\text{Water Level}(t) = \text{Water Level}(0) + \int_0^t (\text{Water Pouring Rate} - \text{Water Draining Rate})dt. \quad (4.2)$$

$$\text{Water Draining Rate} = \text{Water Level} \times \text{Drain Coefficient} \quad (4.3)$$

In the context of system dynamics, differential equations are used to demonstrate the relationships between stocks and flows and model the dynamic behavior of the system. System dynamics models generally involve multiple interconnected stocks and flows, leading to a system of differential equations that can be solved by numerical methods or simulations.

In this project, VENSIM is used to analyze housing market dynamics in Turkey. VENSIM serves robust capabilities for solving systems of differential equations, which are fundamental for simulating dynamic systems. A commonly used method for numerical integration of differential equations within VENSIM is Euler integration. This technique estimates the solution by taking incremental steps over time, enabling the calculation of the next state based on the current state and the rate of change defined by the equations.

5. MODEL DESCRIPTION

This model is built to analyze the endogenous dynamics of real estate supply, demand, and price in Turkey. Each of those three variables has a substantial effect on the other one. The relations between the housing supply, demand and prices are demonstrated in the simplified stock flow diagram. Causal loop diagrams are given to show the causal relations and major loops. Equations, variables, stocks, flows and effect functions used in the stock-flow model are explained in detail in this section.

5.1. Overview of the Model

The main objective of the model is to understand the reasons behind oscillating sales and rental price dynamics in the Turkish housing sector and to analyze what the prices will be in a housing market which resembles Turkey. Prices are denoted as average sales price and average rental price in the model since their dynamics are different and need to be analyzed separately. Both sales price and rental price are affected by supply and demand imbalance created in the model. Thus, each variable in the model is important for understanding the behavior patterns. To understand the dynamics of each variable, the feedback mechanisms, relationships and effects should be observed as a whole rather than separately. Hence, system dynamics perspective is used for this analysis.

The created system dynamics model is a time continuous stock-flow model that is mainly composed of three sectors: housing supply, housing demand and prices. There are in total six house stocks, four price stocks, one rent multiplier stock as well as one perceived investment-oriented demand stock.

According to the real historical data, the model initialization is done in 2010. The overall dynamic behaviors of the key variables are inspected in the later sections.

In this section, a brief explanation of the variables, flows and stocks is provided with causal relations between them. Moreover, model parameters taken from literature and estimated parameters are given. The general stock-flow diagram that imitates the real estate market dynamics of Turkey is given in the figure below:

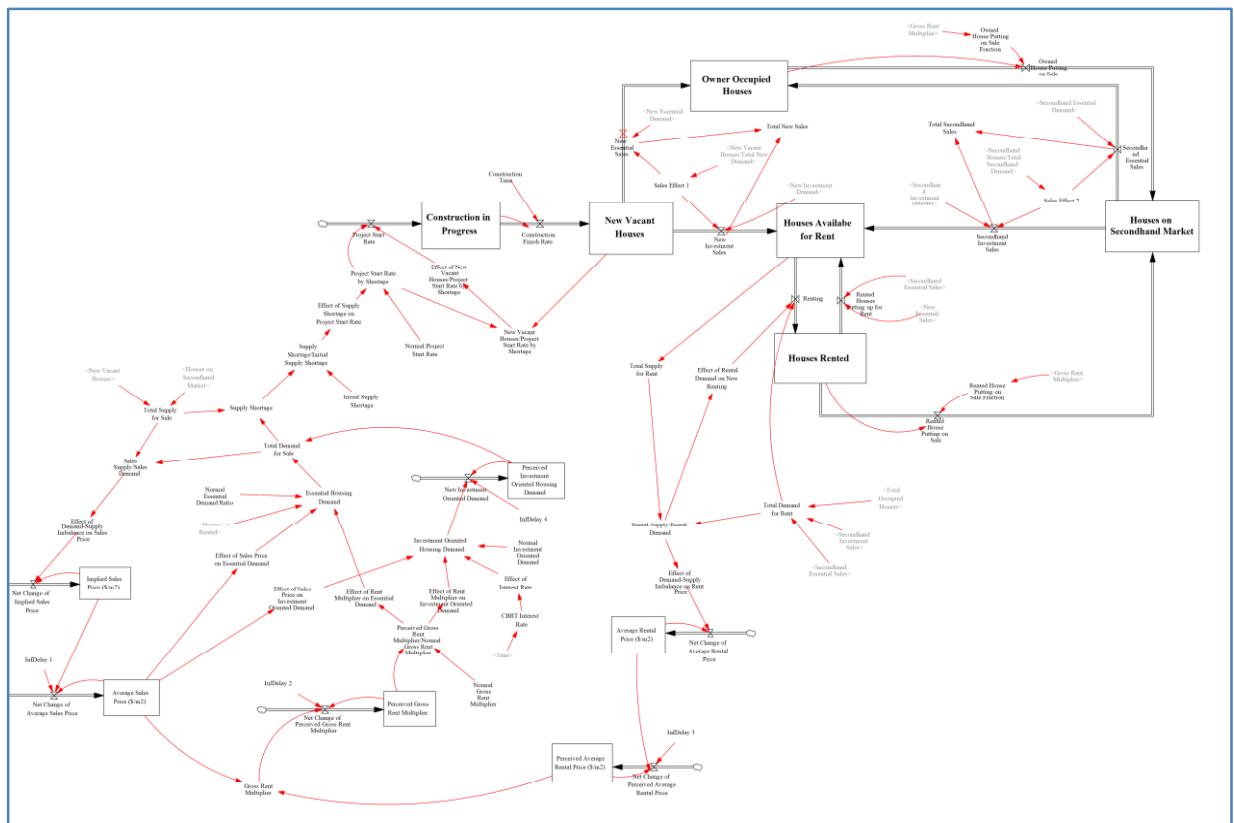


Figure 5.1. Simplified stock-flow diagram of Turkish real estate market.

In Figure 5.1, we see three sectors that constitute the overall dynamics of the real estate system. These sectors are the supply, demand, and price sectors, whose details will be provided in Section 5.3. Firstly, a conceptual explanation of each variable, flow, and stock in the model will be presented:

- Project Start Rate:

This is a flow, and it denotes the houses whose construction permits have been received and constructions for a new building have started. It is the inflow of *Construction in Progress* stock. Project start rate is driven by supply shortage which is the discrepancy between total demand for sale and total supply for sale.

- Normal Project Start Rate:

It represents the project start rate at the reference year, 2010. Its value is 916504 house/year [31].

- Supply Shortage

It is the discrepancy between total demand for sale and total supply for sale. In other words, it is the difference between total demand for sale and total supply for sale.

- Project Start Rate by Shortage:

It is the auxiliary variable that is driven from supply shortage and calculated as the multiplication of normal project start rate and effect function of supply shortage.

- Construction in Progress:

This stock represents houses under construction.

- Construction Time:

Construction time is the completion duration of a house, and it is taken as 3 years [32].

- New Vacant Houses:

This stock exhibits finished projects that are ready to be sold and unoccupied. In other words, new vacant houses represent new houses available for sale. Its initial value is given 300 000 as an estimation [33].

- New Investment Sales:

The new investment sales flow represents sales of new houses made for investment purposes. Landlords rent out those flats if it is favorable to rent out a house. This decision is made according to the gross rent multiplier for a given year.

- New Essential Sales:

It represents people who buy a new house to reside in it.

- Total New Sales:

Total number of sales of new vacant houses. It is the sum of new investment sales and new essential sales.

- Owner Occupied Houses:

This house stock is an occupied stock in which households reside in. The initial value of the stock is 11 283 400. This represents the number of households who own the house they reside in as given in the literature [34].

- Secondhand Investment Sales:

The secondhand investment sales flow represents sales from secondhand houses made for investment purposes. As stated above, landlords rent out those flats if it is favorable to rent out a house. The incentive for this decision is that the lower gross rent multiplier compared to previous years.

- Secondhand Essential Sales:

It represents people who buy a secondhand house to reside in it.

- Total Secondhand Sales:

Total number of sales of secondhand houses. It is the sum of secondhand investment sales and secondhand essential sales.

- Houses on Secondhand Market:

This house stock is an occupied stock in which households stay, and it constitutes sales supply with new vacant houses. In this stock, there are houses that are occupied by the owner of the house who intends to sell it. There are also those houses which are advertised by the owner of the house while tenants are residing. The initial value of the stock is 800 000 as an estimate.

- Total Supply for Sale:

It is the sum of new vacant houses and houses on the secondhand market.

- Average Sales Price (\$/m²):

It represents the average sales price of a house in dollars per m². Its initial value is 650 \$/m² according to the data given in literature [23]. The average sales price stock is different from the implied sales price such that it denotes the updated price after a delay.

- Essential Housing Demand:

This demand represents the number of households who want to purchase a house to reside in it.

- Normal Essential Demand Ratio:

It is taken as 0.15 and it is estimated that 15% of the people who are tenants (houses in houses rented stock) are willing to buy a house to reside in. Thus, they are considered part of the essential demand.

- Perceived Investment-Oriented Housing Demand:

This stock represents investors' point of view to purchase a house. Investment-oriented demand represents the demand of purchasing a house for renting out.

- Total Demand for Sale:

It is the sum of essential housing demand and investment-oriented housing demand. In other words, it is the total sales demand to buy a property.

- Normal Investment-Oriented Demand:

It is assumed that the normal value of investment-oriented demand is 900 000.

- Houses Available for Rent:

In this stock houses that are in rental market (houses that are advertised for rent) are shown. Houses in this stock are unoccupied houses and constitute the total supply for rent in the market. It is estimated that the initial value of the stock is 300 000.

- Houses Rented:

Houses rented stock represent houses in which tenants reside in. Thus, it is an occupied house. Initial value of the stock is given 7.8 million as an estimate compatible with real data [34].

- Total Occupied Houses:

Total occupied houses represent houses in which households stay. It is the sum of the houses "owner occupied houses", "houses on secondhand market" and "houses rented". In other words, this stock is a measure of the total number of households.

- Total Unoccupied Houses:

Total unoccupied houses represent houses in which no household stays. It is the sum of "new vacant houses" and "houses available for rent".

- Total Supply for Rent:

This variable represents the houses available in the market for rent. Thus, the total supply for rent equals to number of houses available for rent.

- Total Demand for Rent:

It represents the number of households who are willing to rent a house. Housing demand resulting from population growth is included here.

- Perceived Average Rental Price (\$/m²):

It represents the average monthly rental price of a house in dollars per m². Its initial value is 2.66 \$/m² (4 TL/ m²) as an approximate estimation due to the literature survey [35].

- Gross Rent Multiplier:

Gross rent multiplier (GRM) is an indicator of how much rent landlord will collect relative to the property cost. In the model it is given as the ratio of the average sales price of a house to the annual perceived average rental income.

- Normal Gross Rent Multiplier:

Normal gross rent multiplier is 17.6 years [36].

- House Owning Rate:

It is the ratio of “Houses for Residing” to “Total Occupied Houses” and this variable represents the ratio of household population who own a house to total household population.

Initial values of stocks and constant parameter values are given in the tables below:

Table 5.1. Initial values of stocks for base behavior.

Stock Names	Initial Values	Unit
Construction in Progress	1400000	house
New Vacant Houses	300000	house
Owner Occupied Houses	11283400	house
Houses Available for Rent	300000	house
Houses on Secondhand Market	800000	house
Houses Rented	7800000	house
Implied Sales Price (\$/m ²)	630	\$/m ² /year
Average Sales Price (\$/m ²)	650	\$/m ² /year
Average Rental Price (\$/m ²)	2.6	\$/m ² /year
Perceived Average Rental Price (\$/m ²)	2.66	\$/m ² /year
Perceived Gross Rent Multiplier	17.6	unitless
Perceived Investment-Oriented Housing Demand	1200000	house

Table 5.2. Constant parameters for the base model.

Variable Name	Value	Unit
Construction Time	3	year
Normal Project Start Rate	916504	house/year
Normal Essential Demand Ratio	0.15	unitless
Normal Investment Oriented Demand	900000	house
Normal Gross Rent Multiplier	17.6	unitless

5.2. Causal Loop Diagram of the Model

In this section, the main causal loop diagram and the causal loop diagrams showing each loop are presented and explained in detail. In the below figure, a general scheme of relations is given as a summary. Black lines represent positive relations where red lines represent negative relations.

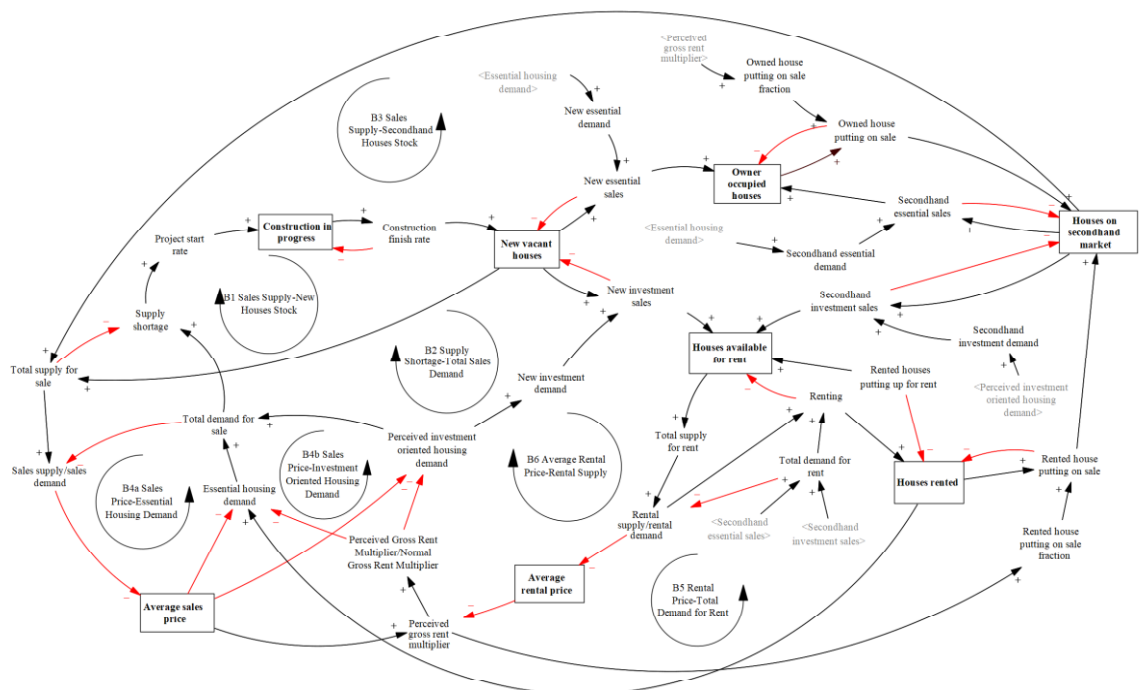


Figure 5.2. Causal Loop Diagram and Main Loops.

Each feedback loop that operates in the system is given and explained below. The majority of the loops are negative loops. In other words, the main loops that constitute the overall dynamic behaviors in the system are balancing loops. Balancing loops counter change in a direction with a change in the opposite direction. The loops pursue to stabilize the system. When the balancing loop detects a gap, the loop will take remedial action to get one variable's actual level closer to the desired level [37].

Below, the main causal loop diagrams in the model are explained in detail.

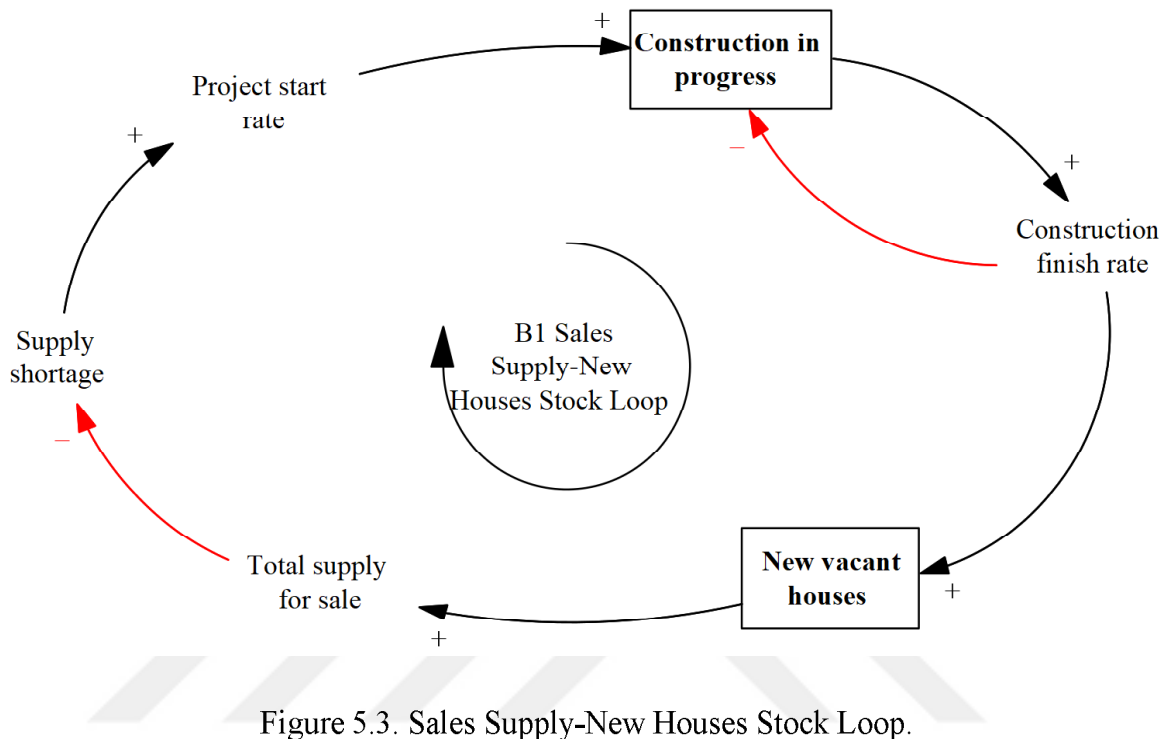


Figure 5.3. Sales Supply-New Houses Stock Loop.

B1 sales supply- new houses stock control loop is a balancing loop between supply shortage and sales supply. Supply shortage triggers project start rate [38]. As a result, houses under construction and then new vacant houses (new houses stock) increase. If new vacant houses increase, then total supply for sale increases. Since there is a negative relation between total supply for sale and supply shortage, supply shortage decreases.

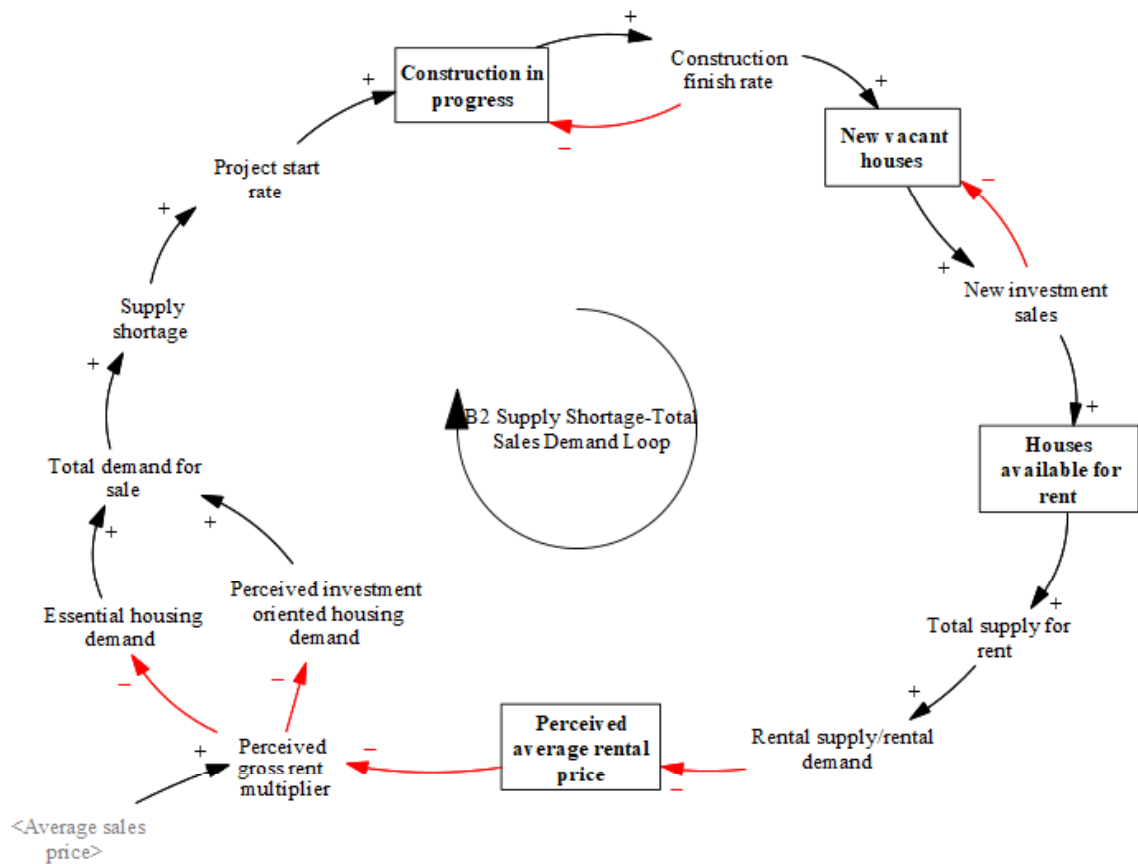


Figure 5.4. Supply Shortage -Total Sales Demand Loop.

B2 represents supply shortage-sales demand balancing loop. When supply shortage increases, new projects start. As a result, new vacant houses and new investment sales increase. New investment sales express sales from new houses made for investment purposes. When new investment sales increase, houses available for rent and total supply for rent increase. Rental supply/rental demand ratio becomes higher and average rent price decreases. The rent multiplier increases and thus essential and perceived investment-oriented demand decreases. Total sales demand decreases as well as supply shortage decreases.

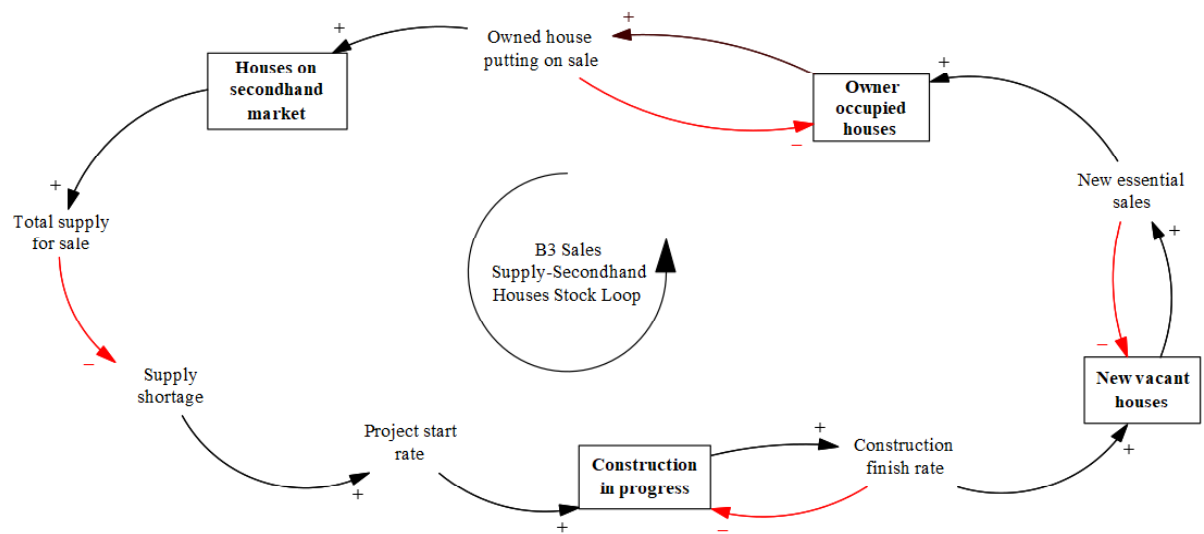


Figure 5.5. Sales Supply -Secondhand Houses Stock Loop.

B3 represents sales supply-secondhand houses stock control loop. When the total supply for sale increases, the supply shortage diminishes. Thus, less projects start resulting in less new vacant houses stock. Since there are not enough new vacant houses to be sold, new essential sales decrease. As a result, houses on secondhand market stock shrink which means total supply for sale decreases.

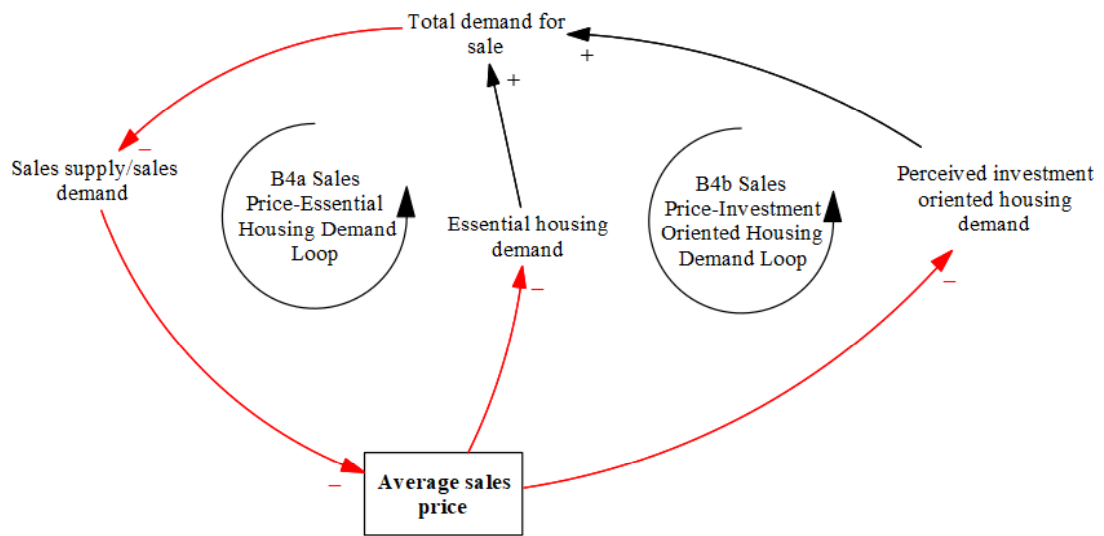


Figure 5.6. Sales Price -Essential Housing Demand and Sales Price -Investment Oriented Housing Demand Loop.

B4 loops represent the negative (balancing) relationship between average sales price and total sales demand. If the average sales price rises, both essential and perceived investment-oriented demand decrease. Thus, total demand for sale decreases. The sales supply/sales demand ratio increases so average sales price falls.

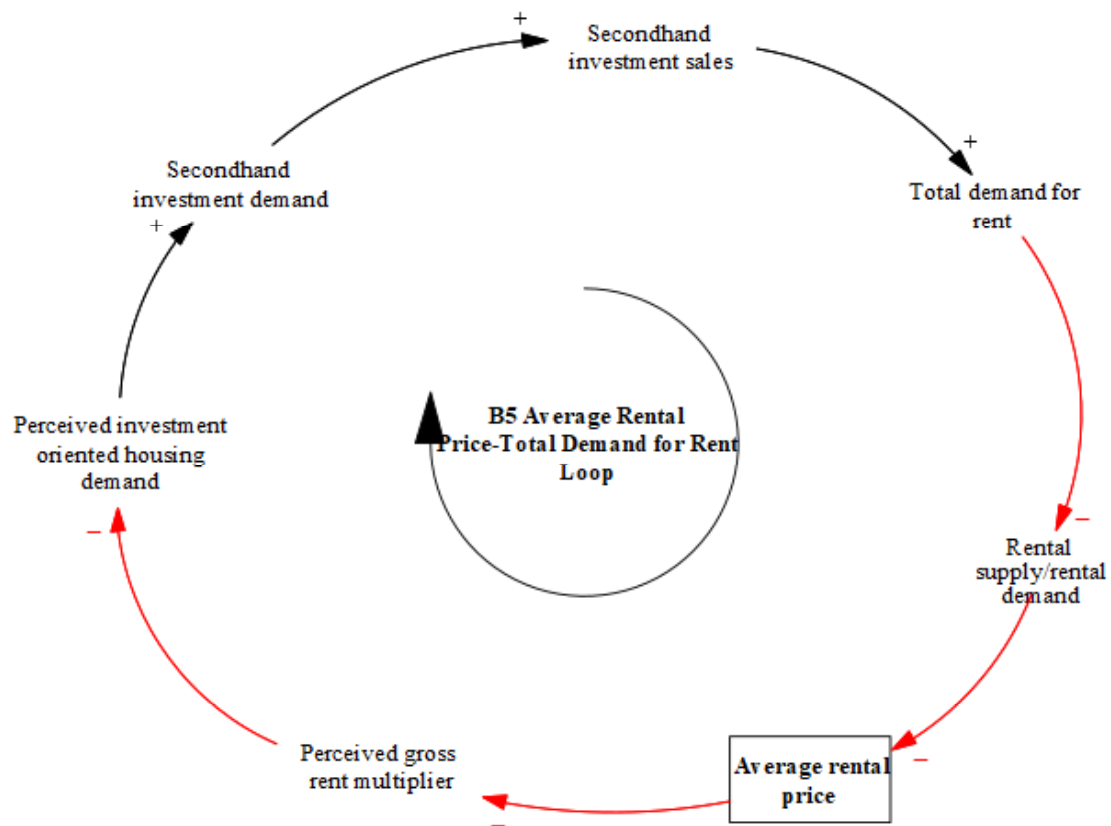


Figure 5.7. Rental Price -Total Demand for Rent Loop.

B5 loop is a reinforcing loop that shows the relation between the average rental price and the total demand for rent. If average rent prices increase, perceived gross rent multiplier decreases since it is the ratio of average sales price to average rental price. As a result, perceived investment-oriented housing demand increases. Investment demand for secondhand properties increases, so secondhand investment sales rise. This creates additional rental demand in the market. Rental supply/rental demand ratio falls and average rental price increases.

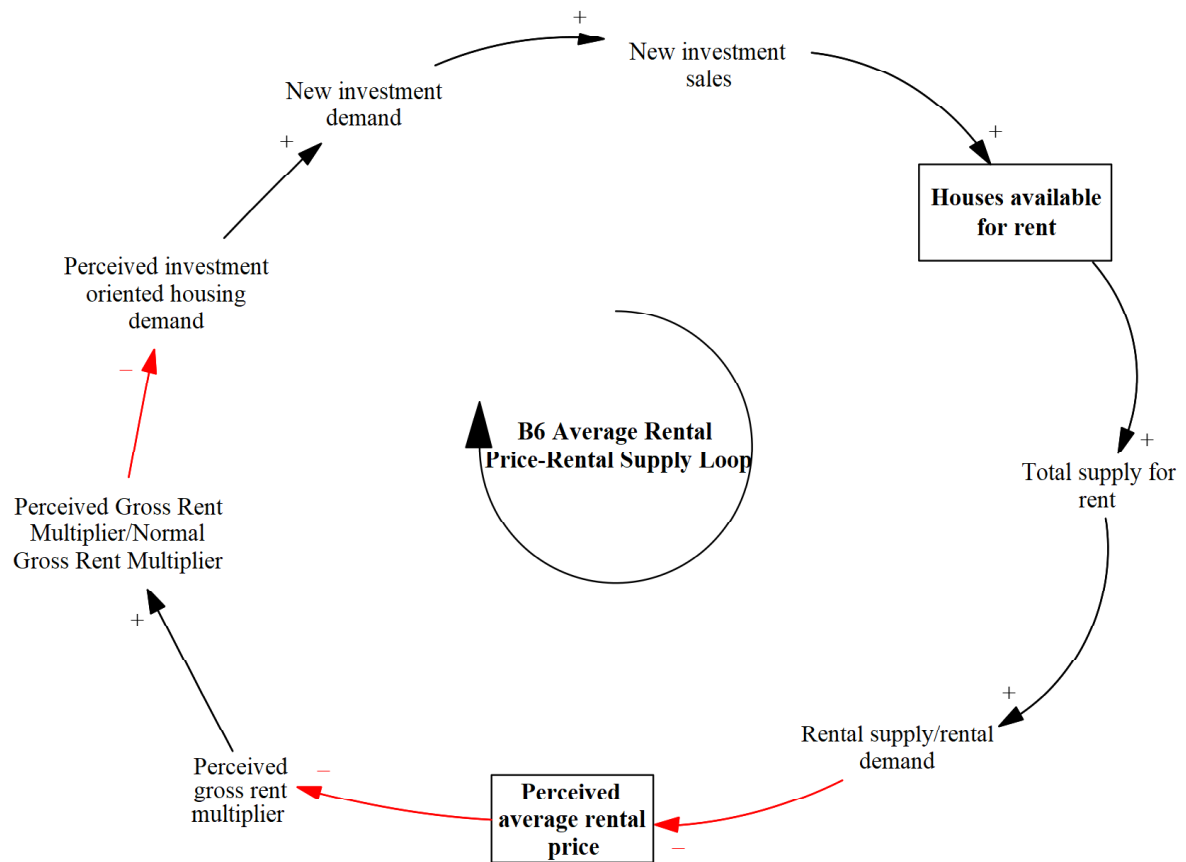


Figure 5.8. Average Rental Price -Rental Supply Loop by New Investment Demand.

B6 is a negative (balancing) loop that shows the average rental price and rental supply relation. When average rental prices rise, the perceived gross rent multiplier decreases which creates demand for investors to invest in a property. Thus, perceived investment-oriented demand increases. The new investment demand is the demand for purchasing a new house for renting out. When new investment demand rises, new investment sales also rise. Those houses bought by investors are announced for rent. Thus, houses available for rent stock increases which in turn leads to an increase in total supply for rent. When the total supply for rent rises, rental supply/rental demand ratio increases. This has a reducing effect on average rental price.

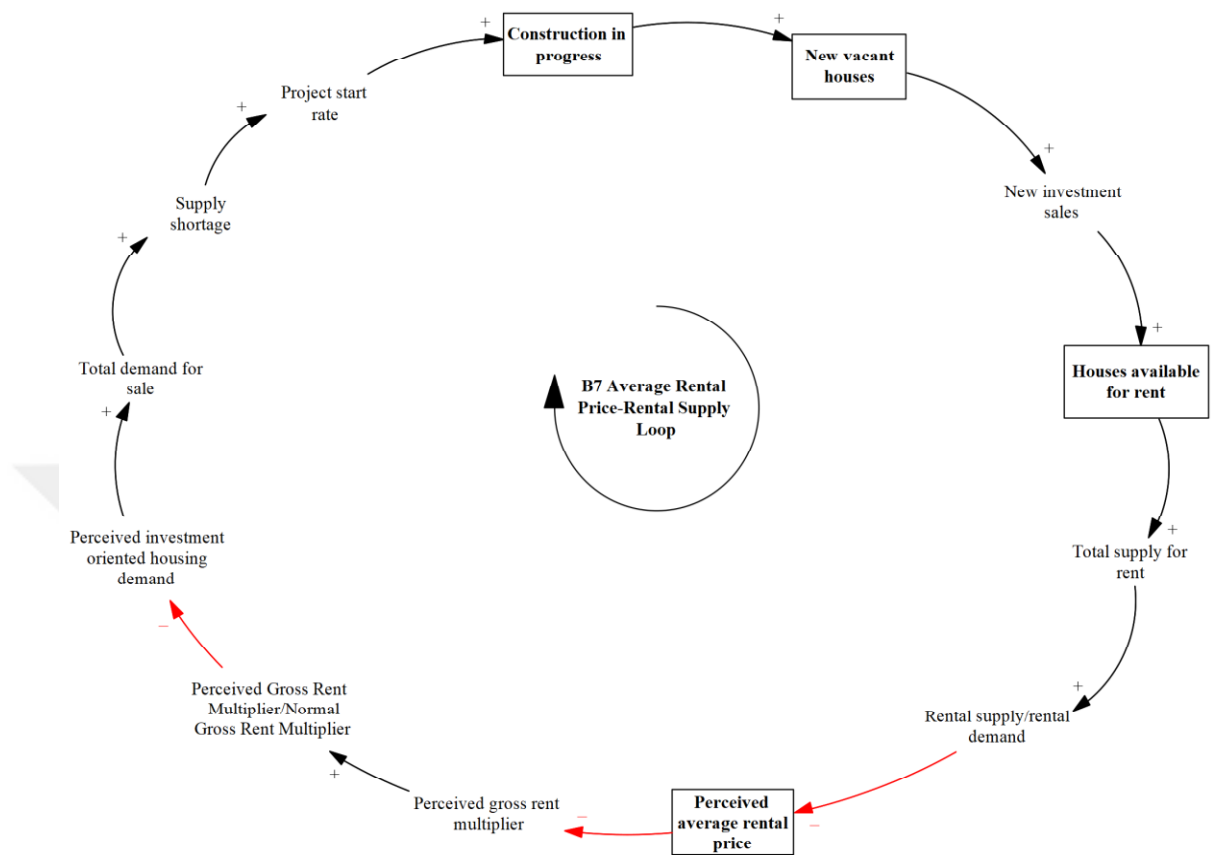


Figure 5.9. Average Rental Price – Rental Supply Loop by New Vacant Houses.

B7 is a negative (balancing) loop which shows the relation between average rental price and total supply for rent. When average rental prices rise, the perceived gross rent multiplier decreases which increases investment-oriented housing demand. When there is demand increase supply shortage triggers project start rate and new vacant houses increase. Since new house supply increases, new investment sales increase and there are more houses available for rent in the market. When the total supply for rent rises, rental supply/rental demand ratio increases. Consequently, the average rental price falls.

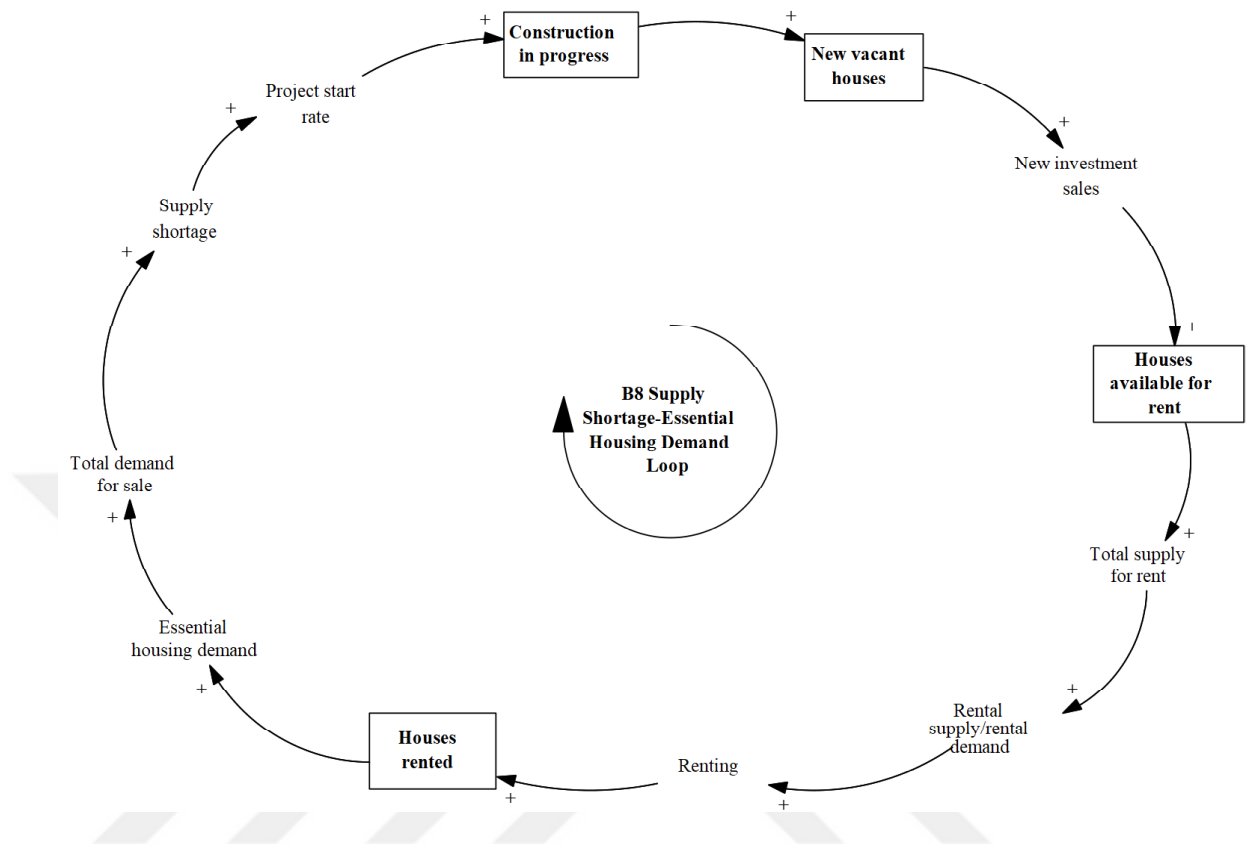


Figure 5.10. Supply Shortage-Essential Housing Demand Loop.

B8 loop is a positive (reinforcing) loop which shows the relationship between supply shortage and essential housing demand. If supply shortage increases, more projects are initiated, leading to an increase in the project start rate. Since more new projects have started, the stock of new vacant houses increases. Because there is more new housing supply, new investment sales increase. As a result, houses available for rent (rental supply) increase. In turn, the rental supply/rental demand ratio increases, and more houses are rented, causing the renting flow to increase. When there are more rented houses in the market, essential housing demand also increases since this demand depends on the number of households that are tenants. When essential housing demand increases, supply shortage also increases.

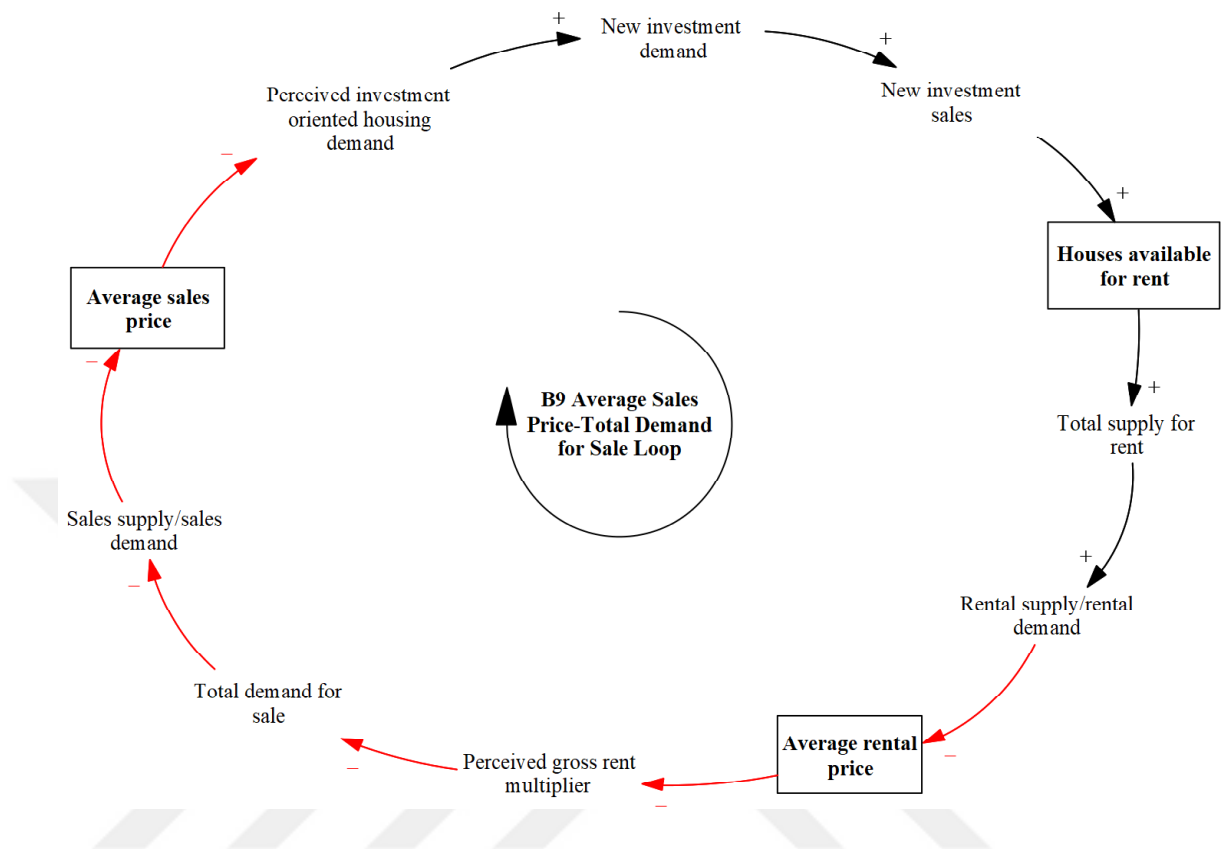


Figure 5.11. Average Sales Price-Total Demand for Sale Loop.

B9 loop is a positive feedback loop. It demonstrates the effect of sales price on average rental price and total sales demand. When the average sales price increases, investment-oriented housing demand decreases. As a result, sales from new houses made for investment purpose decrease. This is shown by *new investment sales* in the model. The number of houses purchased for investment purposes decreases, so there is less supply for rent in the market which decreases rental supply/rental demand ratio. If this ratio decreases, the average rental price increases. Profitability of owning a house increases which is represented by gross rent multiplier. When the average rental price increases, then the gross rent multiplier decreases. Lower gross rent multiplier indicates more return on investment. As a result, total demand for sale increases and the average sales price increases.

5.3. Stock-Flow Diagram of the Sectors

Stock flow diagram representation and detailed model description will be given in three sections which constitute the overall skeleton of the real estate market. These sections are housing supply, housing demand and housing prices.

5.3.1. Housing Supply Sector

Housing supply is provided to the system by new projects. New projects are introduced to the system by “Project Start Rate” flow. This flow represents the houses whose construction permits have been received and construction has started. Project start rate is driven by supply shortage which is the discrepancy between total demand for sale and total supply for sale. The stocks, flows and variables that are related to the housing supply are given in the figure 5.12 below:

$$\text{Project Start Rate} = \text{Project Start Rate by Shortage} \times (\text{Effect of New Vacant Houses} / \text{Project Start Rate by Shortage}). \quad (5.1)$$

$$\text{Project Start Rate by Shortage} = \text{Effect of Supply Shortage on Project Start Rate} \times \text{Normal Project Start Rate}. \quad (5.2)$$

$$\text{Supply Shortage} = \text{Total Demand for Sale} - \text{Total Supply for Sale}. \quad (5.3)$$

$$\text{Normal Project Start Rate} = 916504. \quad (5.4)$$

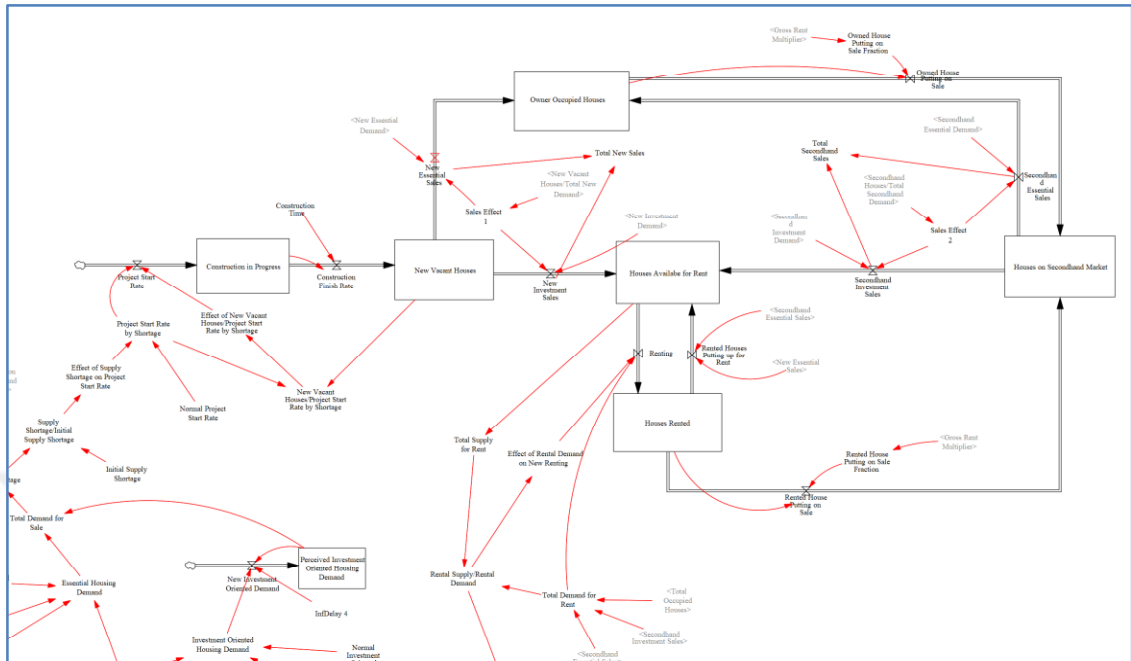


Figure 5.12. Stock-flow diagram of housing supply.

Increasing supply shortage, lack of supply, is one of the reasons of real estate sales price increase in Turkey. Basically, new projects are triggered by excess demand occurred in the market, thus main driver of new project start is supply shortage. The project start rate is also influenced by another variable *Effect of New Vacant Houses/Project Start Rate by Shortage*. To avoid excess supply in the market, *Effect of New Vacant Houses/Project Start Rate by Shortage* is introduced as a multiplicative effect to the formulation. This effect prevents the excessive start of new constructions when there are relatively enough new vacant houses ready to be sold. This effect function is given in the figure 5.13 below:

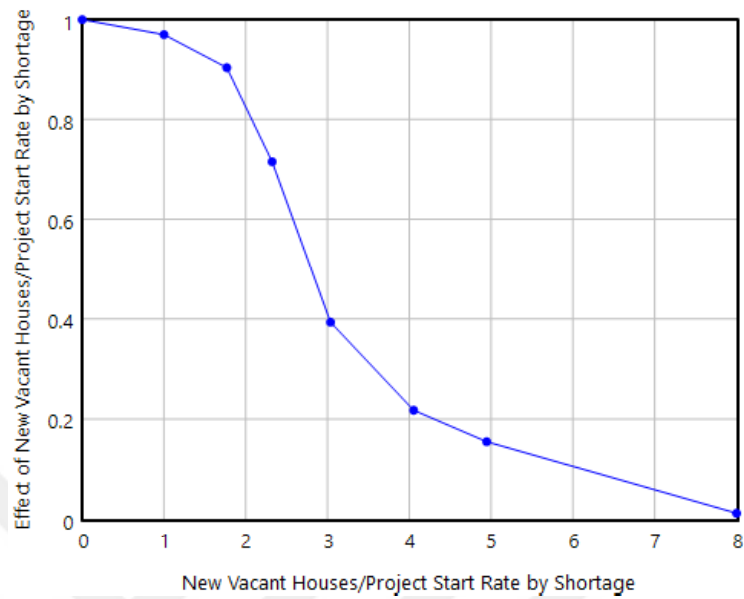


Figure 5.13. Effect of new vacant houses/project start rate by shortage.

Meanwhile, this effect starts to work clearly when New Vacant Houses/Project Start Rate by Shortage exceeds 2 as seen in the figure above. In other words, the project start rate is governed by this effect when new vacant houses become two times, or more than project start rate by shortage. If there are excessive amounts of new vacant houses which are unsold, the new project start rate is diminished.

The normal project start rate is 916 504 for the reference year 2010 [31]. Effect of supply shortage on project start rate is an effect function whose graph is given below:

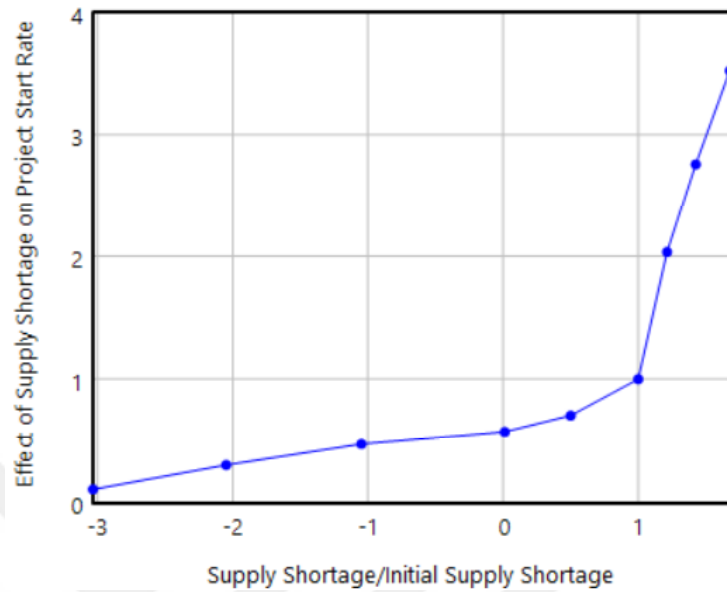


Figure 5.14. Effect of supply shortage on project start rate.

Initial supply shortage is 1 223 490 flats and represents the supply shortage at the beginning of the model (time=2010). This effect increases the project start rate if the supply shortage at a given time unit becomes more than the initial supply shortage. The graph crosses from point (1,1). Thus, the effect is formulated that calibrates the project start rate based on reference year. When supply shortage exceeds initial supply shortage (right of point (1,1)) effect function reacts more severely compared to left of point (1,1). For instance, when supply shortage is 50% of initial supply shortage, project start rate by shortage decreases by 30%. However, when supply shortage becomes two times of initial supply shortage then project start rate by shortage becomes 3.5 times. Here the effect is constructed for increasing new projects and enhancing enough sales supply. According to the graph, the effect function is drawn in such a way that project start rate flow reacts more when supply shortage increases above initial supply shortage to ensure adequate housing stock.

As given in equation 5.3, supply shortage is the difference between total demand for sale and total supply for sale. Total supply for sale is the sum of new sales supply (new vacant houses) and secondhand sales supply (houses on secondhand market):

$$\text{Total Supply for Sale} = \text{New Vacant Houses} + \text{Houses on Secondhand Market}. \quad (5.5)$$

The mechanisms behind the total demand for sale will be explained in section 5.3.2.

Construction in Progress stock represents houses which have construction permits. The houses represented in this stock are ongoing projects which will be completed in 3 years:

$$\text{Construction Time} = 3. \quad (5.6)$$

$$\text{Construction Finish Rate} = \frac{\text{Construction in Progress}}{\text{Construction Time}}. \quad (5.7)$$

$$\begin{aligned} \text{Construction in Progress}(t) = & \text{Construction in Progress}(t - dt) + \\ & (\text{Project Start Rate} - \text{Construction Finish Rate}) \times dt. \end{aligned} \quad (5.8)$$

Completed projects are shown by *Construction Finish Rate* flow and it represents the number of flats which get certificate of occupancy per year. It is assumed in the model that all construction will be completed, and each flat will have a certificate of occupancy after the building is completed. After the constructions are complete, new houses will flow to the *New Vacant Houses* stock. New vacant houses can be sold for two purposes mainly, those two types of sales are *New Essential Sales* and *New Investment Sales*. There are a total of five house stocks and the transfer of houses among each other is displayed by sales flows.

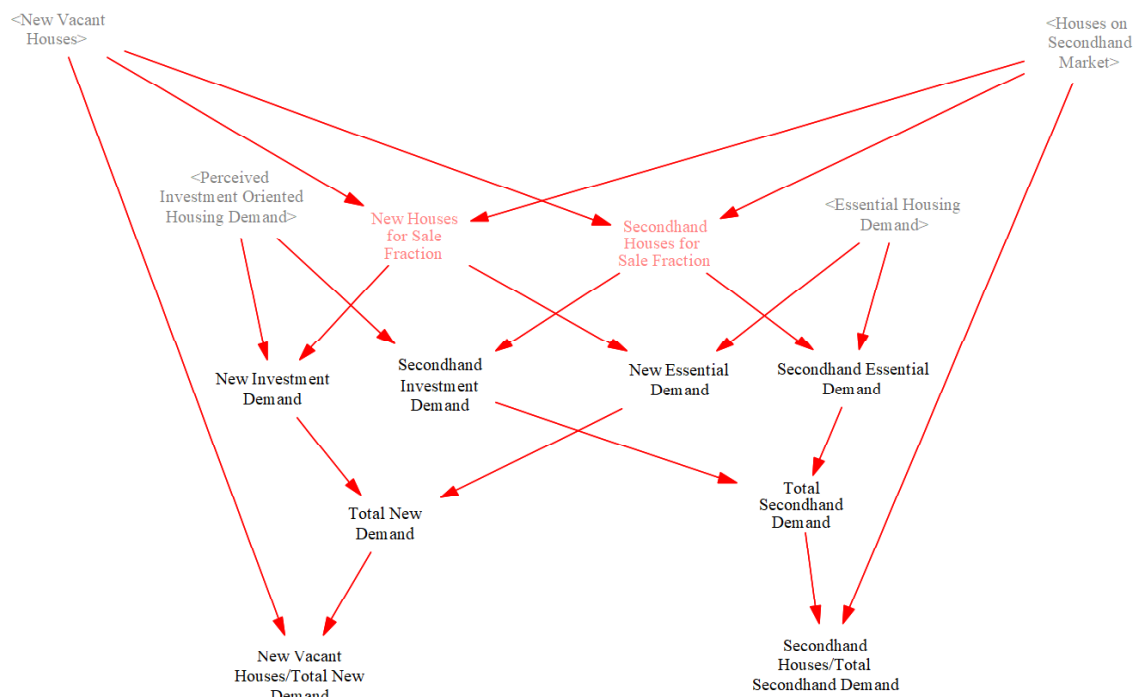


Figure 5.15. Demand creation within the model.

Sales of new houses and secondhand houses take place according to the diagram above. The above diagram is drawn because the distribution of demand among new and secondhand houses should be known precisely. New investment demand, secondhand investment demand, new essential demand and secondhand essential demand should be calculated from the model variables for the determination of sales equations.

Sales is calculated as the minimum of demand and supply. Sales rates cannot be higher than supply or demand. The minimum of supply and demand behaves like a bottleneck, so the sales rates are constrained by minimum limits. A special case of minimum formulation is “fuzzy min”. Fuzzy min (smooth min) formulations are used in the modeling of social systems thus it can be applied to our model [1].

Before explaining the formulation of each sales equation, the distribution of demand between new and secondhand houses must be made clearly. Here, two new fractions are

generated which are new houses for sale fraction and secondhand houses for sale fraction:

$$\text{New Houses for Sale Fraction} = \frac{\text{New Vacant Houses}}{\text{New Vacant Houses} + \text{Houses on Secondhand Market}} \quad (5.9)$$

$$\text{Secondhand Houses for Sale Fraction} = \frac{\text{Houses on Secondhand Market}}{\text{New Vacant Houses} + \text{Houses on Secondhand Market}} \quad (5.10)$$

While calculating these fractions, it is assumed that the demands are proportional to the distribution of the houses between the new and secondhand houses. This is a simplifying assumption used for calculation of demands separately. To exemplify, we calculate the new investment demand as below:

$$\text{New Investment Demand} = \text{Perceived Investment Oriented Housing Demand} \times \text{New Houses for Sale Fraction}. \quad (5.11)$$

Secondhand investment demand, new essential demand and secondhand essential demand are calculated in the same way. Total new demand is calculated as the sum of new investment demand and new essential demand. Total Secondhand demand is calculated as the sum of secondhand investment demand and secondhand essential demand. Finally, New vacant houses/total new demand and Secondhand houses/total secondhand demand ratios are calculated for formulating the sales flow. Sales flows are formulated with fuzzy min structure. Each of the sales flows are formulated as below:

$$\text{New Essential Sales} = \text{New Essential Demand} \times \text{Sales Effect 1}. \quad (5.12)$$

$$\text{New Investment Sales} = \text{New Investment Demand} \times \text{Sales Effect 1}. \quad (5.13)$$

$$\text{Secondhand Essential Sales} = \text{Secondhand Essential Demand} \times \text{Sales Effect 2} \quad (5.14)$$

$$\text{Secondhand Investment Sales} = \text{Secondhand Investment Demand} \times \text{Sales Effect 2}. \quad (5.15)$$

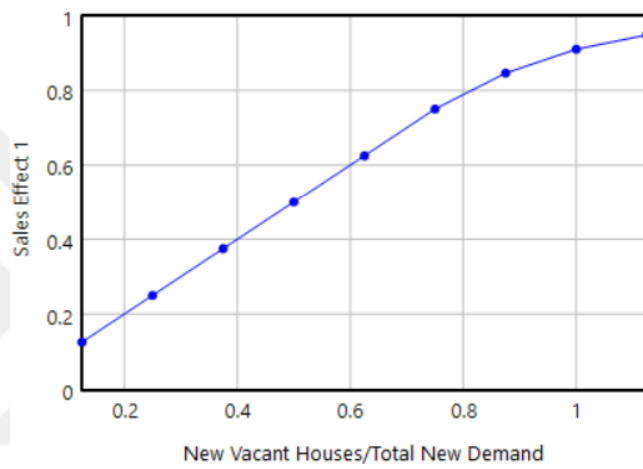


Figure 5.16. Sales Effect 1.

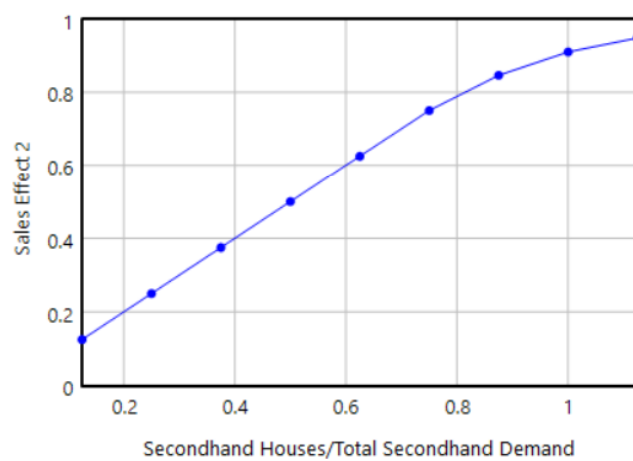


Figure 5.17. Sales Effect 2.

Both sales effects are constructed the same for simplicity. The points on the graphs are given below. According to the points, *sales effect 1* and *sales effect 2* are unity function ($y=x$) until (0.75,075) and after that point function stays below $y=x$ line and the sales effects converge to 1 smoothly.

Input	Output
0.125	0.125
0.25	0.25
0.375	0.375
0.5	0.5
0.625	0.625
0.75	0.75
0.875	0.846
1	0.91
1.125	0.948

Figure 5.18. Points on sales effect graphs.

We can examine separately what happens when the axis is less than 1 and more than 1. For this purpose, new sales formulations can be examined since all 4 sales flows are formulated in the same manner:

$$\text{New Essential Sales} = \text{New Essential Demand} \times \text{Sales Effect 1.} \quad (5.16)$$

The x-axis of the sales effect 1 is *new vacant houses/total new demand*. When *new vacant houses/total new demand* < 1 , the effect function becomes $y=x$ and:

$$\text{New Essential Sales} = \text{New Essential Demand} \times \frac{\text{New Vacant Houses}}{\text{Total New Demand}}, \quad (5.17)$$

$$\text{New Investment Sales} = \text{New Investment Demand} \times \frac{\text{New Vacant Houses}}{\text{Total New Demand}}, \quad (5.18)$$

$$\begin{aligned} \text{Total New Sales} &= \text{New Essential Sales} + \text{New Investment Sales} = \\ \text{New Vacant Houses} \times \frac{\text{Total New Demand}}{\text{Total New Demand}} &= \text{New Vacant Houses}, \end{aligned} \quad (5.19)$$

Thus, when new vacant houses are less than the total new demand it becomes the bottleneck for total new sales. When *new vacant houses/total new demand* > 1, the effect function converges to $y=1$ and:

$$\text{New Essential Sales} = \text{New Essential Demand} \times 1. \quad (5.20)$$

$$\text{New Investment Sales} = \text{New Investment Demand} \times 1. \quad (5.21)$$

$$\begin{aligned} \text{Total New Sales} &= \text{New Essential Demand} + \text{New Investment Demand} = \\ \text{Total New Demand}. \end{aligned} \quad (5.22)$$

When total new demand is the bottleneck, total new sales become total new demand. Houses more than this demand cannot be sold. Thus, we have ensured that sales rates are constrained by sales supply and demand. After explaining sales rate formulations, housing stocks are explained below.

According to the stock-flow diagram of housing supply, change of new vacant houses is represented by the equation below:

$$\begin{aligned} \text{New Vacant Houses}(t) &= \text{New Vacant Houses}(t - dt) + (\text{Construction Finish Rate} - \\ &\text{New Essential Sales} - \text{New Investment Sales}) \times dt. \end{aligned} \quad (5.23)$$

By new essential sales, households purchase a house from new sales stock for residing. Similarly, people also buy houses from old housing stock for residing. *Secondhand essential*

sales represent those sales. *New essential sales* and *secondhand essential sales* become the inflow of *Owner Occupied Houses* stock. The change of this stock is given below:

$$\begin{aligned} \text{Owner Occupied Houses}(t) = & \text{Owner Occupied Houses}(t - dt) + \\ & (\text{New Essential Sales} + \text{Secondhand Essential Sales} - \\ & \text{Owned House Putting on Sale}) \times dt. \end{aligned} \quad (5.24)$$

$$\begin{aligned} \text{Owned House Putting on Sale} = & \text{Owner Occupied Houses} \times \\ & \text{Owned House Putting on Sale Fraction}. \end{aligned} \quad (5.25)$$

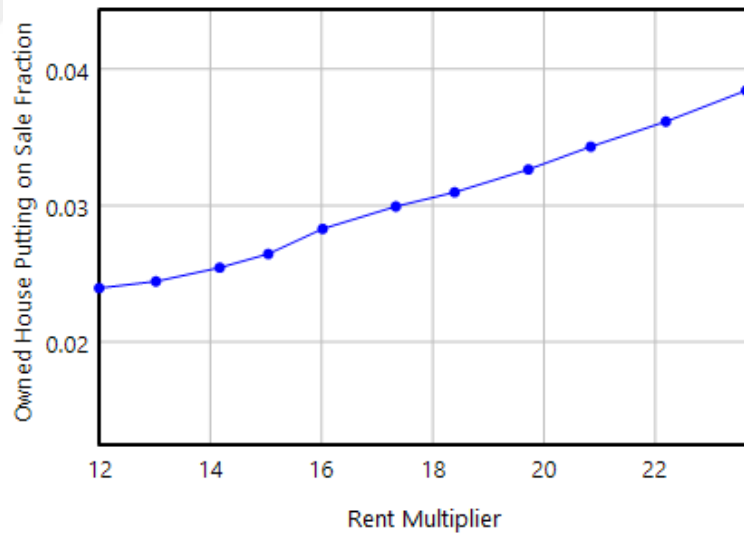


Figure 5.19. Effect of rent multiplier on owned house putting on sale fraction.

According to a study by the Turkish Statistical Institute (TUIK), the proportion of households who own their houses dropped from 60.7% in 2022 to 56.2% in 2023. It is indicated that over 7.3 million households in Turkey are now renting a house to reside in [39, 40]. *Owned house putting on sale* flow represents households' action of putting their own houses on sale. Those households decide to put on sale based on rent multiplier at the given year. Rent multiplier

is a measure for comparison of the market value of a house to rental income of that house. If rent multiplier increases, it means purchasing a house will not bring much return on investment. In other words, rental value of houses decreases and sales value increases. Thus, households tend to sell their own houses. It is assumed that those households do not purchase a house again, they rent a house to reside in it. They continue staying in the houses until they are sold, after those houses are sold, they seek to find a rental house. The change in secondhand market stock is given below:

$$\begin{aligned} \text{Houses on Secondhand Market}(t) = & \text{Houses on Secondhand Market}(t - dt) + \\ & (\text{Owned House Putting on Sale} + \text{Rented House Putting on Sale} - \\ & \text{Secondhand Essential Sales} - \text{Secondhand Investment Sales}) \times dt. \end{aligned} \quad (5.26)$$

$$\begin{aligned} \text{Rented House Putting on Sale} = & \text{Houses Rented} \times \\ & \text{Rented House Putting on Sale Fraction}. \end{aligned} \quad (5.27)$$

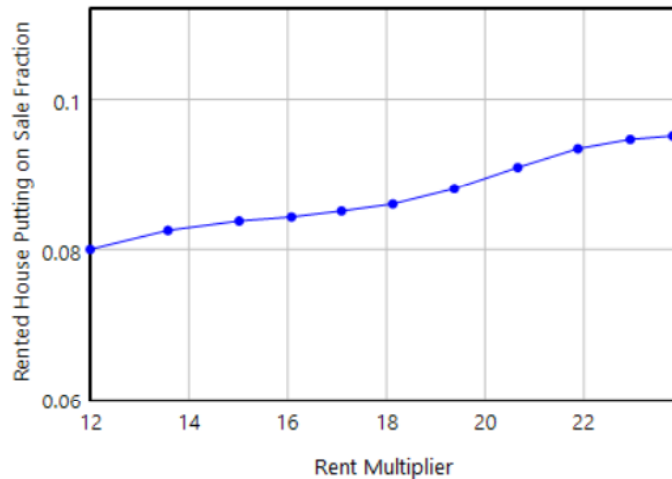


Figure 5.20. Effect of rent multiplier on rented house putting on sale fraction.

Like owned houses, rented houses in the market are also put on sale by the landlords. Rented houses putting on sale flow is affected by rent multiplier. When rent multiplier rises,

landlords start to think that it is not advantageous to rent out their houses to tenants anymore. Thus, they start to evict the tenants. Like homeowners who decide to put their houses on sale because of rent multiplier effect, those tenants also continue staying in the houses until houses are sold. After those houses are sold, they search to find a rental house.

Until now, the sales market is explained on houses supply and sales rates flows. Below, the rental market stocks and flows are given:

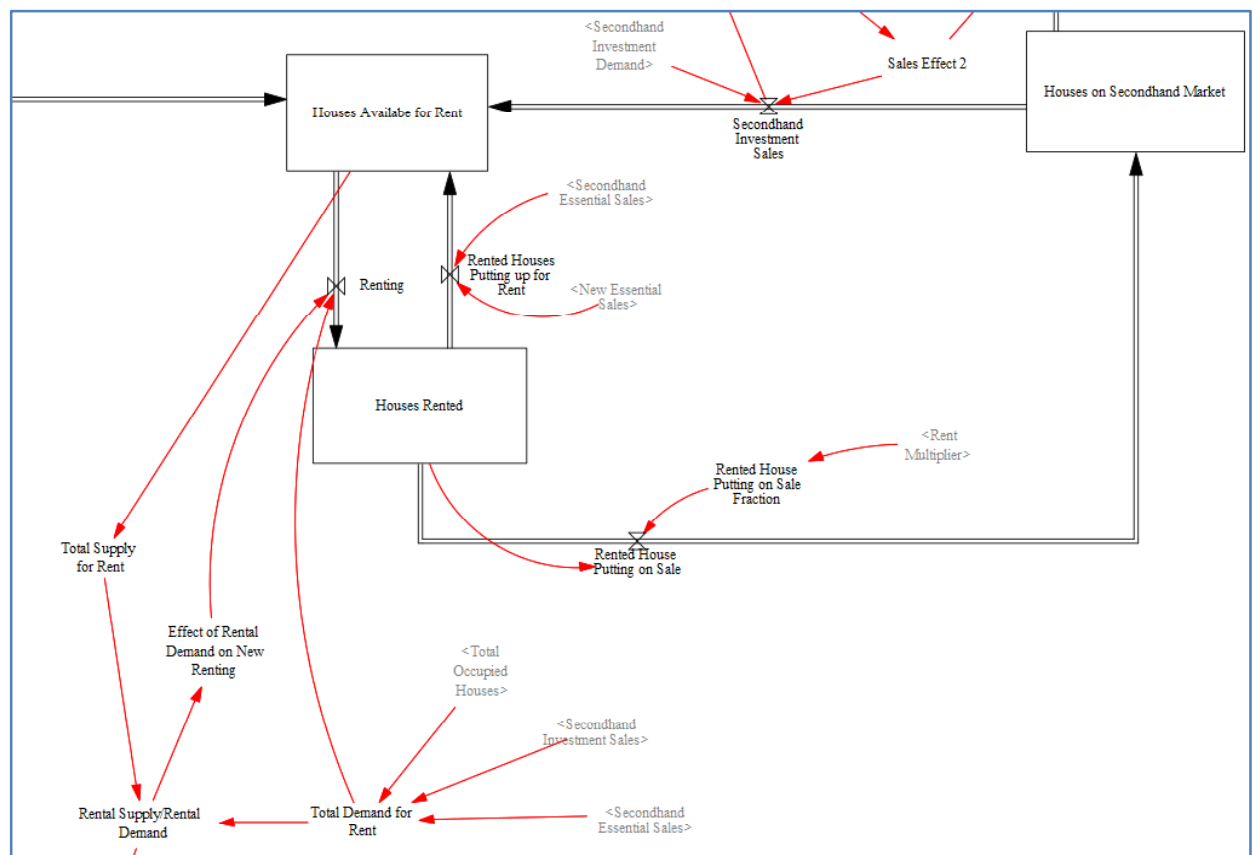


Figure 5.21. Stocks for rental market.

According to the above figure, the rental housing market consists of two stocks: “Houses Available for Rent” and “Houses Rented”. Houses available for rent stock symbolize rental houses on advertisement. If any of these houses are rented by a tenant, this house flows to “Houses Rented” stock by “Renting” flow. Change of “Houses Available for Rent” stock is given below:

$$\begin{aligned}
\text{Houses Available for Rent}(t) = & \text{Houses Available for Rent}(t - dt) + \\
& (\text{New Investment Sales} + \text{Secondhand Investment Sales} + \\
& \text{Rented Houses Putting up for Rent} - \text{Renting}) \times dt.
\end{aligned} \tag{5.28}$$

$$\begin{aligned}
\text{Rented Houses Putting up for Rent} = & \text{New Essential Sales} + \\
& \text{Secondhand Essential Sales}.
\end{aligned} \tag{5.29}$$

“Rented house putting up for rent” flow represents the households’ purchase of a house for residing in. In the model we assumed that households can either reside in the house they own, or rent a house to reside in. No households are homeless. The households who own a house reside in the first house they buy. Thus, a household who does not own property does not purchase his first house for investment purposes. New essential sales and secondhand essential sales represent households’ actions to purchase a house for residing. Previously, they were tenants in the house they reside in. Thus, the houses they were sitting in are counted under “rented houses putting up for rent” flow since when they purchase a new house, the houses they are currently sitting in are advertised for rent.

Lastly, change of “Houses Rented” stock and the formulation for renting is given:

$$\begin{aligned}
\text{Houses Rented}(t) = & \text{Houses Rented}(t - dt) + (\text{Renting} - \\
& \text{Rented Houses Putting up for Rent} - \text{Rented House Putting on Sale}) \times dt.
\end{aligned} \tag{5.30}$$

$$\begin{aligned}
\text{Renting} = & \text{Total Demand for Rent} * \text{Effect of Rental Demand on New Renting}.
\end{aligned} \tag{5.31}$$

$$\begin{aligned}
\text{Total Demand for Rent} = & (\text{Total Occupied Houses} \times 0.03) + \\
& \text{Secondhand Investment Sales} + \text{Secondhand Essential Sales}.
\end{aligned} \tag{5.32}$$

For renting formulation, a fuzzy min structure is implemented as in sales flow. The effect function is given below:

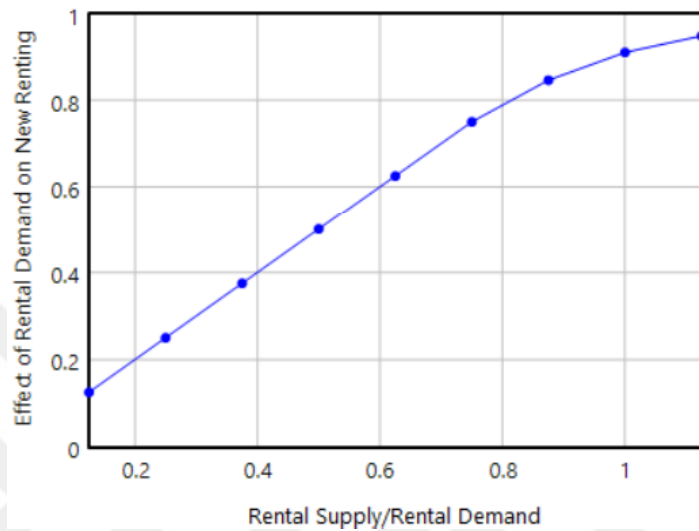


Figure 5.22. Effect of rental demand on new renting.

As explained in detail for new essential and new investment sales flows, “Renting” flow is restricted by rental supply and rental demand. For this purpose, fuzzy min effect function is formulated as in the figure above.

Total occupied houses represent housing stocks in which households reside, so it is a criterion for the number of households, in other words, population. In the base behavior, total occupied houses increase since there is population growth. The population grows by 3% each year according to estimates. For simplicity, we assume that the demand deriving from population growth is included in the rental demand. In other words, every household’s first house is a rental house. For this reason, 3% of the total occupied houses at each time unit is added to total demand for rent. The detailed explanation of the total demand for rent is explained in section 5.3.2.

5.3.2. Housing Demand Sector

In the housing demand sector, housing demand is evaluated with three types of demand. Sales demand is separated into two: essential housing demand and investment-oriented housing demand and there is the total demand for rent. The stock-flow diagram and the relations of these demands with other sectors are shown in the figure below:

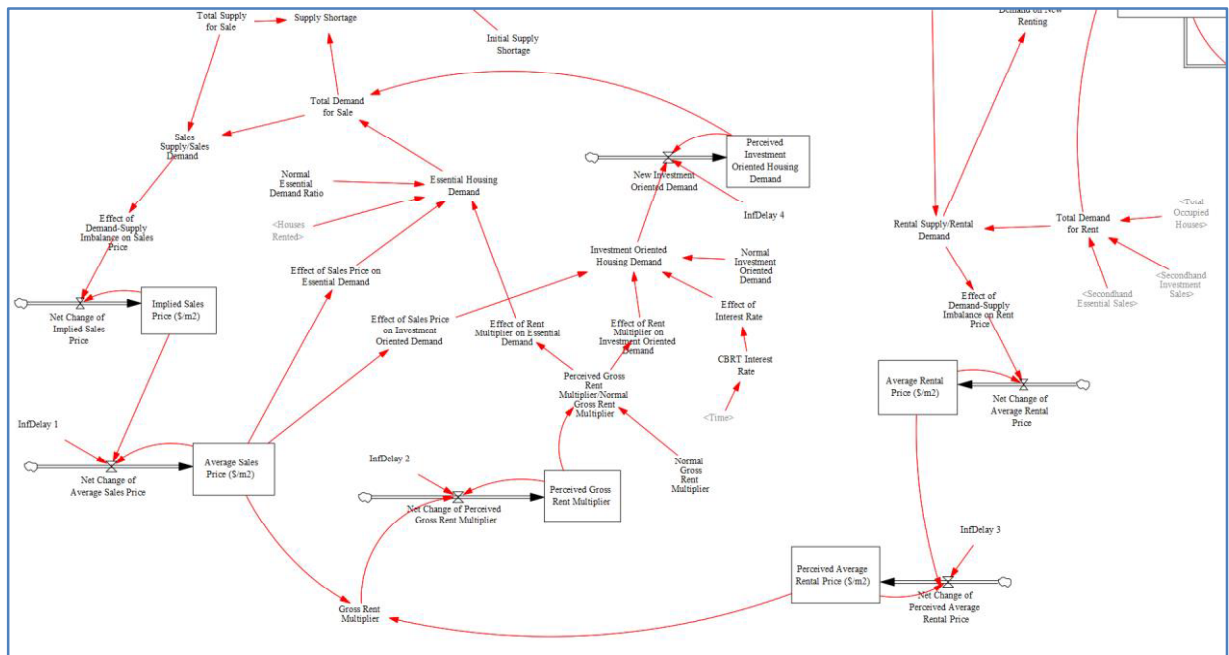


Figure 5.23. Stock flow diagram of housing demand.

$$\text{Total Demand for Sale} = \text{Essential Housing Demand} + \text{Perceived Investment Oriented Housing Demand.} \quad (5.33)$$

Equation for essential housing demand is given below:

$$\begin{aligned} \text{Essential Housing Demand} = & \text{Effect of Rent Multiplier on Essential Demand} \times \\ & \text{Effect of Sales Price on Essential Demand} \times \text{Houses Rented} \times \\ & \text{Normal Essential Demand Ratio.} \end{aligned} \quad (5.34)$$

$$\text{Normal Essential Demand Ratio} = 0.15. \quad (5.35)$$

In equation 5.34, both rent multiplier and sales price affect *essential housing demand*. Rent multiplier is the determining factor in deciding whether to rent or purchase a house. However, a household's ability to buy a house is also related to how much the house costs. Additionally, we added the effect of the sales price separately to the formulation.

Houses rented stock denote the houses in which tenants stay. Since essential demand represents the demand of households that purchase a house to reside in, tenants constitute this demand. It is guessed that 15% of households in *Houses Rented* stock wants to buy a house to reside in. There are two effects that change the essential demand.

The average sales price influences both essential housing demand and investment-oriented housing demand. It also affects housing demand over gross rent multiplier. The effect of sales price on essential housing demand is a decreasing function and it is given below:

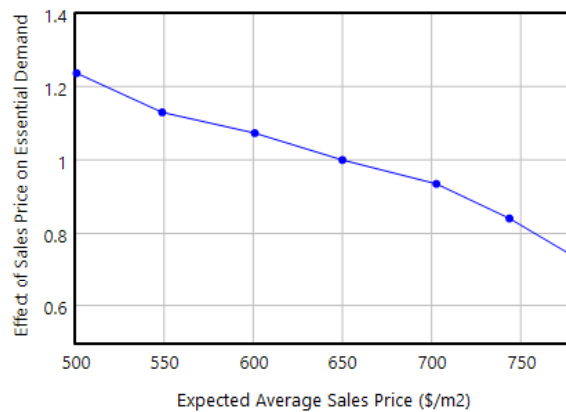


Figure 5.24. Effect of sales price on essential housing demand.

The approximate average sales price is 650 \$/m² in 2010 given in the literature [23]. The effect becomes 1 at the reference year conditions. When the sales price increases compared to the reference year's price, essential demand lowers, while below 650 \$/m² demand increases up to 20% more. When the sales price of a house becomes 780 \$/m² essential demand is decreased by 25% and does not decrease more if the average sales price exceeds 780 \$/m². Since there is no exact data for the essential demand of a house, the effect of sales price on essential demand is adjusted with reference to the base year 2010.

The effect of rent multiplier on essential demand is shown in the figure below:

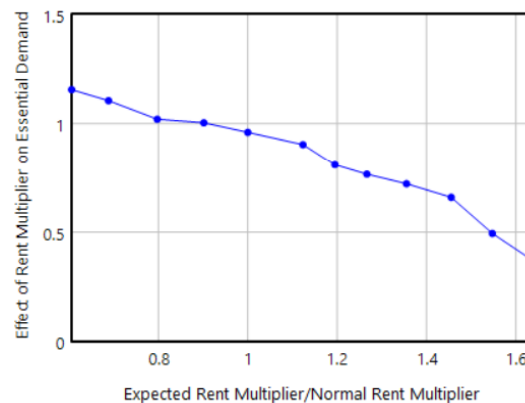


Figure 5.25. Effect of rent multiplier on essential housing demand.

The effect is adjusted with respect to normal rent multiplier which is 17.6 years [36]. If the gross rent multiplier falls below normal gross rent multiplier, this indicates either the rental value of a house increases or sales cost a house decrease. In both cases, essential housing demand increases. As a result, the effect becomes more than 1 and makes essential demand increase.

Investment-oriented housing demand refers to purchasing residential properties mainly for the aim of generating returns, rather than for personal use or shelter. We include the actions of investors to show the effect of investment-related decisions on the price of houses by *Investment oriented housing demand* stock. However, the effect of speculation on investment-oriented demand is not included in the model for simplicity.

Equation for investment-oriented housing demand is given below:

$$\begin{aligned} \text{Investment Oriented Housing Demand} = & \\ & \text{Effect of Sales Price on Investment Oriented Demand} \times \\ & \text{Effect of Rent multiplier on Investment Oriented Demand} \times \\ & \text{Normal Investment Oriented Demand} \times \text{Effect of Interest Rate.} \end{aligned} \quad (5.36)$$

$$\text{Normal Investment Oriented Demand} = 900000. \quad (5.37)$$

In equation 5.36, both rent multiplier and sales price affect *investment housing demand*. The gross rent multiplier is a screening metric used by investors to compare rental property opportunities in a given market. The rent multiplier shows how many years it will take to recover the amount paid for a property through rental income. A high value for this ratio indicates that the return period for real estate investments is long. Similar to the case for essential housing demand, rent multiplier affects investment-oriented housing demand. Moreover, a household's ability to buy a house is also related to the cost of the house. Thus, the effect of the sales price and the effect of rent multiplier are included in the formulation.

The *effect of sales price on investment-oriented housing demand* is also a decreasing function and it is given below:

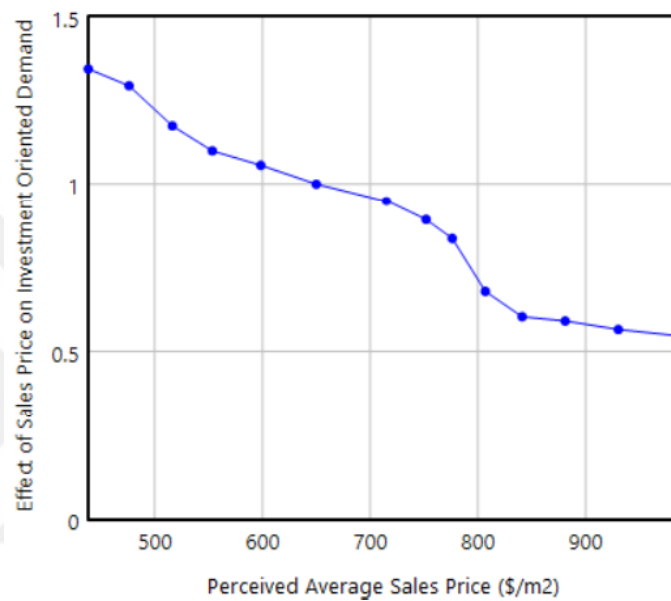


Figure 5.26. Effect of Sales Price on Investment Oriented Demand.

The double S-shaped curve structure is used to represent the effect of sales price on investment-oriented demand. The S-shaped curve typically has three main phases: slow initial growth, rapid escalation, and stabilization. S-shaped curve can be utilized to show how demand responds to changes in sales price. The effect is built with respect to the reference year where the average sales price is 650 \$/m². The effect function is detailed more when the expected sales price exceeds 650 \$/m² since the trend is towards increasing prices after 2010. The effect is drawn in such a manner since the reaction of the market to the sales price is very sensitive and the demand changes significantly when the price moves near to reference price (650 \$/m²). Moreover, according to the literature, the average sales price of a house is around 650 \$/m² after 2010 [23]. After the price moves far away from the reference price of 650 \$/m², the effect of price settles down. This effect function can be supported by the nature of s-shaped growth. A small reduction in price could result in a considerable increase in demand, since consumers

become more willing to purchase a house. This represents the initial growth phase. In the acceleration phase, when prices continue decreasing and housing becomes more affordable, more consumers enter the market and the increase in demand accelerates. In the stabilization phase, further decreases in price do not have a considerable increase in demand, because most potential buyers have already purchased houses. This situation is demonstrated by the flattening of S-curve [1].

The effect of rent multiplier on investment-oriented housing demand is a decreasing function and it is given below:

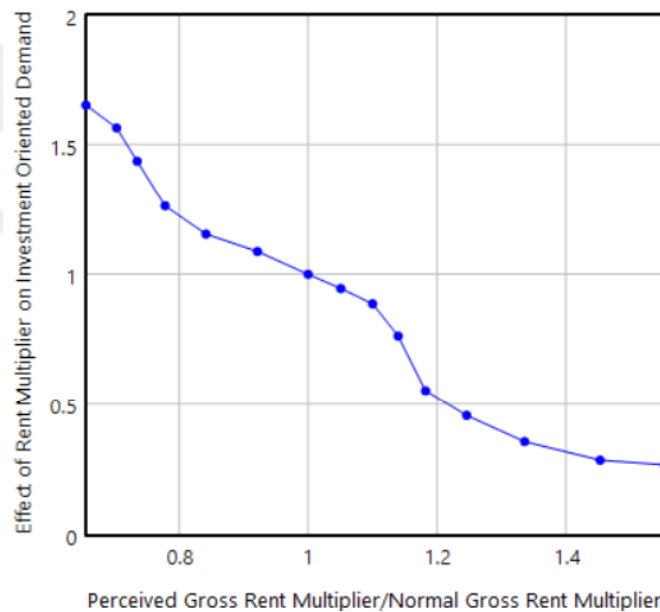


Figure 5.27. Effect of Rent Multiplier on Investment Oriented Demand.

Investment-oriented demand demonstrates the demand for purchasing a house since its rental yield is more advantageous compared to property yield. Again, the effect becomes 1 at the reference value and it is drawn with respect to normal gross rent multiplier which is 17.6 years. Compared to the normal gross rent multiplier, if the perceived rent multiplier becomes smaller, the property cost of the house covers the rental price in a shorter period. Lower gross rent multiplier brings more return on investment. As a result, investment-oriented demand

increases. As explained above, double S-shaped curve structure is used with respect to the reference point (1,1).

There is an interplay between the interest rates and housing market variables. Thus, examining how interest rates fluctuations affect the housing market is very important, especially for investment. In Turkey, investment on housing is popular and affected by economic conditions such that with the increasing interest rates, investment costs rise, and households cannot afford housing loans and demand for housing falls. Hence, the effect of interest rates is included as a multiplier of investment-oriented housing demand [27, 41]. According to the literature data, The Central Bank of the Republic of Turkey (CBRT) set the interest rates between 2010 and 2024 as in the figure below [42]:

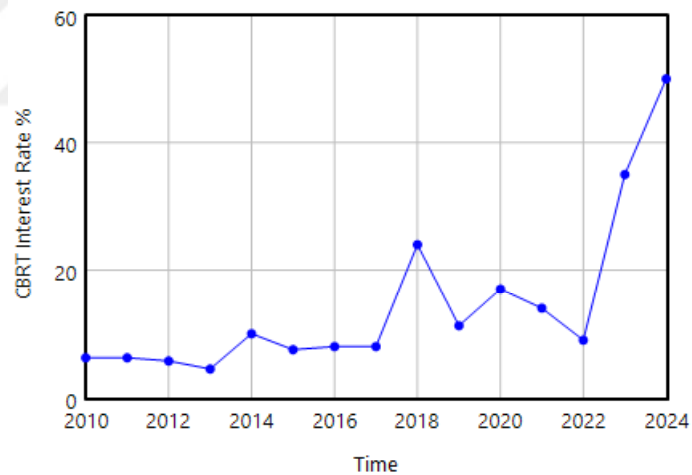


Figure 5.28. CBRT Interest Rates from 2010 to 2024 (%).

The multiplicative effect function of CBRT interest rate on investment-oriented housing demand is a decreasing function as drawn in figure 5.29:

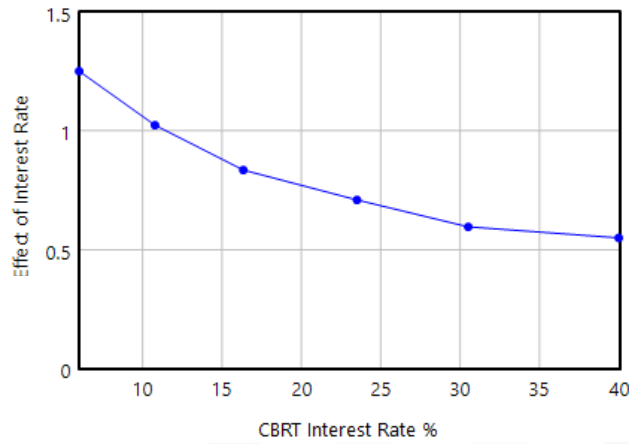


Figure 5.29. Effect of CBRT Interest Rates on Investment-oriented Demand.

First order information delay structure is used to represent perceived investment-oriented demand which is the delayed output of investment-oriented housing demand. This information delay represents the lag that is inherent in the flow of information through households and investors. Since the effect of price and rent multiplier on investment-oriented housing demand is a decision-making process, displaying this process by a delay structure is a sensible way to show how this system works in the real world:

$$\text{New Investment Oriented Demand} = \frac{\text{Investment Oriented Housing Demand} - \text{Perceived Investment Oriented Housing Demand}}{\text{InfDelay4}}. \quad (5.38)$$

$$\begin{aligned} \text{Perceived Investment Oriented Housing Demand}(t) = & \\ \text{Perceived Investment Oriented Housing Demand}(t - dt) + & \\ \text{New Investment Oriented Demand} \times dt. & \end{aligned} \quad (5.39)$$

Equation regarding total demand for rent is given below:

$$\begin{aligned} \text{Total Demand for Rent} = & (\text{Total Occupied Houses} \times 0.03) + \\ & \text{Secondhand Investment Sales} + \text{Secondhand Essential Sales}. \end{aligned} \quad (5.40)$$

Each year it is assumed that the population grows 3% and the additional demand created by population growth is included in total demand for rent for simplicity. Secondhand investment sales and secondhand essential sales represent sales from “Houses on Secondhand Market”. When these sales take place, it is assumed that households that were previously in this stock go searching for a rental house immediately. Thus, they are included in the total demand for rent in the period when the sale takes place. For further simplicity, we assume that those households find a house and settle in during the sales period.

5.3.3. Housing Price Sector

Sales and rental prices are modeled separately because they exhibit different dynamics. Depending on the period, either renting or buying a house might be more advantageous than the other. Sales and rental price of a house is directly affected by the supply demand imbalance in the model. When there is high demand for housing but limited supply available, it creates a seller's market where prices tend to increase. Conversely, when there is an excess supply and not enough demand, it creates a buyer's market where prices decrease. Therefore, the balance between supply and demand is a key factor influencing housing prices. In other words, prices react to the supply and demand sector dynamics [9, 17, 43]. However, the price response does not take place immediately. There is usually an information delay in the time it takes for awareness of supply and demand shifts in the market. Additionally, inertia in the market can deter immediate price changes. For instance, sellers could be indecisive to drop prices suddenly. Similarly, buyers might need time to change their purchasing behaviors after thoroughly evaluating market conditions. Thus, price response with respect to buyers' and sellers' perspectives is a delayed outcome of demand-supply imbalance in the market.

The stock-flow representation related to the sales and rental price dynamics are shown below:

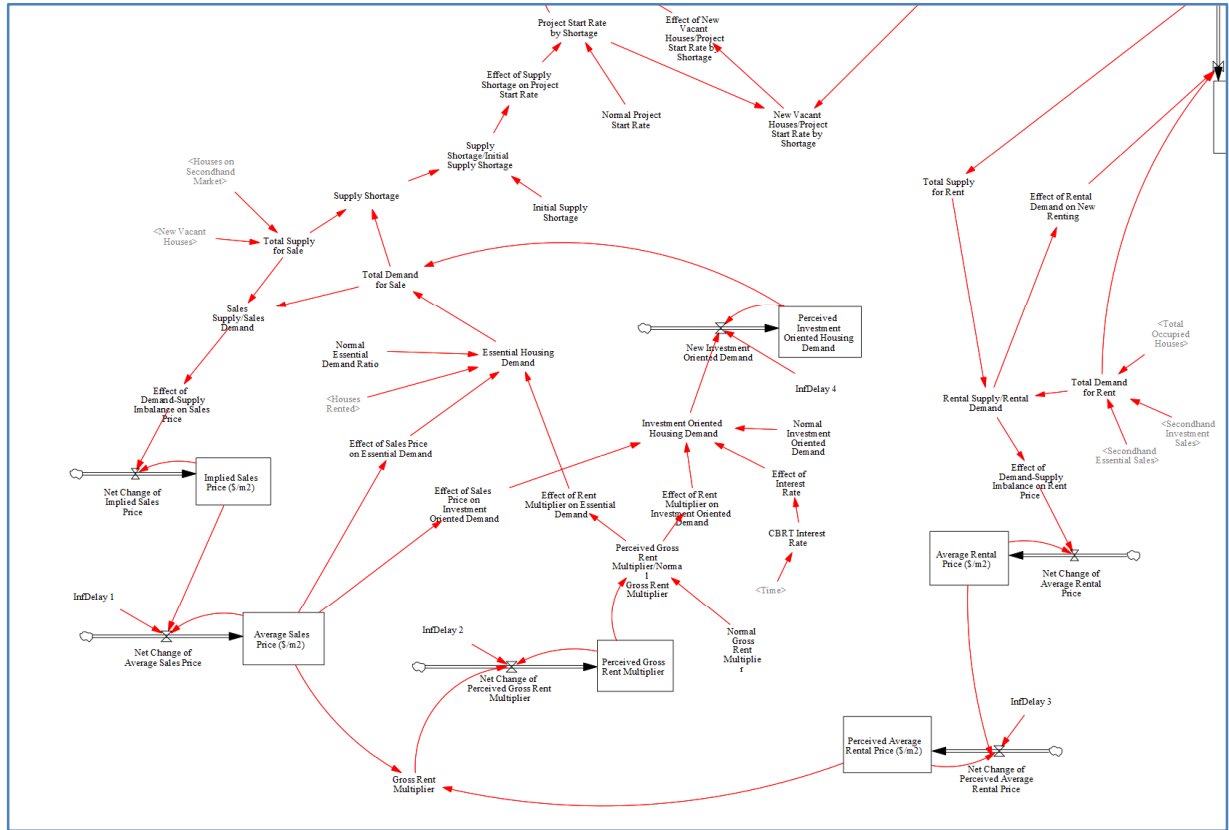


Figure 5.30. Stock flow diagram of housing price sector.

There are two stocks showing average prices and each stock gives average prices in terms of \$/m². Sellers' action to update the price depends on "Average Sales Price". When landlords, contractors and construction companies are convinced that there is actually an imbalance between the demand and supply, the sales price is updated:

$$\text{Sales Supply Demand Ratio} = \frac{\text{Sales Supply}}{\text{Sales Demand}} = \frac{\text{Total Supply for Sale}}{\text{Total Demand for Sale}} \quad (5.41)$$

Effect of Demand-Supply Imbalance on Sales Price is an effect function which displays the effect of demand and supply balance on sales price, and it is given in the figure 5.31:

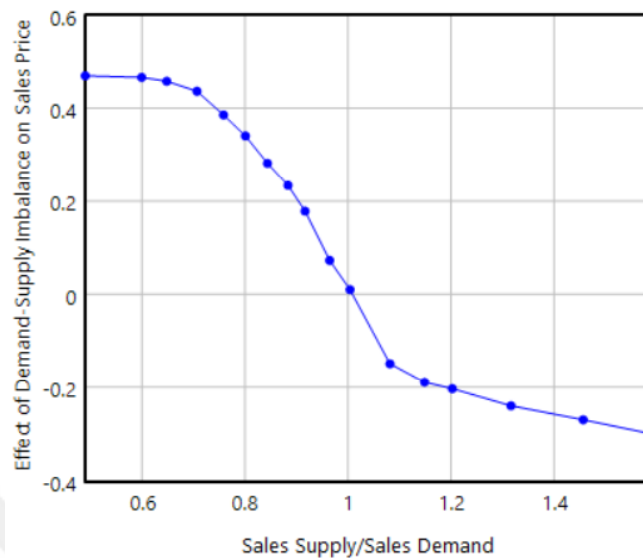


Figure 5.31. Effect of Demand-Supply Imbalance on Sales Price.

According to literature, Kenny (1999) worked on demand-supply dynamics of Irish housing market [9]. According to his findings, sales prices tend to increase when there is excess demand. The shape of the effect graph is drawn as S-shaped decreasing function similar to the formulations found in published work [44].

When sales supply exceeds sales demand, which indicates the ratio becomes higher than 1, the effect becomes negative and sales price decreases. When sales demand is higher than sales supply, sales price increases since the effect is positive.

Stocks, flows and effects related to sales price change are given in the figure below:

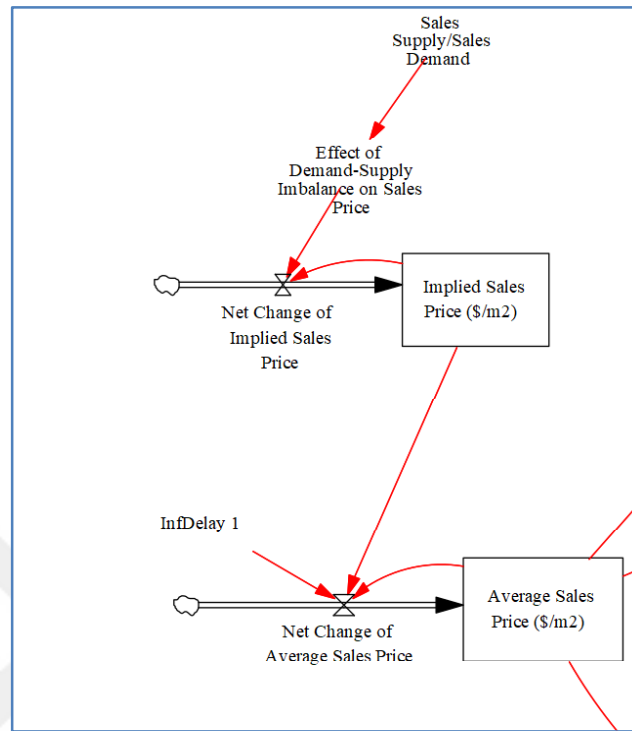


Figure 5.32. Change of average sales price.

The *implied sales price* and *average sales price* change according to their inflows. *Net Change of Average Sales Price* is the net flow showing the price increase and decrease. The equation for this flow is:

$$\text{Net Change of Implied Sales Price} = \text{Implied Sales Price} \times \text{Effect of Demand} - \text{Supply Imbalance on Sales Price}. \quad (5.42)$$

Change of the stock is the given by the differential equation below:

$$\begin{aligned} \text{Implied Sales Price}(t) = & \text{Implied Sales Price}(t - dt) + \\ & \text{Net Change of Implied Sales Price} \times dt. \end{aligned} \quad (5.43)$$

The *average sales price* stock shows the updated price after a delay. Information delay structure is used to exhibit behavior, which is commonly used in system dynamics models to show delays [1]. From the figure above, the *implied sales price* is an input to the information delay structure, and the delayed output is *average sales price*. Correction flow equation corresponding to this representation is given below:

$$\text{Net Change of Average Sales Price} = \frac{\text{Implied Sales Price} - \text{Average Sales Price}}{\text{InfDelay 1}} \quad (5.44)$$

$$\begin{aligned} \text{Average Sales Price (t)} &= \text{Average Sales Price (t - dt)} + \\ &\quad \text{Net Change of Average Sales Price} \times dt. \end{aligned} \quad (5.45)$$

The effect of demand-supply imbalance and the related equations are similar for both sales and rental price. There are two stocks showing rental price and each stock gives average rental price in terms of \$/m². The *perceived average rental price* stock denotes applied average rental prices. It displays the contractor's action to update the price. Similar to the case in sales price, when contractors and construction companies are convinced that there is actually an imbalance between the demand and supply, the rental price is updated.

$$\text{Rental Supply Demand Ratio} = \frac{\text{Rental Supply}}{\text{Rental Demand}} = \frac{\text{Total Supply for Rent}}{\text{Total Demand for Rent}}. \quad (5.46)$$

Effect of Demand-Supply Imbalance on Rental Price is an effect function which displays the effect of demand-supply imbalance on rental price, and it is given in the graph below:

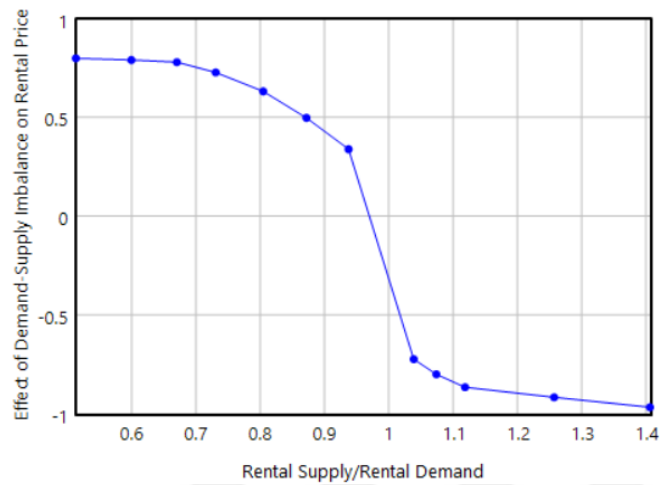


Figure 5.33. Effect of Demand-Supply Imbalance on Rental Price.

When rental supply exceeds rental demand, which means the ratio becomes higher than 1, the effect becomes negative and rental price decreases. If rental demand exceeds rental supply, rental prices increase.

Stocks, flows and effects related to rental price change are given in the figure below:

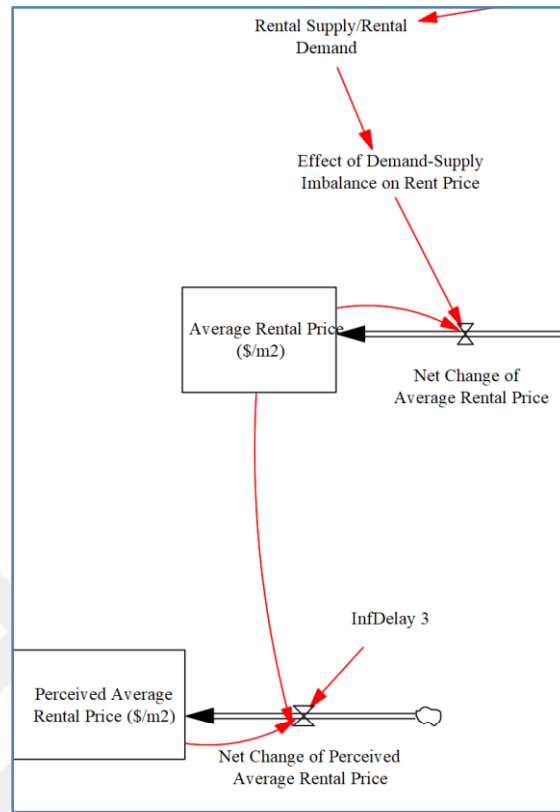


Figure 5.34. Change of average rental price.

Average rental price and perceived average rental price change according to their inflows. Net Change of Average Rental Price is the net flow (biflow) showing the price increase and decrease. The equation for this flow is:

$$\text{Net Change of Average Rental Price} = \text{Average Rental Price} \times \text{Effect of Demand} - \text{Supply Imbalance on Rent Price}. \quad (5.47)$$

The change in average rental price is the given by the differential equation below:

$$\text{Average Rental Price}(t) = \text{Average Rental Price}(t - dt) + \text{Net Change of Average Rental Price} \times dt. \quad (5.48)$$

Perceived average rental price stock demonstrates the updated rental price after a delay. Again, first-order information delay structure is used to exhibit behavior. From the figure above, *average rental price* is an input to the information delay structure, and the delayed output is *perceived average rental price*. Correction flow equation is given below:

Net Change of Perceived Average Rental Price

$$= \frac{\text{Average Rental Price} - \text{Perceived Average Rental Price}}{\text{InfDelay 3}}$$

(5.49)

Perceived Average Rental Price (t)

$$= \text{Perceived Average Rental Price (t - dt)}$$

$$+ \text{Net Change of Perceived Average Rental Price} \times dt$$

(5.50)

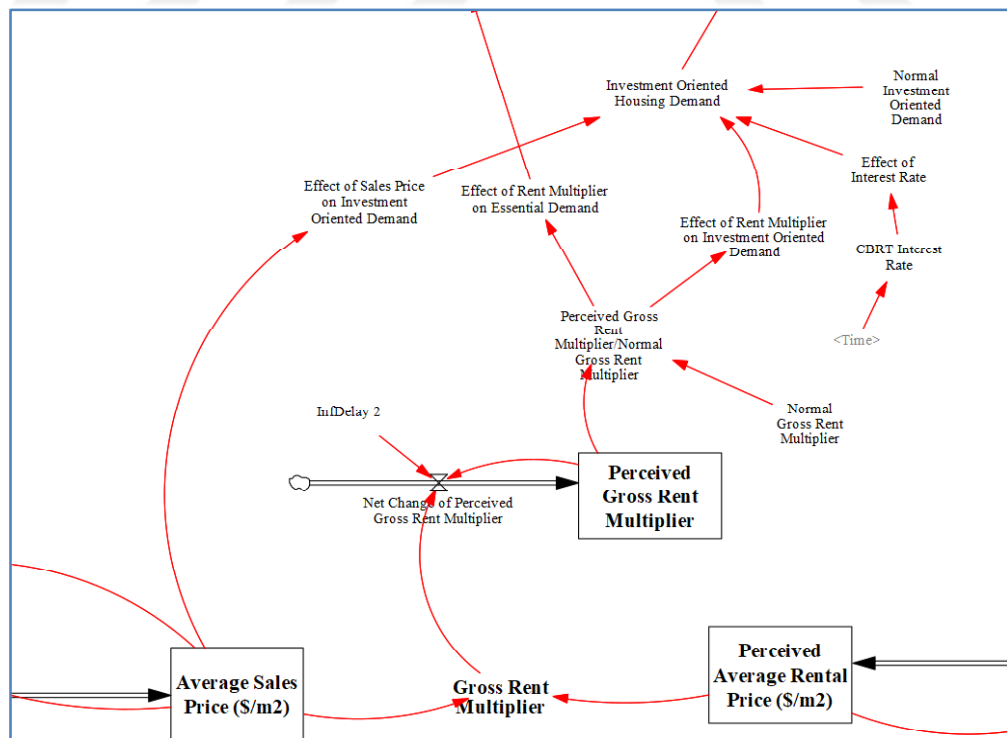


Figure 5.35. Rent multiplier.

In the above figure, the effect of average sales price and perceived average rental price to demand is shown. Gross rent multiplier is calculated as follows:

$$\text{Gross Rent Multiplier} = \frac{\text{Average Sales Price}}{(\text{Perceived Average Rental Price} \times 12)} \quad (5.51)$$

Gross rent multiplier (GRM) is an indicator of how much rent will be obtained relative to the property cost. It is used by investors to evaluate rental property opportunities. Property cost is divided by the gross annual rental income as in the equation above. Property that costs higher in annual rental income delivers more return on investment. Thus, a smaller rent multiplier increases investment-oriented demand. An information delay structure is applied here to demonstrate the effect of rent multiplier on demand:

$$\begin{aligned} &\text{Net Change of Perceived Gross Rent Multiplier} \\ &= \frac{\text{Gross Rent Multiplier} - \text{Perceived Gross Rent Multiplier}}{\text{Information Delay 2}}, \end{aligned} \quad (5.52)$$

$$\begin{aligned} &\text{Perceived Rent Multiplier}(t) \\ &= \text{Perceived Rent Multiplier}(t - dt) \\ &+ \text{Net Change of Perceived Rent Multiplier} \times dt, \end{aligned} \quad (5.53)$$

The effect of rent multiplier on essential housing demand and investment-oriented housing demand is shown and explained in section 5.3.2.

The reference and the base year of the simulation model is 2010. The model's time unit is “years” because the major changes in the market can be measured in years. The actual data taken from the literature and estimations are implemented to the model for the reference year 2010.

The time horizon 2010-2024 is inspected for validation in the next section. After the initialization of the model is done for the year 2010, model behavior between 2024 and 2050 is evaluated in the base behavior section.



6. VALIDATION OF THE MODEL

Model validity tests should be implemented before policy analysis. The aim in model validity (credibility) testing is to ensure that the model is an acceptable and adequate description of the real system with respect to the dynamic problem of interest. Validity of the model behavior can be checked by observing real behavior patterns from literature, or by detecting reasonably predicted behaviors under extreme conditions. Consequently, validation tests of a system dynamics model generally consist of structural validity and behavioral validity [45].

Firstly, structural credibility of the model is tested and then behavioral or output credibility is tested.

6.1. Structural Validity

In the structure test, it is examined whether the totality of relations, loops and links in the system are adequately described in the model. It is a logical and qualitative test. Structure tests include testing the meaning of the variables and equations with respect to real life, equations' robustness under extreme initial conditions, and extreme conditions tests. There are many key variables and structures used in the model to simulate Turkey-inspired housing market. All these variables used in the model have a counterpart in real life according to the literature. For instance, project start rate being triggered by supply shortage is given by the study of DiPasquale & Wheaton [38]. Moreover, the delays in price adjustments and completion of construction are mentioned in the study of Barras [46]. Information delay structures are used in the model to represent the delayed effect of one variable on another one [1]. The representation of "Construction in Progress" stock and its inflow "Project Start Rate" and outflow "Construction Finish Rate" has meaningful counterpart in real life and in the study of Zhang et al., a similar stock-flow representation is used to incorporate Chinese housing market trends [47]. Sterman also explained in his book, *Business dynamics: system thinking and modeling for a complex*

world, the causal structure of the market that creates cycles in the housing market. The causal structure proposed by Sterman includes buildings under construction as a separate stock, and the outflow of the stock which is construction rate flows to new buildings [1]. In our model, Sterman's proposed housing market structure is taken into consideration and Turkish housing market key variables are added to construct a Turkey-inspired housing model. Sterman's proposed housing model represents commercial real estate markets. Turkey has local properties such that inflation and interest rates are important determinants of housing investment which is not studied by Sterman.

To test the validity of the model, extreme condition tests are implemented in this study. This testing method includes examining the model equations under extreme conditions. The results are evaluated in terms of their credibility. Each equation in the model can undergo this testing by implementing extreme values to the input variables. Output variables are assessed and compared with the knowledge of what may happen under a similar situation in real life [45].

6.1.1. Test 1: No Sales Demand

As the first extreme condition test, model is tested in the case of no sales demand. In real life, if there is no demand for a commodity, we expect to see sales rates converging to 0. Sales are constrained by supply and demand in the real market. Sales rate formulations are adjusted according to this constraint as explained in section 5.3.1. There are two types of sales demand in the model: essential housing demand and perceived investment-oriented housing demand. *Normal Essential Demand Ratio* and *Normal Investment-Oriented Demand* are formulated to decay to 0 at the initialization, and the initial value of *Perceived Investment Oriented Housing Demand* stock is set to 0 as extreme input condition. Behavior of the related variables when there is no sales demand is given below:

Implemented changes for *Normal Essential Demand Ratio* and *Normal Investment-Oriented Demand* are given in the figures below:

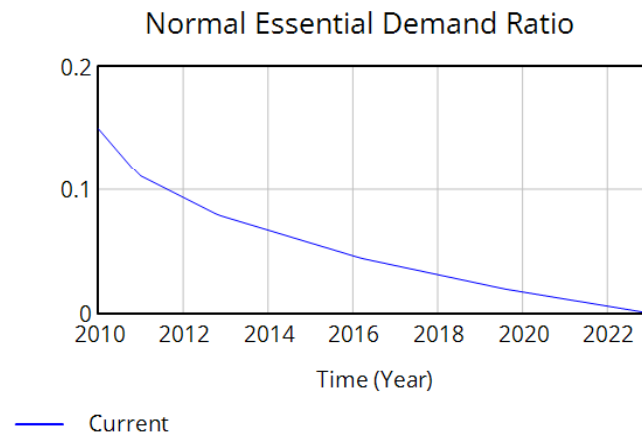


Figure 6.1. Normal essential demand ratio for test 1.

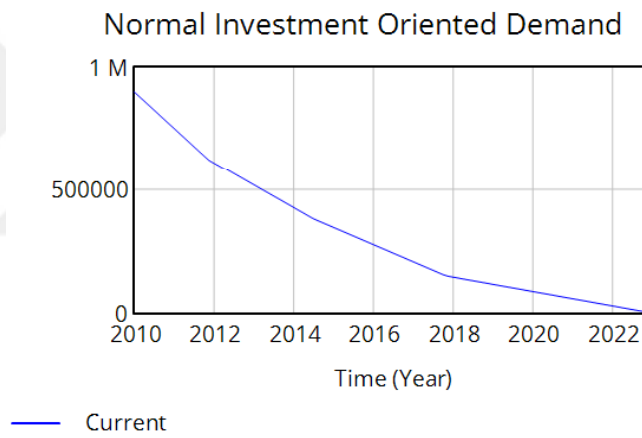


Figure 6.2. Normal investment-oriented demand for test 1.

Since Normal Essential Demand Ratio decays to 0, Essential Housing Demand also goes to 0:

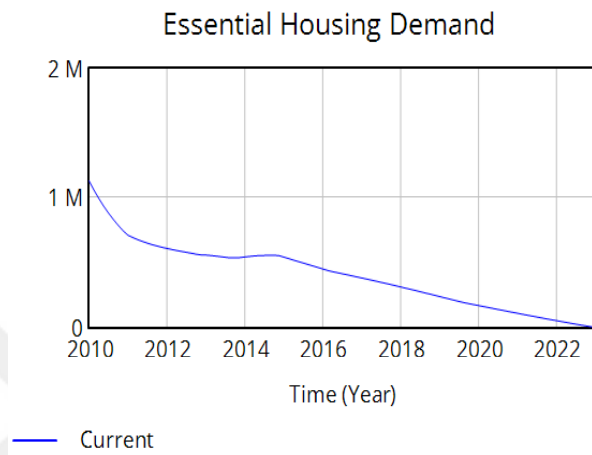


Figure 6.3. Essential housing demand for test 1.

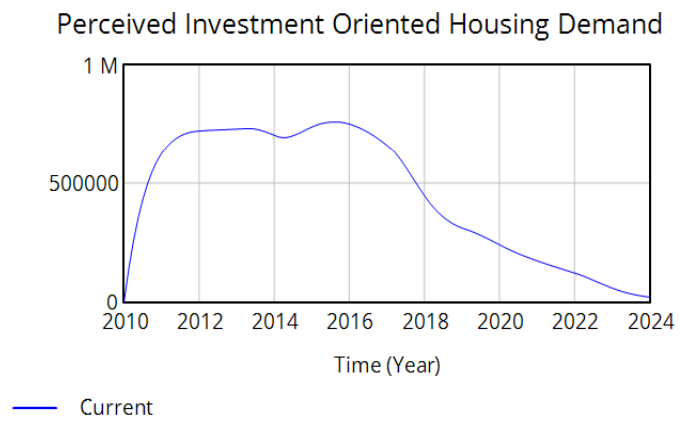


Figure 6.4. Perceived investment-oriented housing demand for test 1.

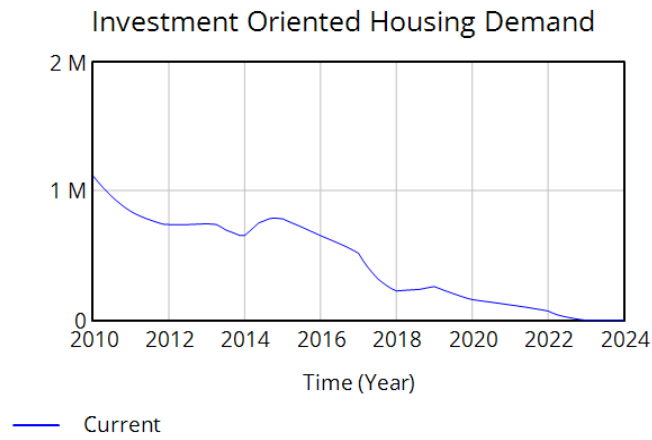


Figure 6.5. Investment-oriented housing demand for test 1.

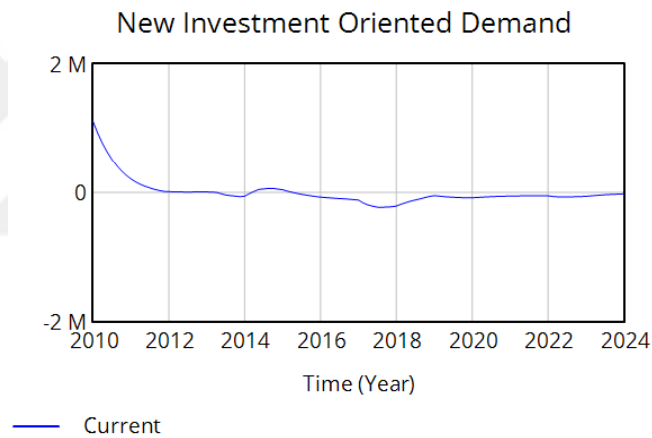


Figure 6.6. New investment oriented demand for test 1.

New Investment Oriented Demand is the inflow of *Perceived Investment Oriented Housing Demand*. At the beginning of 2010, as seen from the figure 6.5, there is around 1 million housing demand which declines until 2024. From figure 6.6, we observe that the inflow of the *Perceived Investment Oriented Housing Demand* is positive until 2012, so we see an increase in *Perceived Investment Oriented Housing Demand* until 2012.

Since total demand for sale is the sum of essential and perceived investment-oriented demand, it also goes to 0.

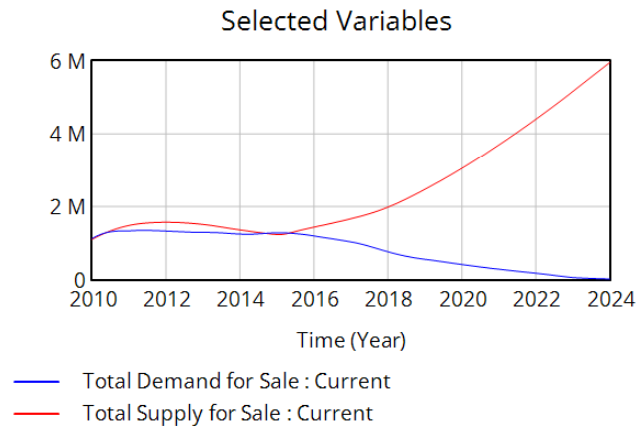


Figure 6.7. Total demand for sale and total supply for sale for test 1.

Supply shortage is the difference between total demand for sale and total supply for sale. Total supply for sale increases since unsold housing stock (new vacant houses and houses on secondhand market) accumulates. Thus, there is a supply surplus. There are more than enough houses.

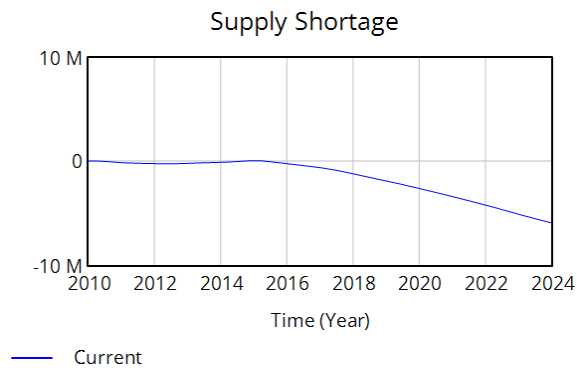


Figure 6.8. Supply shortage for test 1.

According to figure 6.9, houses under construction are completed till 2024. From figure 6.7, we see that between 2014 and 2016, total demand exceeds total supply so there is a supply shortage which triggers new project start. As a result, we see an increase in *construction finish rate* between 2014 and 2016.

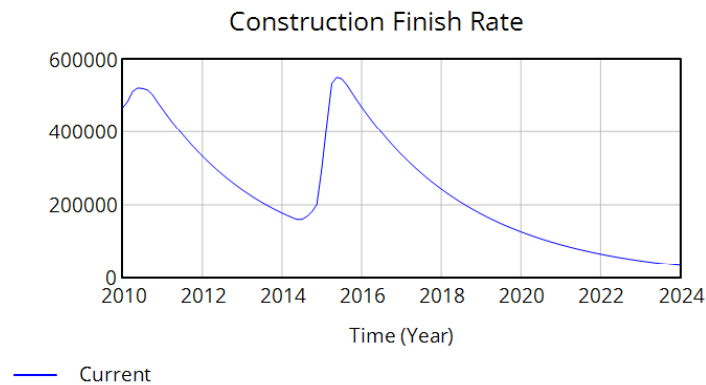


Figure 6.9. Construction finish rate for test 1.

We also expect to see total sales converging to 0 since the demand for sales becomes 0. As seen from the graphs below, both total new sales and total second sales decay to 0. Total new and secondhand sales are the outflows of sales supply stocks. Since the outflows of the sales supply stocks become 0, new houses and secondhand houses accumulate in the stocks through years.

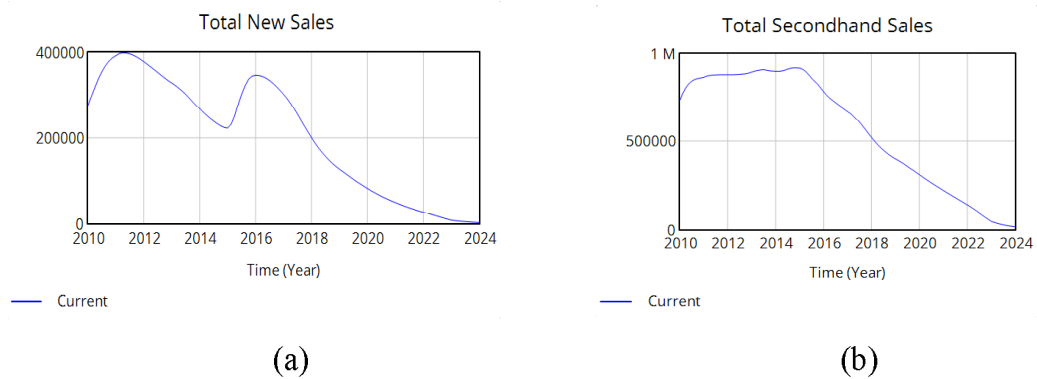


Figure 6.10. Total new (a) and second (b) sales for test 1.

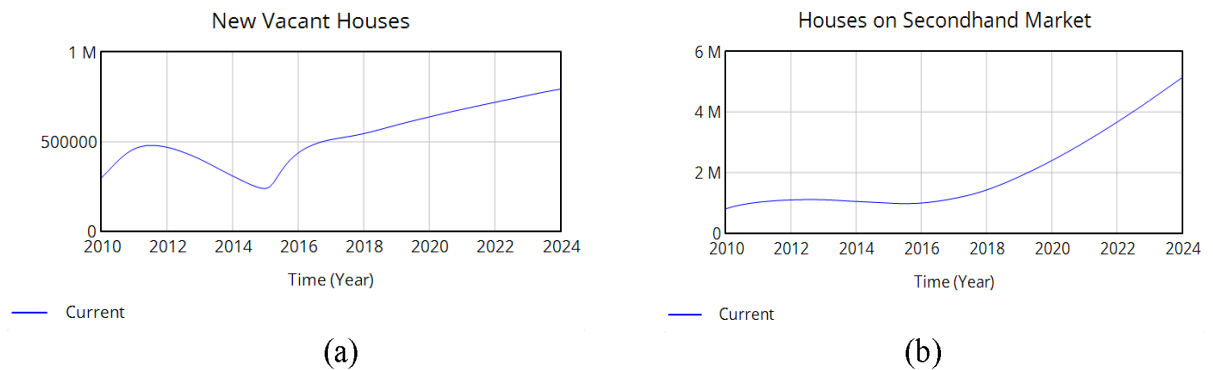


Figure 6.11. New vacant houses (a) and houses on secondhand market (b) for test 1.

As seen in the above figure, both *New Vacant Houses* and *Houses on Secondhand Market* increase clearly after 2018. Through years, *Total New Sales* declines to 0 since there is no sales demand. Thus, *New Vacant Houses* stock grows. Same logic applies to secondhand houses. *Total Second Sales* declines to 0 and *Houses on Secondhand Market* grows as expected.

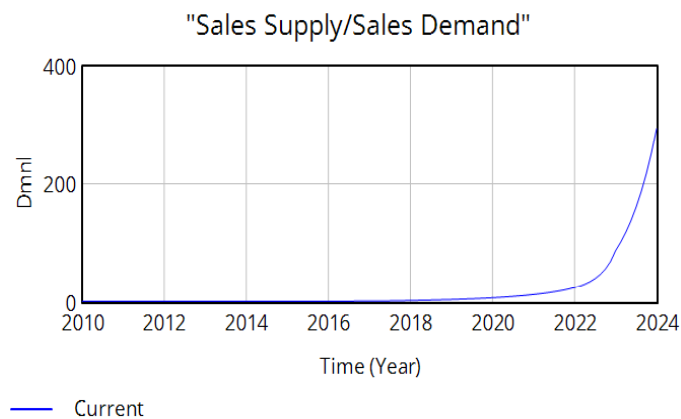


Figure 6.12. Sales supply to sales demand ratio for test 1.

In the above figure, we can see the growth of sales supply, as a result "sales supply/sales demand" ratio grows exponentially until 2024. In those conditions, we expect to see a reduction in the average sales price since there is excessive supply when there is no demand for housing.

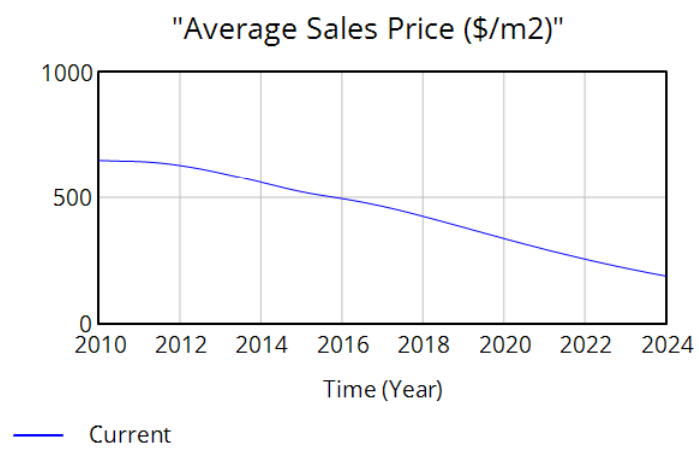


Figure 6.13. Average sales price for test 1.

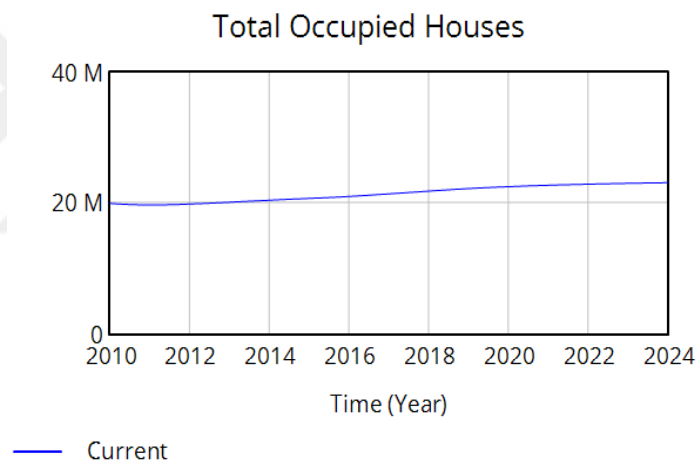


Figure 6.14. Total occupied houses for test 1.

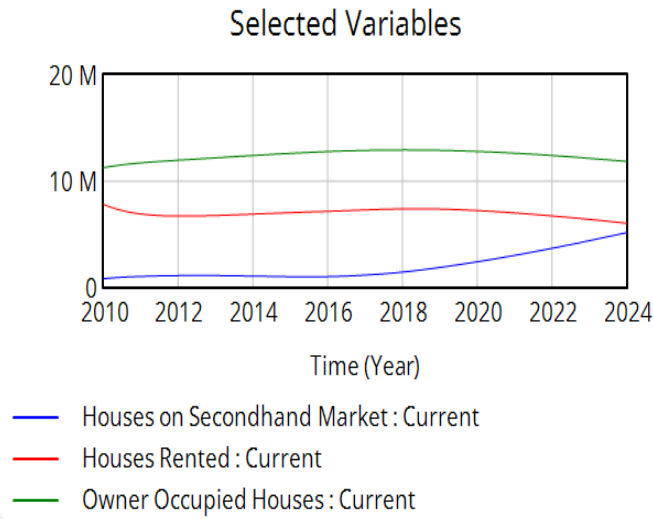


Figure 6.15. Occupied house stocks for test 1.

Even though there is no sales demand, the population continues growing. We track the population growth by observing the trend of *Total Occupied Houses*. According to the trend above *Total Occupied Houses* reach approximately 23 million from 19 million in 14 years period. *Owner Occupied Houses*, *Houses on Secondhand Market* and *Houses Rented* constitute occupied houses in the model. The increase in *Total Occupied Houses* originates from secondhand market as seen in the figure 6.15. Secondhand sales declined overtime and houses on the secondhand market grew to 5 million from 800 000 households.

Since the population continues to grow, there is a demand for rent. According to the graphs below, rental demand always remains high compared to rental supply. Inherently, *Perceived Average Rental Price* grows exponentially until 2024.

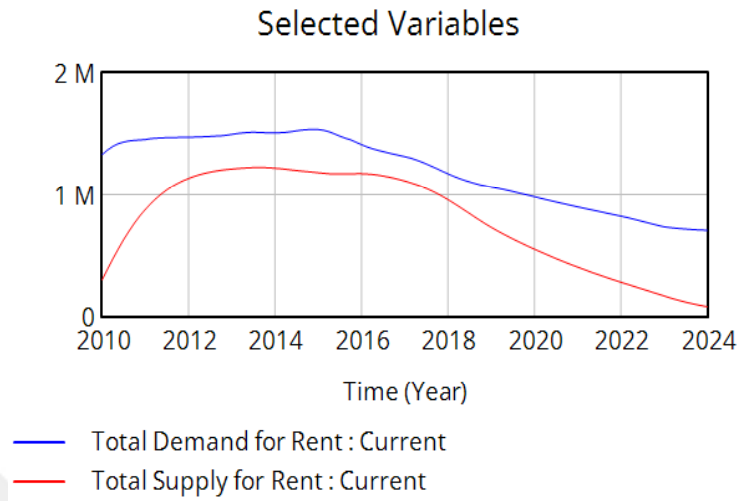


Figure 6.16. Rental demand and supply for test 1.

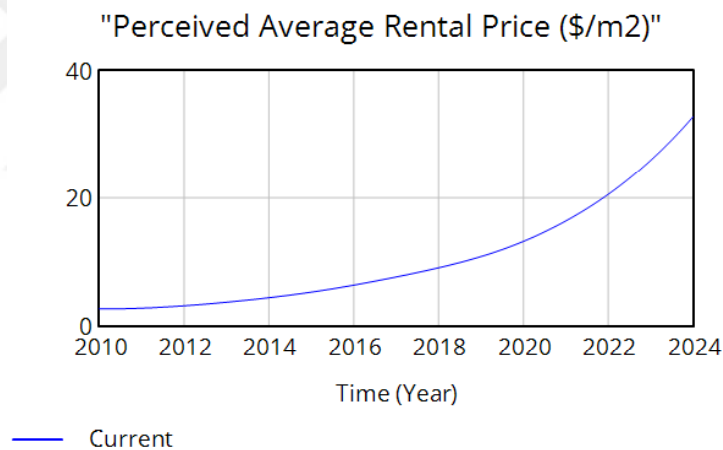


Figure 6.17. Perceived average rental price for test 1.

To sum up, *Average Sales Price* displays decreasing behavior since there is no sales demand for housing. However, there is still population growth which introduces rental demand to the market. As a result, the *Perceived Average Rental Price* grew as expected. All the above figures demonstrate realistic results compared to the real dynamics in the extreme condition of no sales demand. Thus, this extreme condition test reveals that our model is consistent with real life under extreme condition of no sales demand.

6.1.2. Test 2: Extremely High Sales Price

In this test, we tested what happens if we start the model with initially very high sales price. In 2010, the average sales price of a house is 650 $\$/m^2$. The initial value of *Average Sales Price $\$/m^2$* stock is given as 500 000 $\$/m^2$. According to the real data, average sales prices of houses from 2010 to 2023 are given in the figure below:

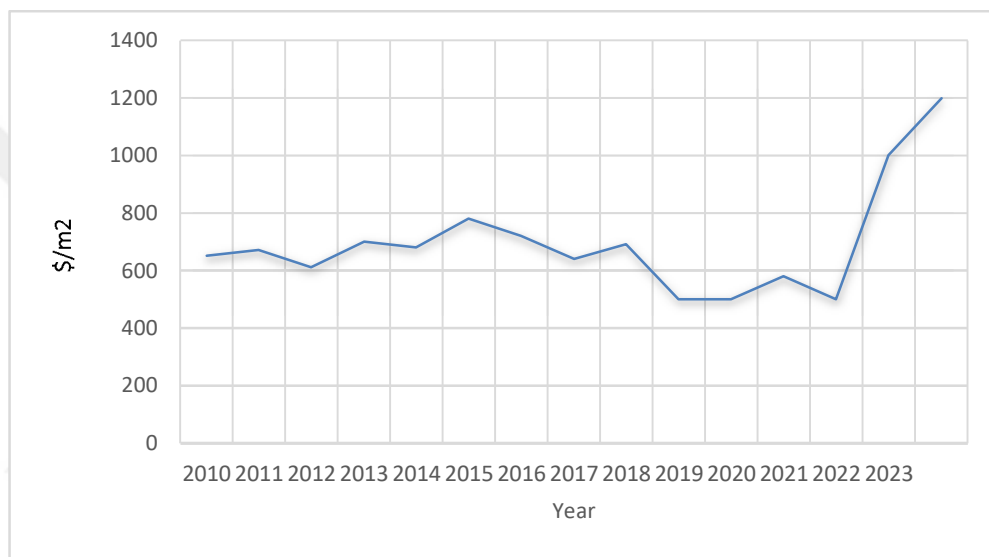


Figure 6.18. Nominal house prices in Turkey from 2010 to 2023 ($\$/m^2$) [23]

According to the real behavior above, it is unusual to observe a sales price of 500 000 $\$/m^2$, thus it is accepted as an extreme condition and tested on simulation. In real life, the sales price of a commodity has a decreasing effect on the demand, and it is represented in our model by effect functions. Sales prices affect essential housing demand and investment-oriented housing demand. The behaviors of those two demands are shown below:

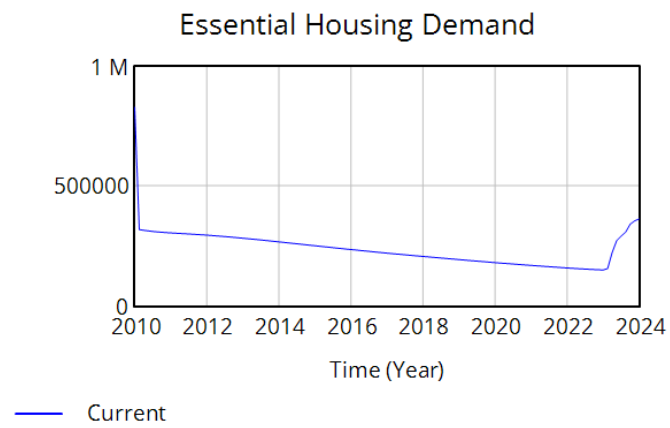


Figure 6.19. Essential housing demand for test 2.

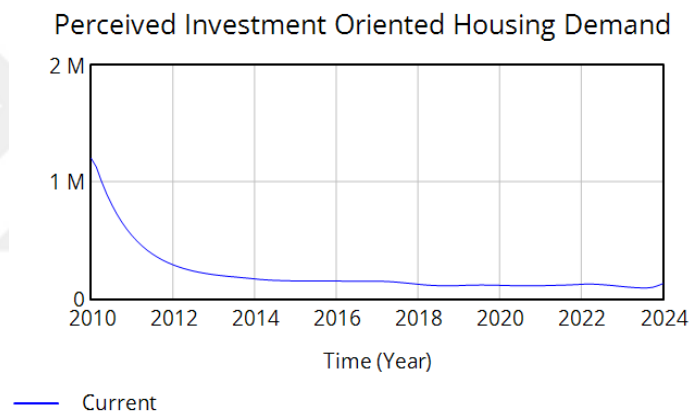


Figure 6.20. Perceived investment-oriented housing demand for test 2.

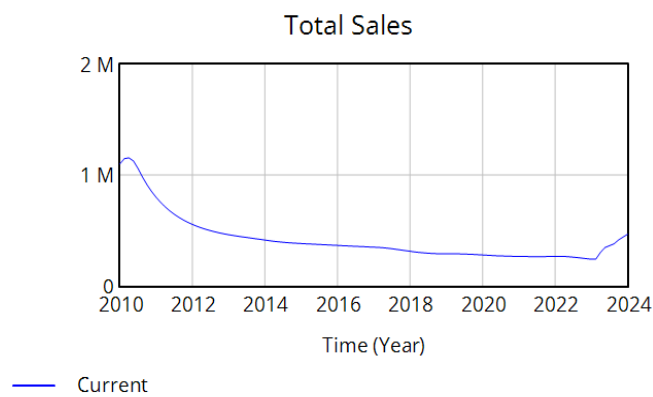


Figure 6.21. Total sales for test 2.

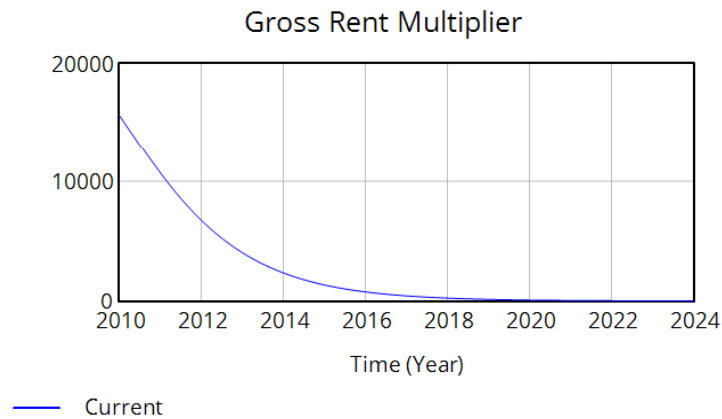


Figure 6.22. Gross Rent Multiplier for test 2.

Sales demand, *Essential Housing Demand* and *Perceived Investment Oriented Housing Demand*, depend on *Perceived Gross Rent Multiplier* and *Average Sales Price*. Since the initial sales price is extremely high, it is expected to see a reduction in sales demand. We observed that sales demand has decreased fast, and as a result total sales also decreased. When *gross rent multiplier* converges to 0, there is an increase in demand after 2022. As a result, total sales rose after 2022. Based on the results, our model could be accepted as valid under this extreme condition.

6.2. Sensitivity Analysis

Sensitivity analysis is important in system dynamics studies, conducted primarily to inspect how variations in input parameters or underlying assumptions affect the behavior of the system [45]. In this section, we will examine whether the model is highly sensitive to the constant parameters or not.

Table 6.1. Selected parameters for sensitivity analysis.

Parameter Name	Base Model Value	Min-Max	Increment
Normal Essential Demand Ratio	0.15	0.1-0.4	0.05
Normal Investment Oriented Demand	900000	700000-1200000	100000

NEDR represents *Normal Essential Ratio* in the figure 6.23 and 6.24 below. In our model it represents the fraction of tenants who decide to purchase their own houses. Normal essential demand ratio is tested for sensitivity analysis with minimum value of 0.1, and maximum value of 0.4 with increments of 0.05 at each run. According to the results, the normal essential demand ratio between 0.15 and 0.2, can be considered as a critical ratio. We observe an increase in sales prices after 2018 when this ratio becomes 0.1 and 0.15, but we do not observe it when this ratio exceeds 0.2.

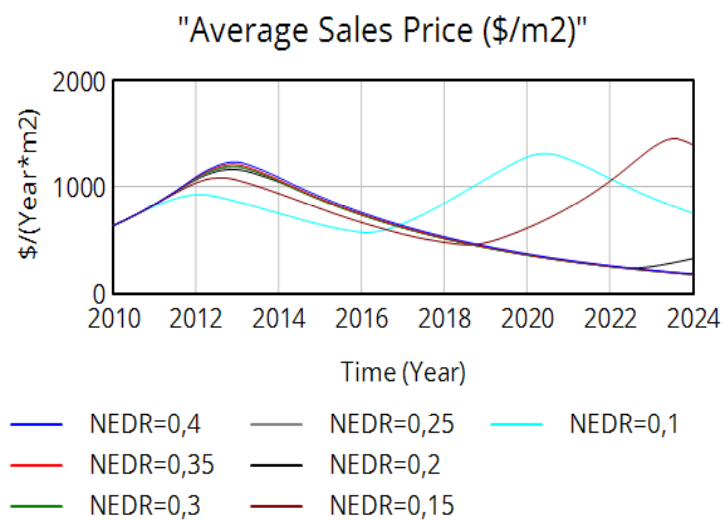


Figure 6.23. Average Sales Price in sensitivity test-1.

When NEDR is 0.1, during the years when prices reach their peak around 2015 there is no noticeable increase; therefore, the peak point is comparatively lower.

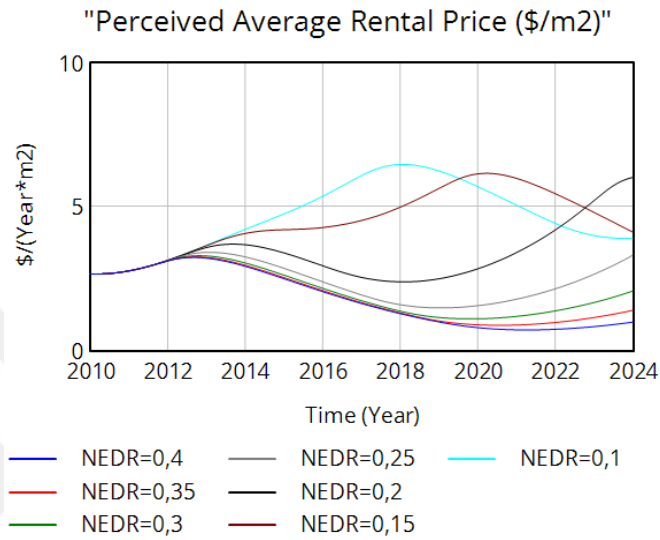


Figure 6.24. Perceived Average Rental Price in sensitivity test-1.

In conclusion, average sales and rental prices are sensitive to normal essential demand ratio. In real life, sales and rental prices of houses are considerably affected by housing demand, as known. In our model, NEDR affects *essential housing demand*. We can say that essential housing demand is very important and has a strong influence on sales and rental prices.

Normal Investment Oriented Demand is a constant parameter, and its base value is assumed to be 900 000 in the base model. In this section, this parameter is tested for sensitivity analysis between the values between 700000 and 1200000 by increments of 100 000. *NInvDemand* represents the parameter *Normal Investment Oriented Demand* in the below figures.

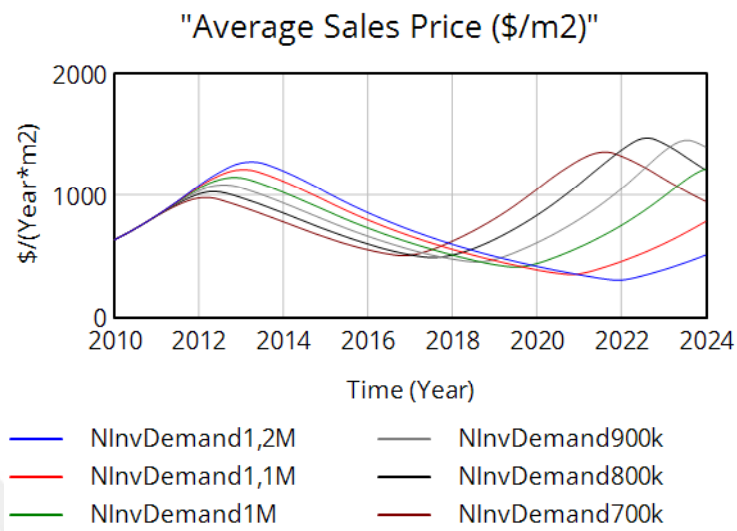


Figure 6.25. Average Sales Price in sensitivity test-2.

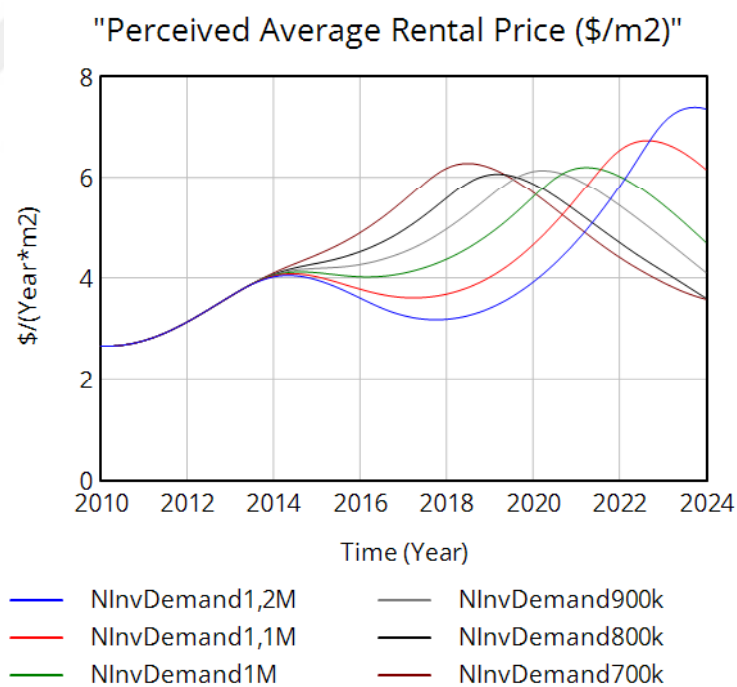


Figure 6.26. Perceived Average Rental Price in sensitivity test-2.

In conclusion, both the average sales price and perceived average rental price are not strongly sensitive to NInvDemand.

6.3. Behavioral Validity

For assuring the behavioral validity of the model, the dynamic patterns created by the model are evaluated and compared with the real dynamic patterns of interest. We will investigate the behavior of stocks and flows that are mainly responsible for the market dynamics throughout the years to ensure behavioral validity of the model. In the graphs given, some of the main components are compared with real data represented by red lines. The aim is to capture which dynamics resemble the real historical behaviors, and to explain the reasons of the deviations from real data.

By the stock-flow model we obtained a behavior between the years 2010 and 2024 which is like the real behavior of the Turkish market. Created model behavior does not match exactly to the real behavior of the Turkish real estate market through the given time horizon. However, the main endogenous dynamics are obtained to a certain extent by the model.

According to the historical data given below, nominal house prices (\$/m²) in Turkey shows an increasing trend until 2016, after 2016 there is a decline until 2020. After 2020, there is a significant increase in sales prices.

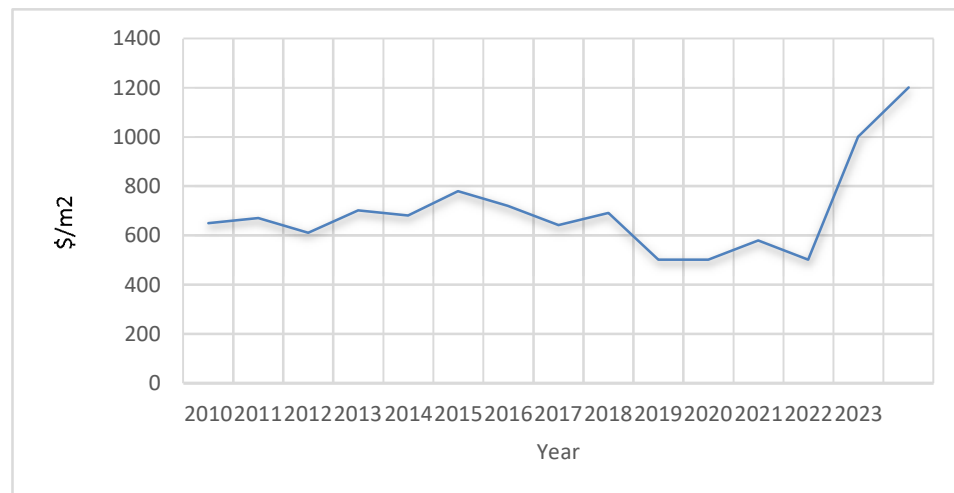


Figure 6.27. Nominal House Prices in Turkey from 2010 to 2023 (\$/m²) [23]

All drawn behaviors with red lines represent real data and blue lines are the outcomes of the model in the below graphs.

For example, real average sales price of houses in \$/m² are demonstrated under the label “r-average sales price”. If we run our model until 2023, we observe similar house price behavior, and the output of the model is compared with the real behavior as in the graph below:

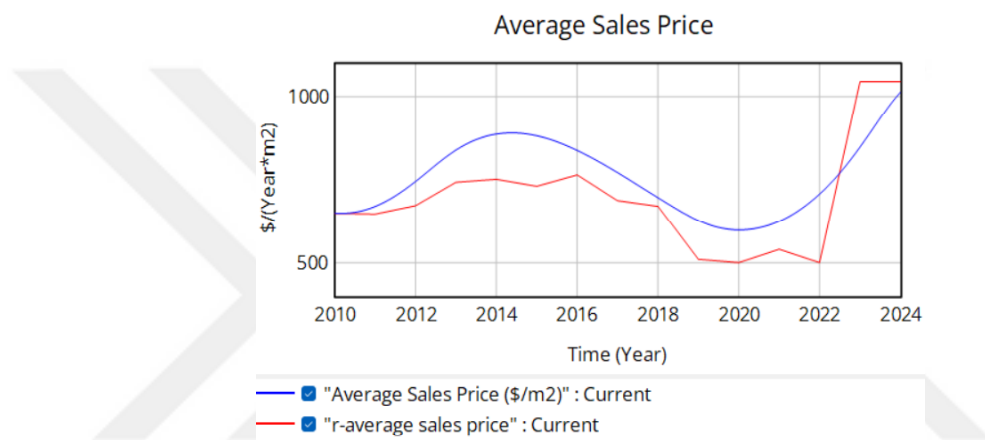


Figure 6.28. Average sales price between 2010 and 2023.

The dynamic behavior endogenously created by the model is behavior wise similar to the real average sales price behavior (r-average sales price). As explained in the previous sections, in this model main dynamics of housing market are inspired by Turkish housing system, however there are additional mechanisms and economic conditions in Turkey which we cannot add to the scope of the model. Hence, our model cannot replicate the exact sales, demand and price data of Turkish housing market. However, from the figure 6.28 it can be concluded that sales price is comparatively compatible with real sales price data. Because the booms and busts in sales price are captured around corresponding years in the model.

In the below graphs, r-total sales, r-total new sales, r-total secondhand sales represent real historical data and are put in the graphs for comparison.

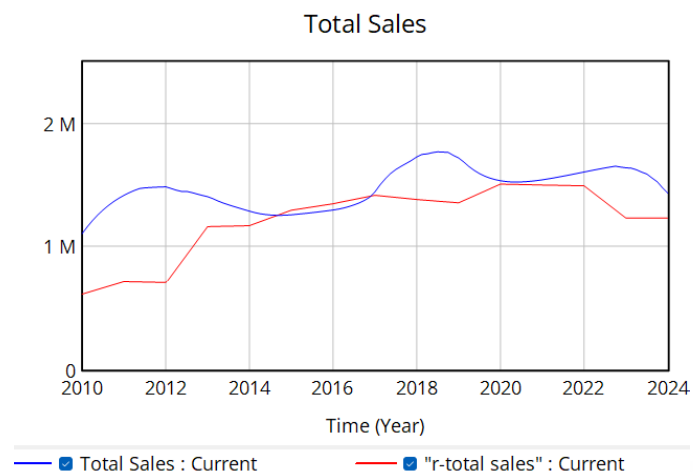


Figure 6.29. Total sales between 2010 and 2024.

Blue line, represent “total sales” that is generated by the model and red line represents the historical data of total number of sales. At first years of the simulation, the total number of sales generated by model looks higher than real data. The total number of new sales and total number of second sales are given in the graphs below:

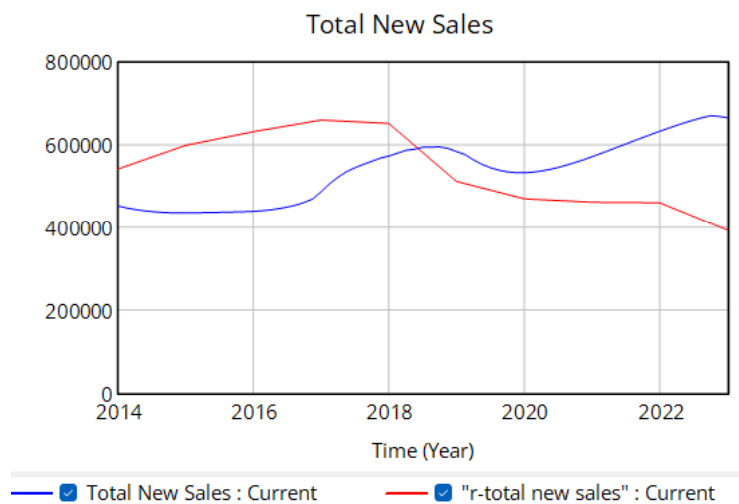


Figure 6.30. Total new sales between 2014 and 2023.

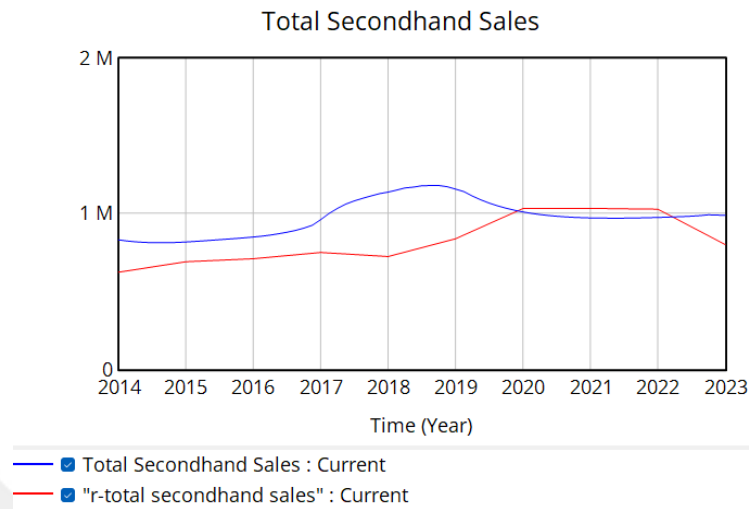


Figure 6.31. Total second sales between 2014 and 2023.

For total new sales and total second sales, historical data is available from 2014. Thus, we cannot talk about the validation before 2014. The total number of secondhand sales (blue line) generated by the model is slightly higher than the actual number of secondhand sales. In other words, our model creates excess secondhand sales which is not seen in real life between the years 2014 and 2019. The reason is that there are more secondhand houses in the market compared to new houses and the demand for the secondhand market is higher than the demand for new house market. Thus, people tend to buy more secondhand houses. This high second sales created by the model results in initially higher total sales compared to real data as seen in the above figure 6.31. However, the total sales produced by the model are still in line with the actual data, so we can accept the model is behavior wise acceptable in terms of total number of sales.

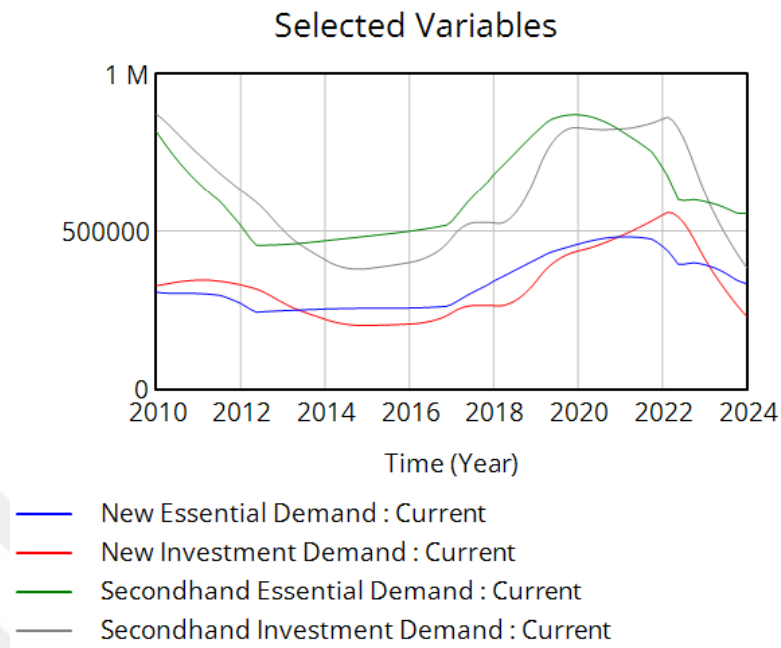


Figure 6.32. Demands between 2010 and 2024.

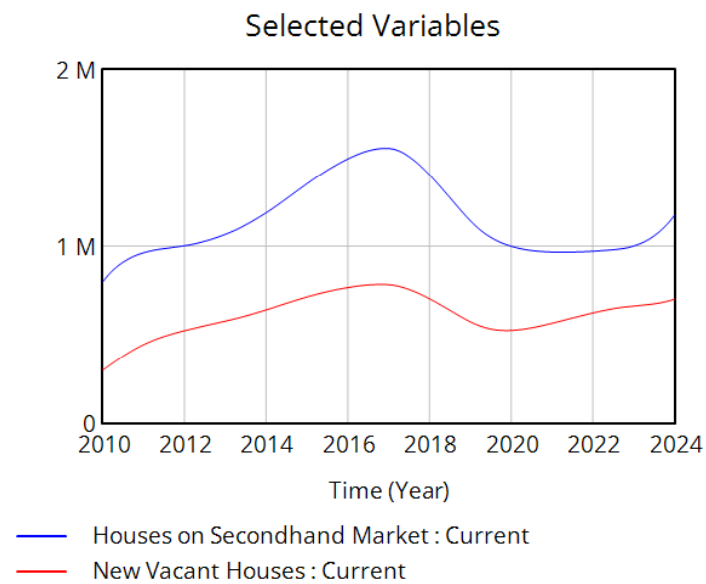


Figure 6.33. Sales supply between 2010 and 2024.

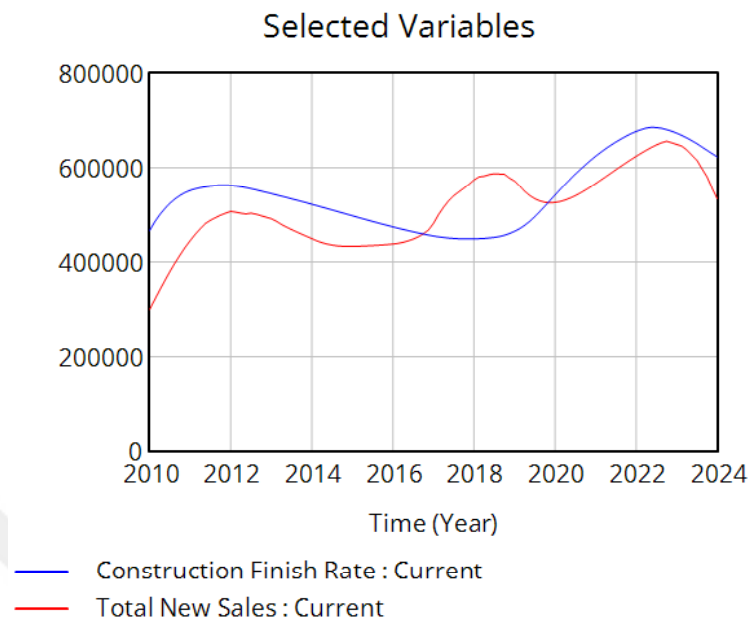


Figure 6.34. Construction finish rate and new sales between 2010 and 2024.

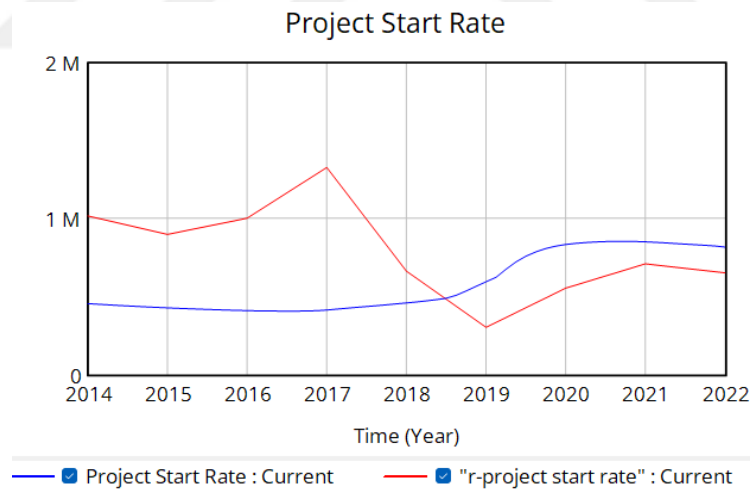


Figure 6.35. Project start between 2010 and 2024.

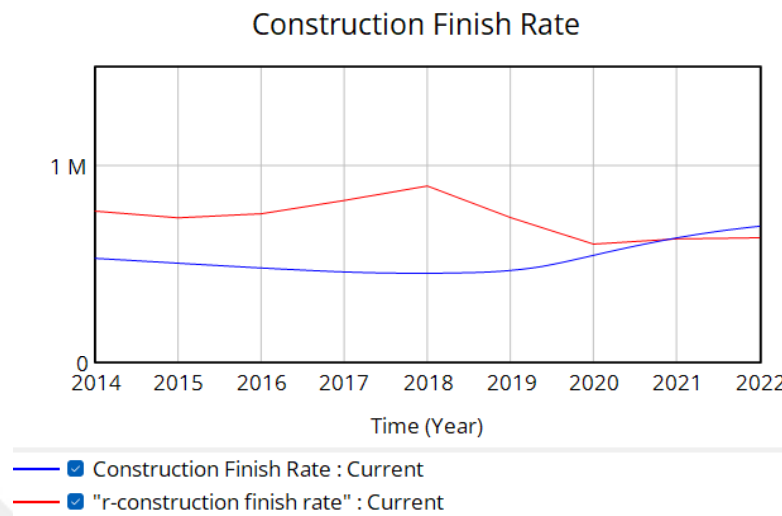


Figure 6.36. Construction finish rate between 2010 and 2024.

New vacant houses represent new unsold housing supply and increase by construction finish rate and decrease by total new sales. The dynamic behavior of new vacant houses depends on the flows in figure 6.34. If we compare the construction finish rate and total new sales, construction finish rate remains higher than total new sales until 2016. As a result, houses are accumulated in new vacant houses stock. New houses accumulation leads to an increase in total new sales after 2016 which in turn leads to a reduction in new vacant house stock for a short period. There is a decrease in new vacant houses between 2016-2018 due to total new sales being higher than finished constructions.

There is no real data that shows the exact total sales supply. Thus, the comparison with real data cannot be made. The total supply for sales is the sum of new vacant houses and houses on the secondhand market. As seen in the figure 6.33, both new vacant houses and houses on secondhand market increase till 2016 and decrease between 2016 and 2019. After 2019 supply again increases since houses on the secondhand market and new vacant houses increase.

There is a strong relationship between the number of new projects starts and the number of construction permits, and it has been known that the numbers for new project development and construction permits have rapidly declined, particularly after 2018, due to increasing

inflation, exchange rates, and interest rates [27]. These changes can be observed from figures 6.35 and 6.36 demonstrated by red lines.

We can also mention that the number of households who own the house they reside in is compatible with real historical data as seen in graph 6.38:

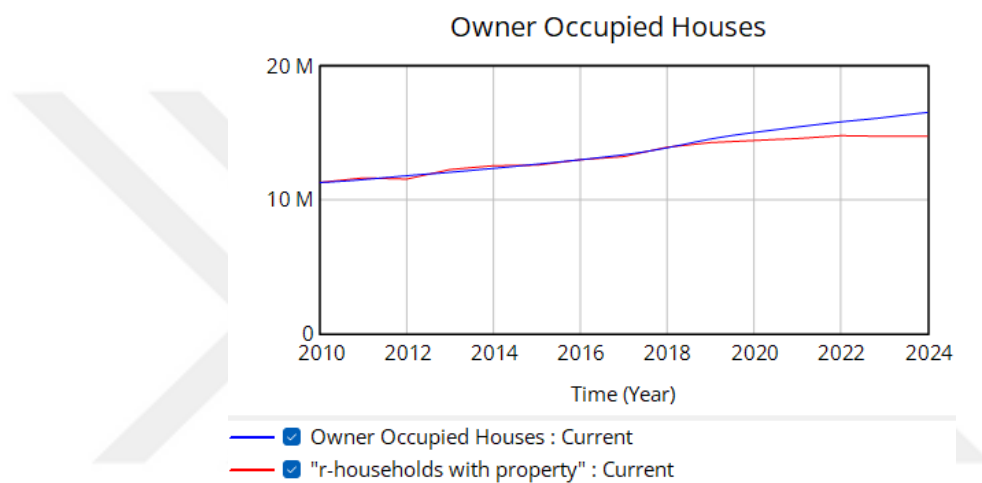


Figure 6.37. Owner Occupied Houses between 2010 and 2024.

Owner Occupied Houses represents houses bought to live in and “r-households with property” represents the households who are the owner of the houses they live in. Thus, they can be compared and used as analogous variables. According to the above graph, our model is also behaviorally valid in terms of this aspect until 2018. *Owner Occupied Houses* increase with *New Essential Sales* and *Secondhand Essential Sales*. From the figure 6.37, model output for *Owner Occupied Houses* is a bit higher than the *real households with property* shown by red line. In the model, the total number of sales is higher compared to literature behavior as discussed above. Thus, there are more households that own a property in the model. However, the increasing trend of *Owner Occupied Houses* is compatible with literature.

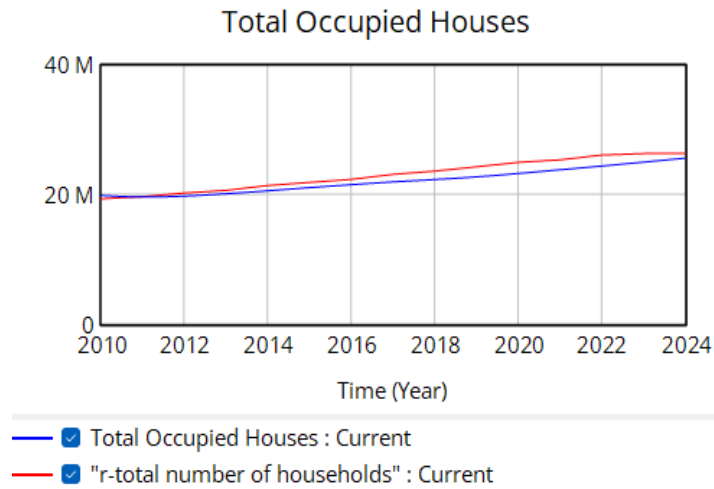


Figure 6.38. Total Occupied Houses between 2010 and 2024.

To sum up, while the model fits the real data in some years, there are some deviations from reality throughout the time horizon. Although there are deviations from real behavior, the sales price behavior of the model resembles real trend between 2010 and 2024. Total new sales and total secondhand sales behavior of the model is acceptable in terms of range of outputs. The outputs of the model do not overlap with actual behavior exactly, as explained before there are other economic and political concepts that affect housing market in Turkey but could not be fit into the model. Thus, this model does not aim to mimic Turkish housing market structure exactly the same. However, in the constructed model sales price fluctuations, number of houses owned, and sales rates are close to what they are in real life between 2010 and 2024. Therefore, the created model is not a representation of Turkish housing market, but it can give valuable insights about the future of the Turkish housing market.

7. THE BASE BEHAVIOR

In the base model, we want to observe price dynamics and oscillations over the next 25 years in a housing market which resembles the real estate market in Turkey. Amplitudes of oscillations, their periods will be given by investigating the root causes of changes by causal loops. Due to the results presented in 6.2 *Behavioral Validity*, the base model can give us information about the scenarios that can be seen in Turkey in the future.

In the base model analysis, the model is run until 2050 to observe the long-term changes in the system. Base run behavior is investigated under 2 subsections to capture the internal dynamics of the system in the short and long run separately.

7.1. 2024-2030 Behavior

Given the initial values of the stocks and constant variables, at the beginning of 2024 the model supply shortage is negative as seen in the graph below. Thus, there is a supply surplus as given in figure 7.1. It is expected that when there is a supply shortage in the market, new projects should be launched. In the base run, there is only a supply shortage between 2037 and 2043. Thus, *project start rate* starts to increase after 2037 considerably.

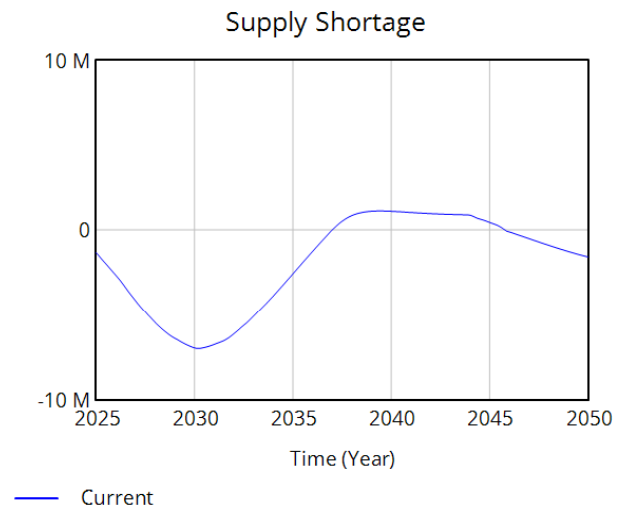


Figure 7.1. Supply shortage for the base run.

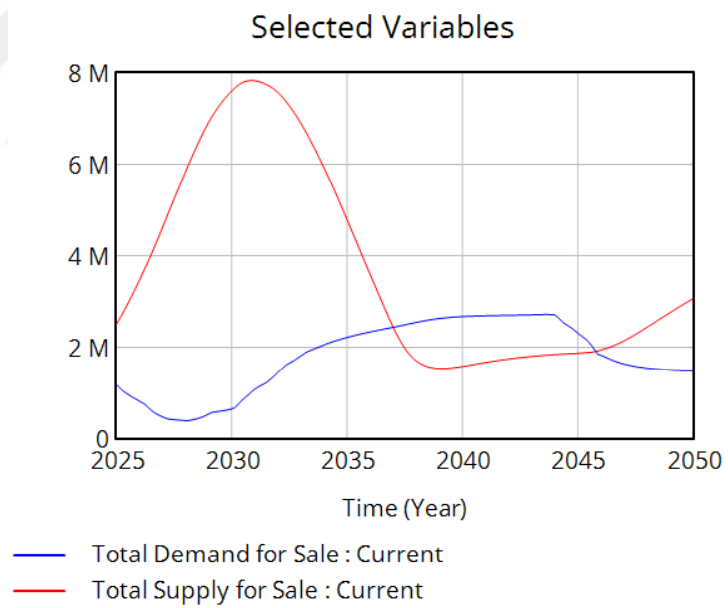


Figure 7.2. Sales supply and sales demand for the base run.

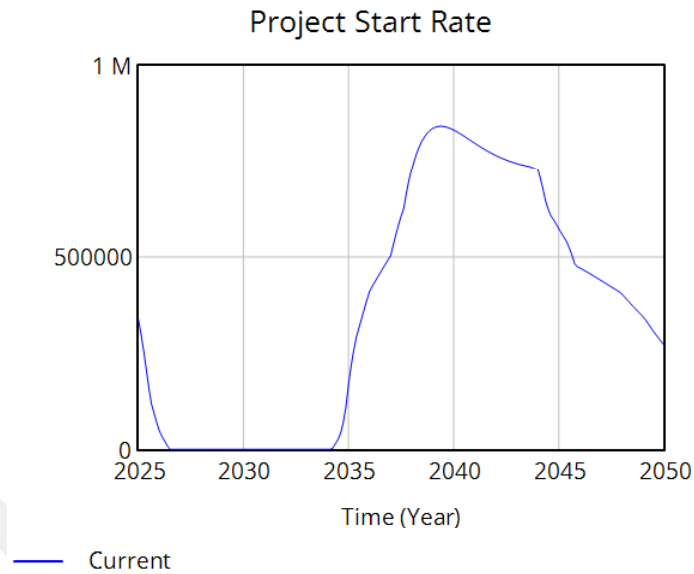


Figure 7.3. Project start rate for the base run.

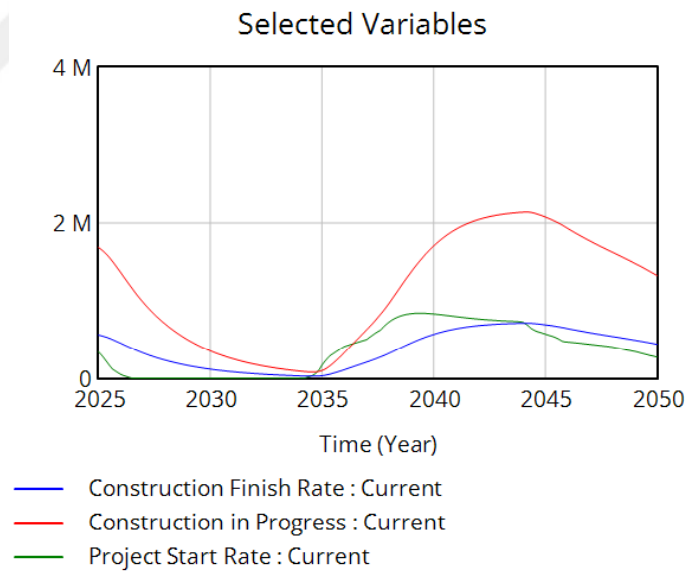


Figure 7.4. New constructions for the base run.

As seen in figure 7.2, there is excessive and growing supply until 2030 as well as the project start rate is very low. In 2024, *Project start rate* is 456500 houses/year. According to figure 7.4, the new constructions and their finish rates are low in this period. Figures 7.5 and 7.6

demonstrate the components of sales supply and sales demand. Most of the increase in *sales supply* stems from houses on the secondhand market. If we explore the sales demand, demand has been decreasing for 2-3 years. However, after 2028 there is an increase in essential housing demand that lasts until 2038. Sales demand is affected by the rent multiplier and average sales price. Essential and investment-oriented housing demand follows similar paths between 2010 and 2050.

If we investigate the behavior of investment-oriented housing demand, we can see from figure 7.6 that demand falls a little after 2024 and then increases above 1 million. It is also affected by the rent multiplier and sales price. Since the gross rent multiplier began to fall after 2028, as a result of falling sales prices, investment-oriented housing demand grew.

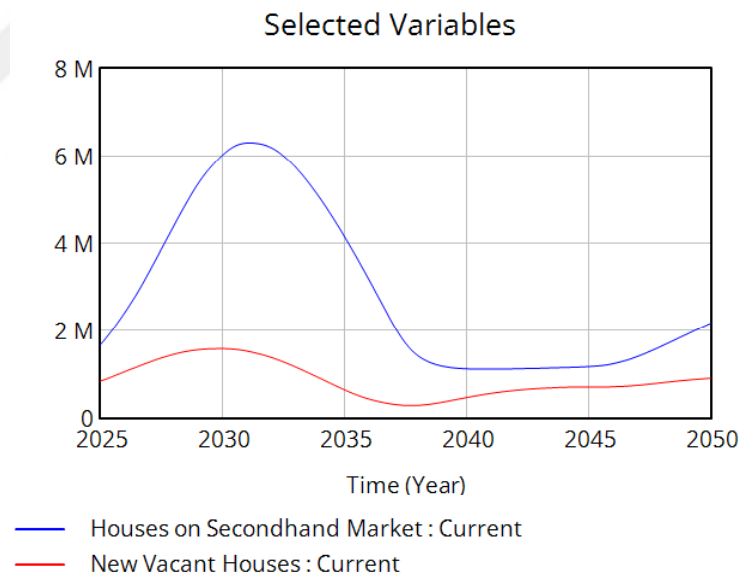


Figure 7.5. Sales supply for the base run.

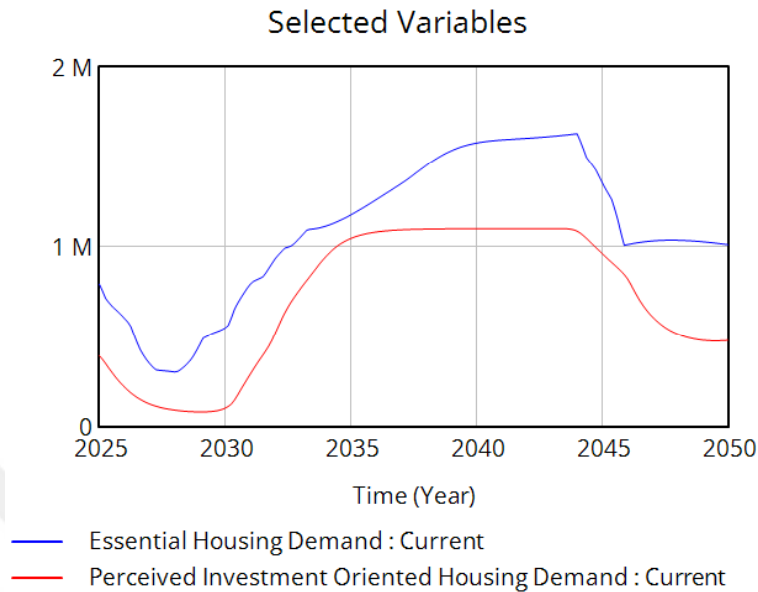


Figure 7.6. Essential and perceived investment-oriented housing demand for the base run.

If we further investigate the behavior of essential housing demand, we can look at graph 7.8. Gross rent multiplier diminishes the growth of essential housing demand until 2028. As explained before, rent multiplier is conversely related to essential housing demand. Since there is a little increase in rent multiplier after 2024, essential housing demand falls. Rent multiplier is affected by sales and rental price. Below, the change of those variables are given to investigate their effect on demand. There is a decreasing trend in sales price while rental prices are increasing just after 2024. As a result, rent multiplier starts to decrease with a delay after 2026. The sales and rental prices are affected by demand and supply imbalance. First, we can see why sales prices are decreasing until 2040 from the figure of 7.10. The sales supply/sales demand ratio increases almost linearly due to the growth of secondhand house stock. There is not much change in sales demand in this period, mostly secondhand houses supply causes sales price decrease.

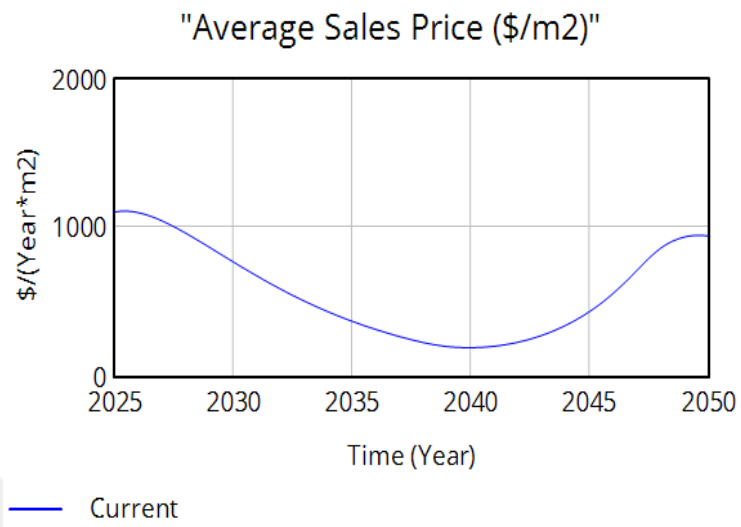


Figure 7.7. Average sales price for the base run.

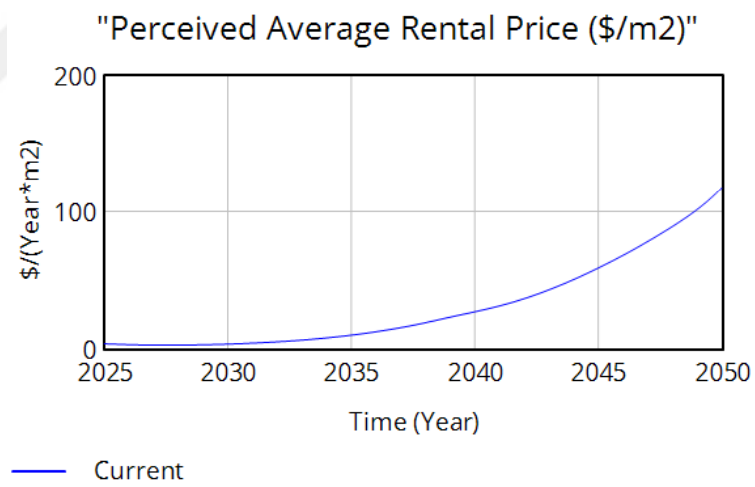


Figure 7.8. Perceived average rental price for the base run.

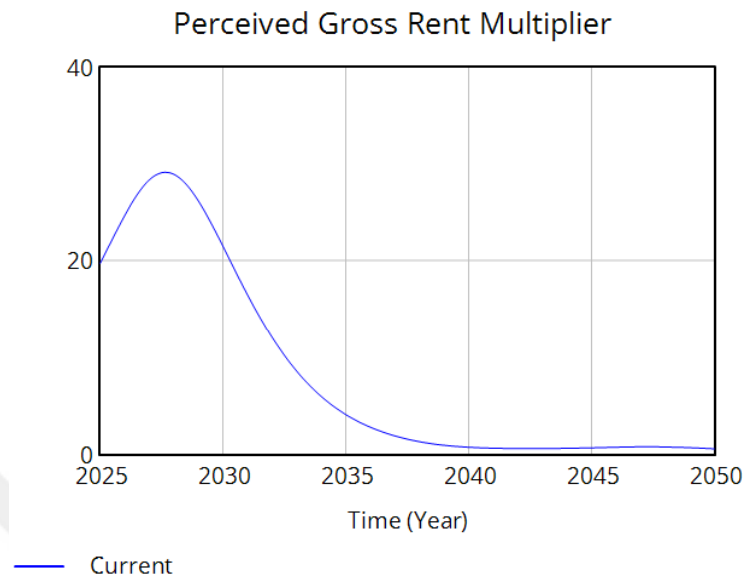


Figure 7.9. Perceived gross rent multiplier for the base run.

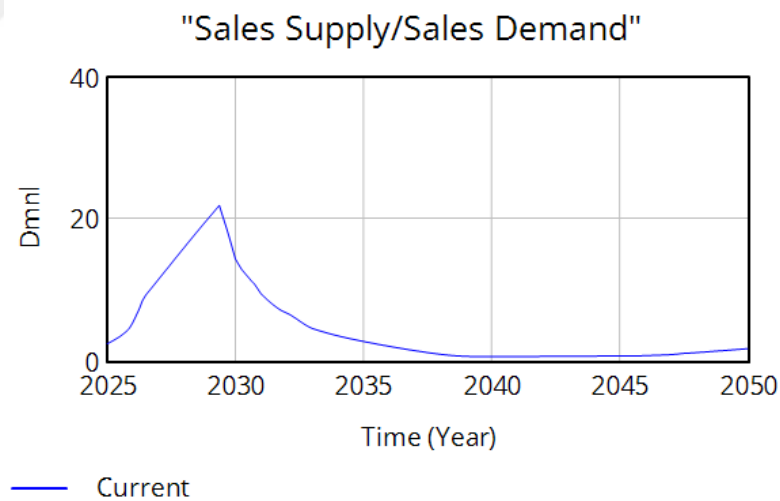


Figure 7.10. Sales supply to sales demand ratio for the base run.

Houses under construction are being completed in this period as seen in figure 7.11. Since there are not many new projects starting in this period, houses in the stock diminish as in figure 7.14. New vacant houses increase. New vacant houses grow as in the figure 7.12, since newly finished constructions are higher than the total number of new sales.

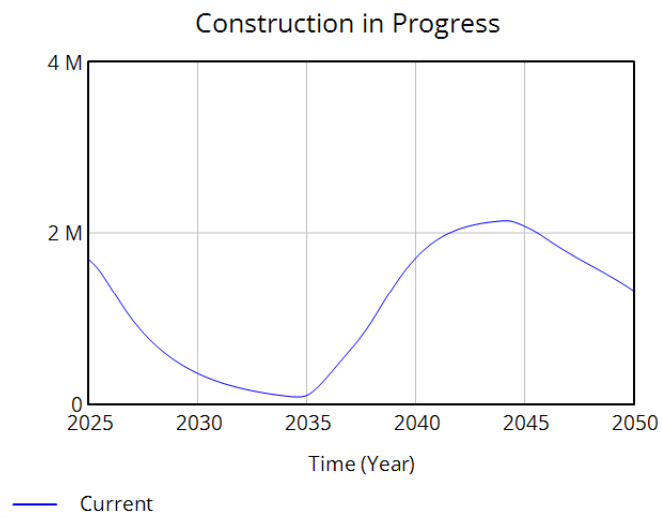


Figure 7.11. Construction in progress for the base run.

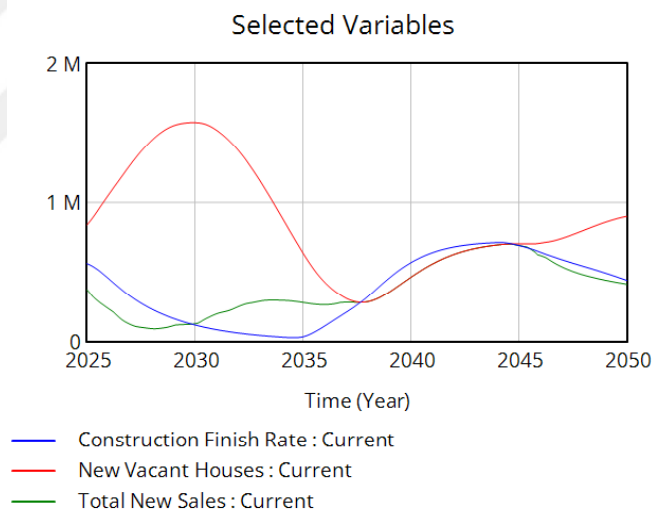


Figure 7.12. New vacant houses for the base run.

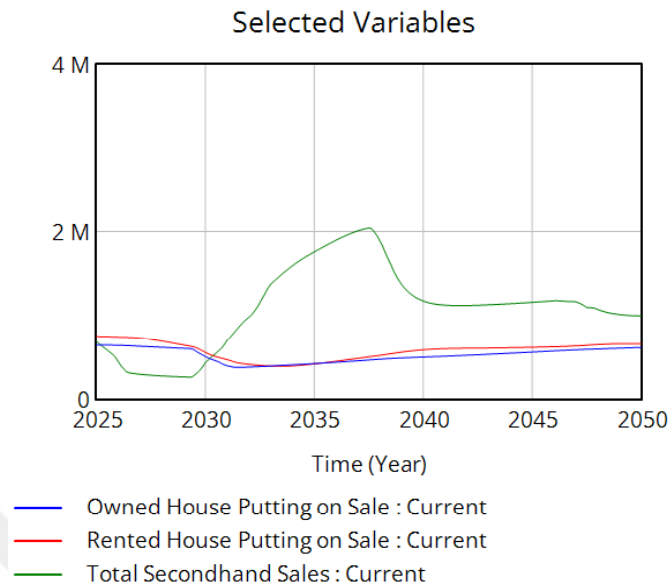


Figure 7.13. Change of houses on secondhand market for the base run.

Secondhand houses stock increases by *Owned House Putting on Sale* and *Rented House Putting on Sale* flows while it is depleted by *Total Second Sales*. From figure 7.13, it is observed that inflows are higher than the total sales between 2025 and 2030. As a result, houses accumulate in stock and sales supply increases.

Before 2024, sales prices were increasing, there is a peak in 2024. As a result, rent multiplier had also a peak around 2024. Because of the peak in rent multiplier, total sales demand started to decrease as in the figure of 7.2. *New Investment Sales* and *New Essential Sales* fall, and since there is less investment sale *Houses Available for Rent* also decrease as in the figure 7.14. This stock constitutes the rental supply in the market. From the figure 7.15 it is seen that rental supply falls beyond the rental demand. As a result, rental prices increase like in figure 7.8. The interest rate is assumed to be constant and 50% in the base run. Thus, its effect on investment-oriented housing demand is constant until 2050.

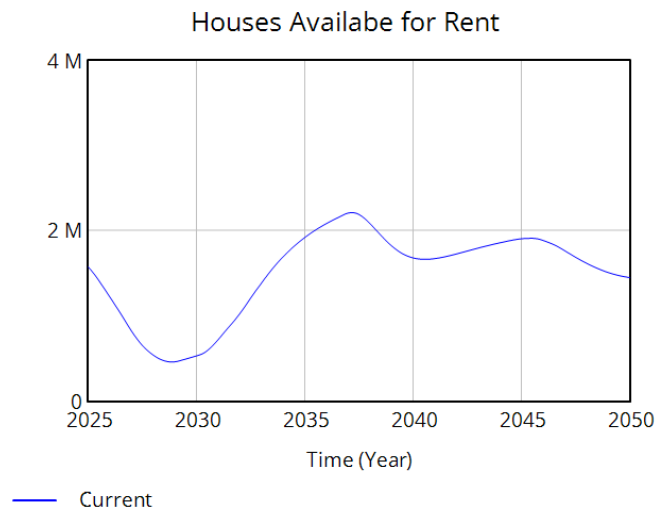


Figure 7.14. Houses available for rent for the base run.

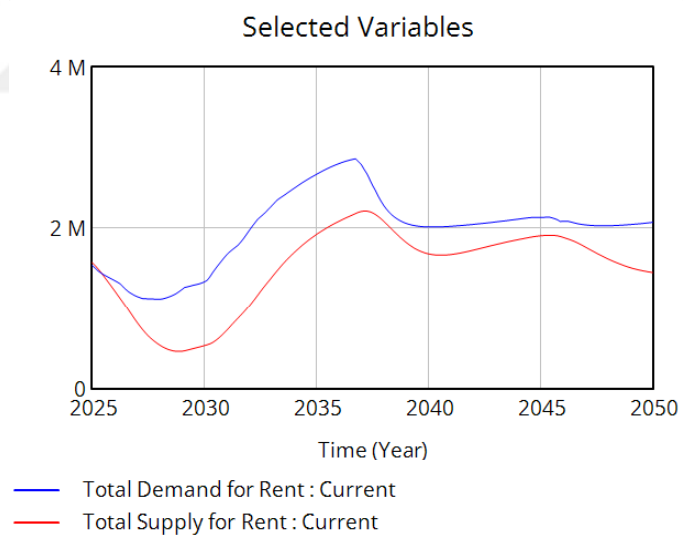


Figure 7.15. Rental supply and demand for the base run.

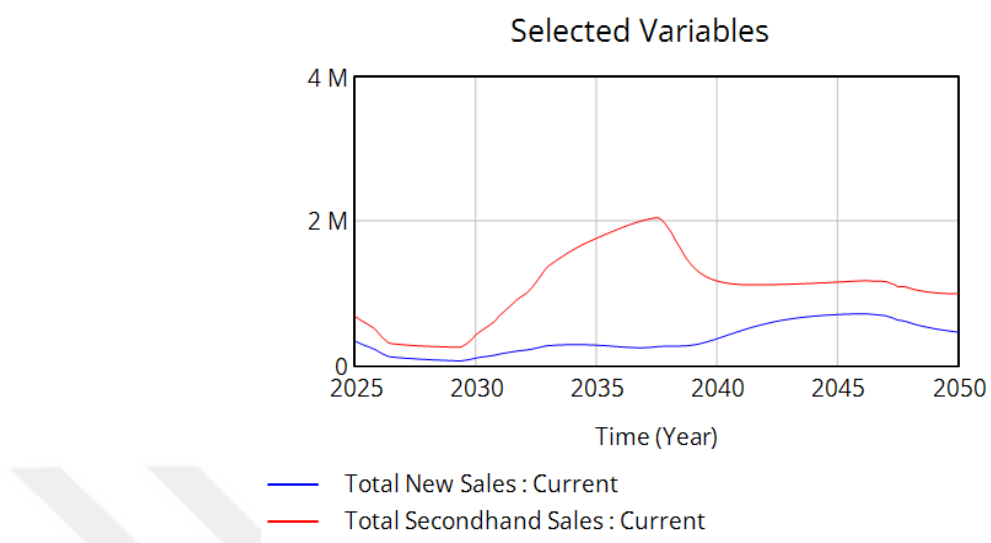


Figure 7.16. Total new and second sales for the base run.

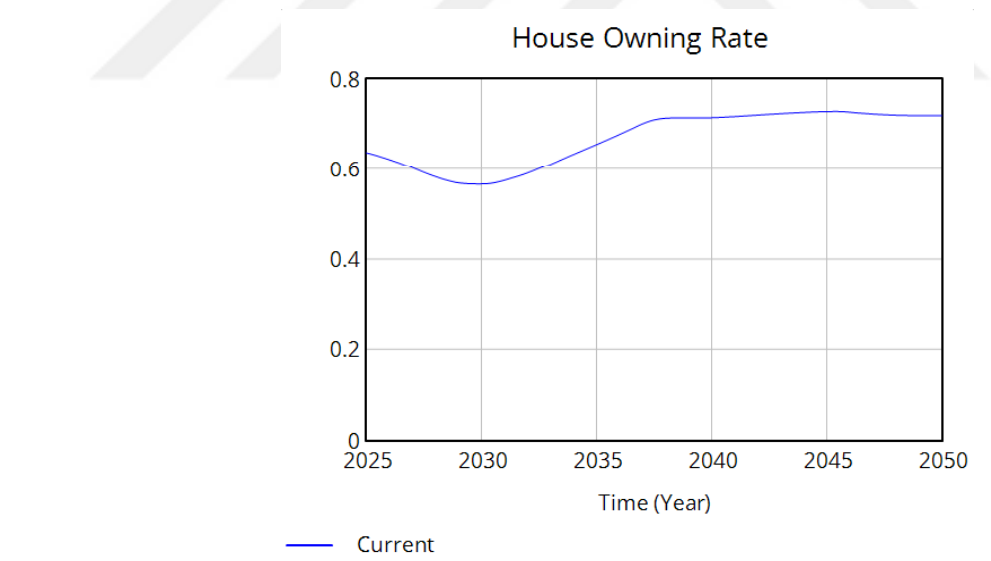


Figure 7.17. House owning rate for the base run.

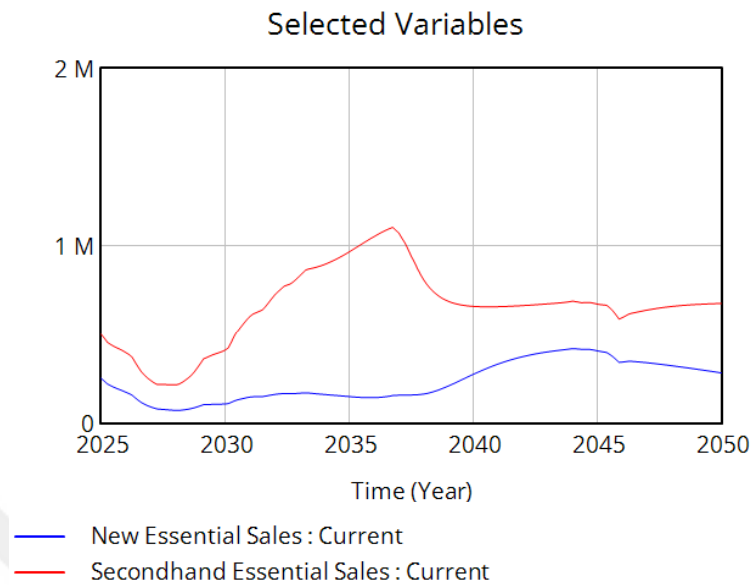


Figure 7.18. New and secondhand essential sales for the base run.

Between 2024-2030, house owning rate decreases until 2030 because the new and secondhand essential sales decrease due to the decrease in essential housing demand. In this period, average sales price also decreases, however this decrease is not sufficient to create a sales demand in the market. Below 1000 \$/m², there is a critical price after which people start to think about purchasing a house. This critical price is reached in 2030, such that we can observe an increase in essential housing demand and sales after 2030.

Rental price increases exponentially where we observe oscillation in sales price. From the figure 7.15, it is seen that rental supply is not enough to meet rental demand until 2030. The number of houses advertised for rent (Houses Available for Rent) decreased due to the fall in investment-oriented housing demand. As explained in the above paragraph, sales prices are high thus people do not favor buying a house for investment until 2030. Thus, new and secondhand investment sales fall so rental supply decreases. Average rental price increases exponentially.

All in all, the sales demand for housing decreases until 2030 because of the high average sales prices. Since sales prices reached a peak in 2024, they fall during the period 2024-2030. In this period, housing sales have decreased. Fewer households put their houses on sales. In

2030, the average sales price of a house becomes 763 \$/m², which is a critical price point because, after 2030, sales demand starts increasing. In the rental market, there is no considerable price change until 2030. Households wait until 2030 to purchase a new or secondhand house in these conditions.

7.2. 2030-2050 Behavior

After 2030, total sales supply starts to decrease while total sales demand rises as seen in the figure 7.2. However, during that period supply is above demand thus there is still a supply surplus which is decreasing in magnitude. New projects are starting towards the end of 2035 since demand begins to emerge. The number of houses under construction begin to increase as houses start to accumulate with new projects starting. Since new projects start, constructions in progress also increase. After a delay, the number of new vacant houses starts to increase (after 2038). Houses available for rent also increase, thus rental supply in the market rises. However, rental supply still cannot meet rental demand. Thus, rental prices continue to grow. Rent multiplier decreases and total sales demand increases. Supply shortage begins to emerge after 2037.

The decrease in sales supply can be explained by the reduction of houses on the secondhand market (from the figure of 7.5). In this period, total second sales start to rise rapidly after 2030. As a result, houses on the secondhand market decline. From figure 7.6, it is concluded that both essential and investment-oriented demand increase after 2030. Both rent multiplier and sales price have an increasing effect on essential and investment-oriented demand. Between 2030 and 2035, sales prices are decreasing, and rental prices are increasing. Thus, the perceived rent multiplier falls and becomes almost 2 years in 2037. Consequently, sales demand rises in total. With the increase of sales demand and decrease of sales supply, sales supply to sales demand ratio decays to 0. Due to this situation, average sales prices start to increase after 2040.

New vacant houses have declined considerably until 2038 since total sales demand has increased. Total new sales have also increased because of demand increase.

Project start rate makes a peak around 2039. As explained in previous sections, project start rate gets triggered by two variables: *Supply Shortage* and *New vacant Houses / Project Start Rate by Shortage*. Because supply shortage increases in this period, new projects start. With these changes, B1 causal loop begins to work as in figure 7.19. Constructions that are being completed increase. After 2037, new vacant houses start to increase until 2050. Since the sales supply increase, supply shortage begins to decline, the B1 loop is closed.

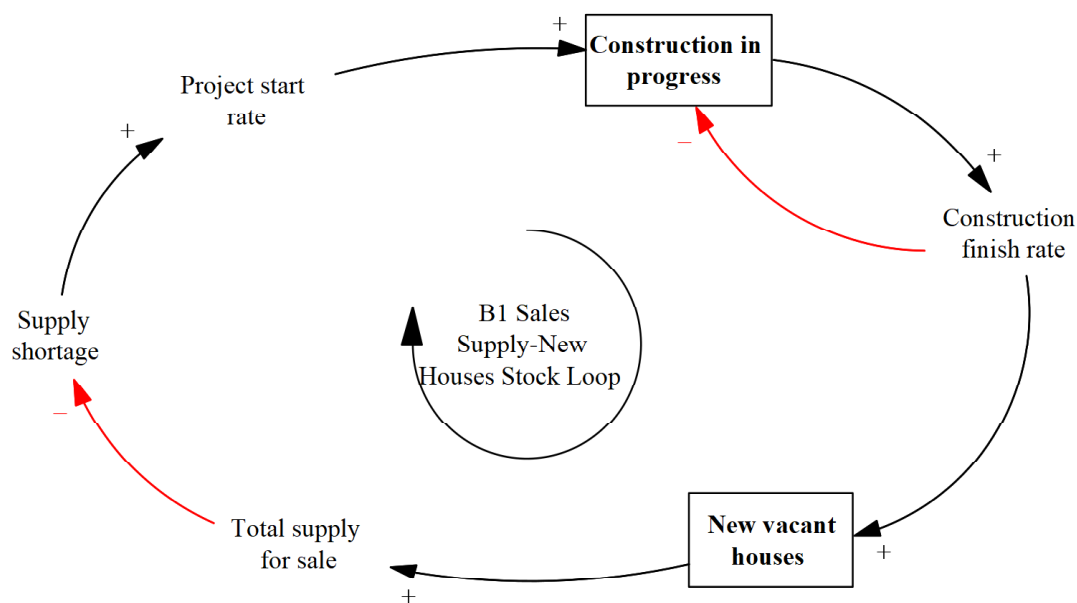


Figure 7.19. B1 causal loop diagram.

Since there is a considerable supply shortage between 2037 and 2045 (around a million), the *Effect of Supply Shortage on Project Start Rate* increases the *Project Start Rate*. To understand the reason for this rapid project starting after 2035, sales supply and sales demand dynamics are investigated further. The total sales supply consists of *New Vacant Houses* and *Houses on Secondhand Market*. From the figure 7.5, it can be seen that secondhand market

grows excessively between 2025-2030. Figure 7.13 demonstrates the inflow and outflow of the secondhand market stock. *Rented House Putting on Sale* and *Owned House Putting on Sale* flows represent houses that are advertised to put on sale. Within the period 2025-2030, those flows are higher than total second sales, thus houses are accumulated in secondhand market. After 2030, there is a sharp increase in total second sales which is derived from increasing demand.

To sum up, due to the accumulation of secondhand house stock before 2030, secondhand house demand increased considerably after 2030. Since there was increased sales demand, secondhand house sales increased. Households that were previously residing in those houses started to search for rental houses thus rental demand increased considerably. Because there was not enough rental house supply, average rental prices continued to grow. According to those findings, when there is a demand for secondhand properties, and when those houses are sold, households that were previously residing in those houses will need housing. This additional housing need can be considered as sales or rental demand, however in our model we assume that this demand is counted as rental demand. When those secondhand houses are sold, some of them are purchased for residing purposes while some of them are purchased to rent out. By the second purpose, rental housing supply increases by *Secondhand Investment Sales* since they are advertised for rent. However, in total there is more additional housing demand. Thus, eventually sales and rental prices of properties will increase.

We also observe that the gross rent multiplier decays to 0 as seen in the figure of 7.9. Normally, we expect to see an increase in sales demand whenever the gross rent multiplier decreases. However, the demand for a house also depends on the sales price of the house. After 2040, there is an increase in average sales price which makes it difficult to purchase a house, so the essential and investment-oriented housing demand starts to decrease after 2044 as in figure 7.6. In real life, this condition is not likely to be seen. In our model, rent multiplier goes to zero and demand does not increase due to the sales price effect on demand. Increase in average sales price restricts the growth of essential and investment-oriented housing demand. This situation represents a boundary condition of the model. Beyond these conditions, it is not plausible to infer what households will do in the future. In real life, the market will respond to the decrease

in rent multiplier. However, our constructed model cannot react to it. This decrease in gross rent multiplier is outside the valid boundary conditions of the model. It is not plausible to guess the actions of households in Turkey after a certain period from our model.

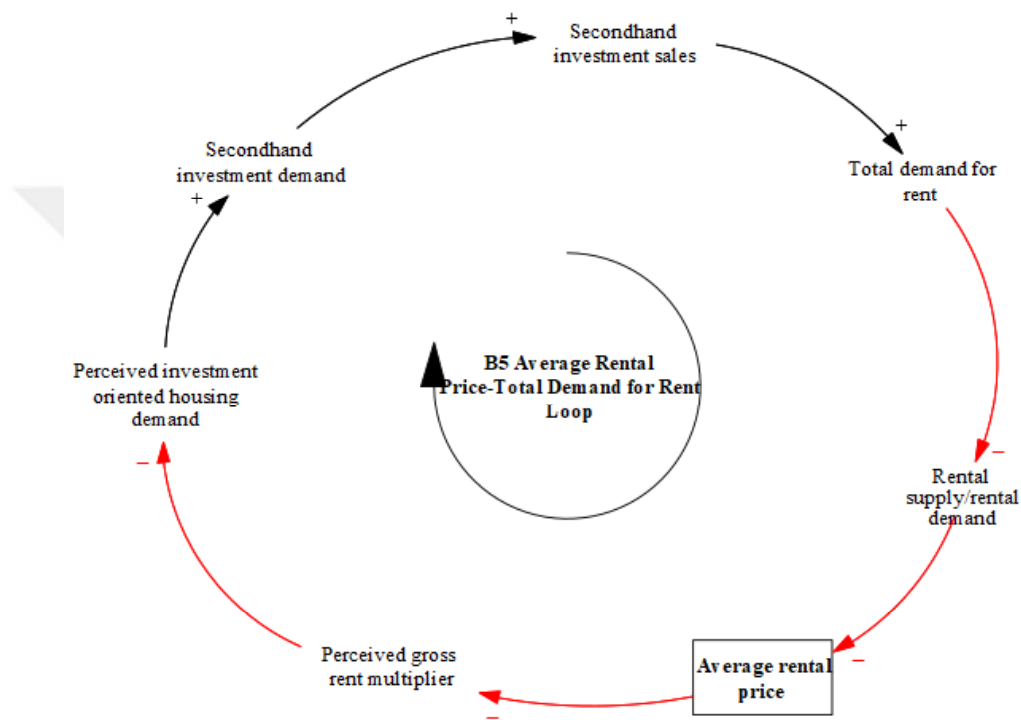


Figure 7.20. B5 causal loop diagram.

All in all, between 2025 and 2050, the main problem in the market is the exponential increase of *average rental price*. Within this period, the total rental supply cannot meet total rental demand. This increase in average rental price is reinforced by a loop which is shown by figure 7.20. In policy and scenario analysis, we will investigate ways of reducing average rental prices.

8. SCENARIO AND POLICY ANALYSIS

8.1. Scenario Analysis

Until now, model validity in terms of structure and behavior has been analyzed as well as the base behavior of the model is examined. In this section, we define two changes in the model and observe the effects of those changes on market behavior.

8.1.1. Decreased CBRT Interest Rate

According to the central bank interest rate announced in September 2024, The Central Bank of the Republic of Turkey (CBRT) Monetary Policy Committee (PPK) kept the policy rate constant at 50 %. CBRT has kept its policy rate unchanged at 50% for the last five months. According to economists' estimates, interest rates are expected to decrease between October 2024 and the first quarter of 2025 [48]. Banks that take actions toward expectations, lowered long-term deposit interest rates. There were also signs of a decline in loan interest rates [49]. While falling loan interest rates rise demand in the housing market, prices also increase due to increased demand. Thus, if loan interest rates decrease, housing prices increase [50].

In this scenario, we test what may happen in the model if the CBRT Interest Rate is reduced to 30% and 20% linearly until 2030. The reduction in the CBRT Interest Rate is implemented as in the graph below (Figure 8.1). Green line represents base model condition where CBRT Interest Rate is assumed to be 50% and unchanged after 2024 (Case: C1). The red line represents the condition where CBRT Interest Rate is decreased linearly to 30% (Case: C2) and blue line represents the condition where CBRT Interest Rate is decreased linearly to 20%. (Case: C3).

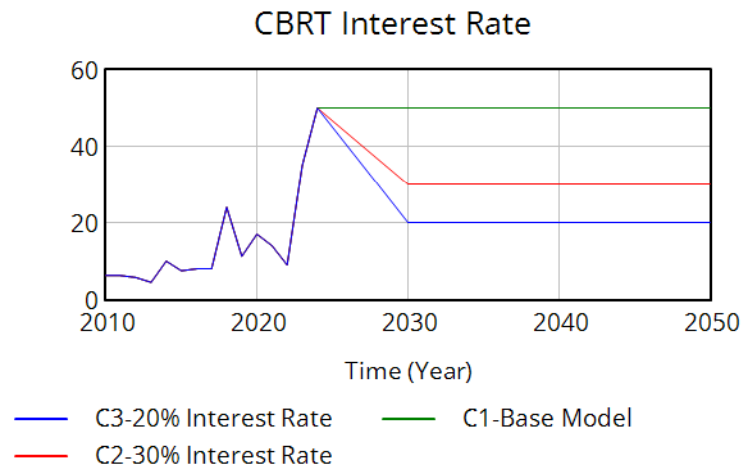


Figure 8.1. Change of CBRT Interest Rate.

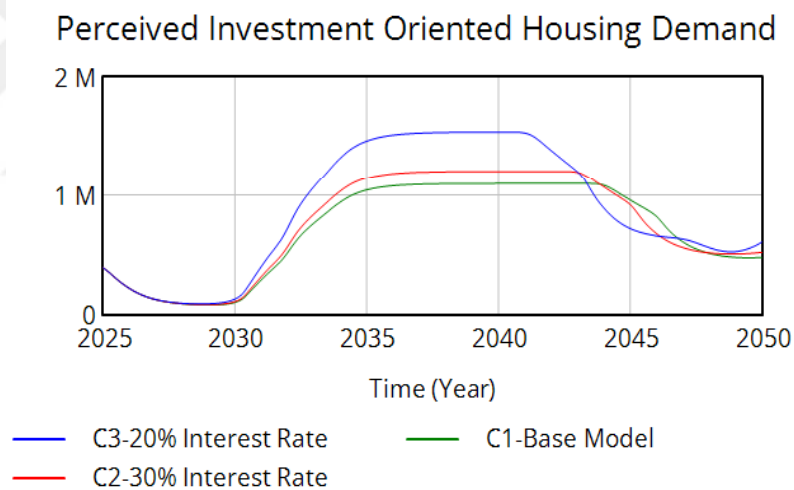


Figure 8.2. Perceived Investment Oriented Housing Demand for Scenario 1.

As explained above, decreasing interest rates prompt the banks to decrease loan interest rates. Falling loan interest rates inspire households to purchase a house. The effect of CBRT Interest Rate on investment-oriented housing demand is a multiplicative effect function of Investment Oriented Housing Demand. Investment oriented housing demand is affected by sales price, gross rent multiplier and interest rate and its equation is given in section 5.3.2 by equation 5.36.

Perceived investment-oriented housing demand is the delayed output of investment-oriented housing demand as explained in section 5.3.2. Perceived investment-oriented housing demand increases when CBRT Interest Rate is decreased, however, the difference in demand is observed clearly after 2030. When the CBRT Interest Rate is decreased to 20% from 50%, investment-oriented housing demand increases to nearly 1.5 million from 1 million and this considerable increase is not observed when the CBRT Interest Rate is reduced to 30%. When the CBRT Interest Rate is decreased to 20% from 50%, with respect to the base model conditions, the difference in essential housing demand is maximum around 200000 households.

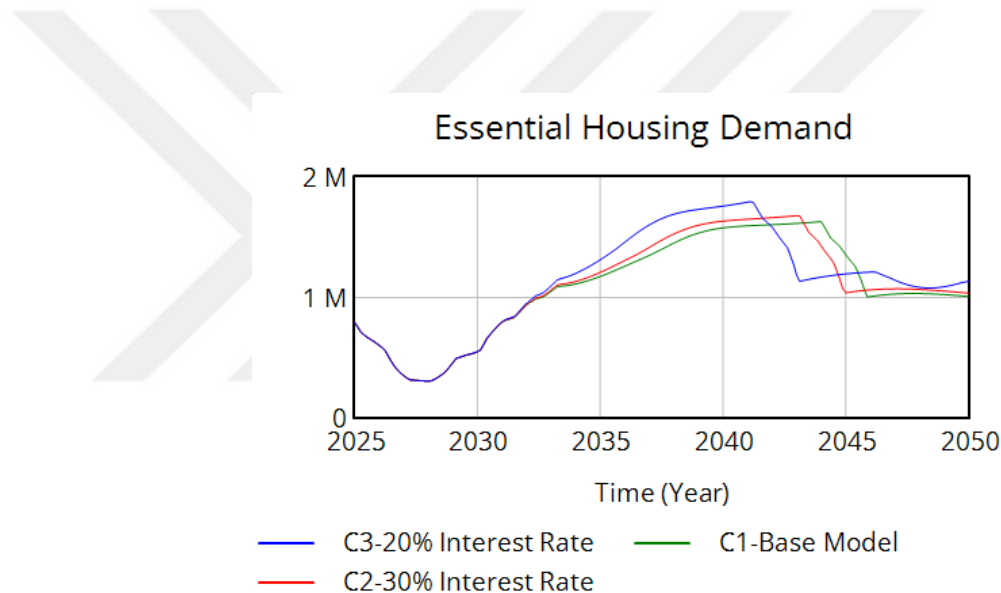


Figure 8.3. Essential Housing Demand for Scenario 1.

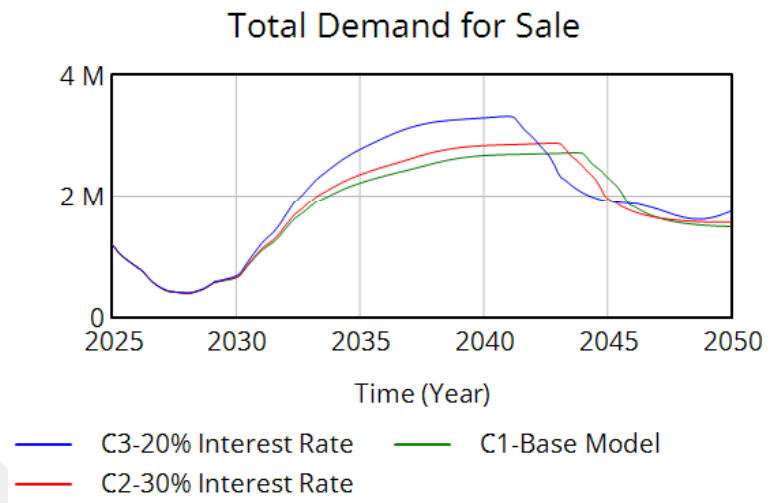


Figure 8.4. Total Demand for Sale for Scenario 1.

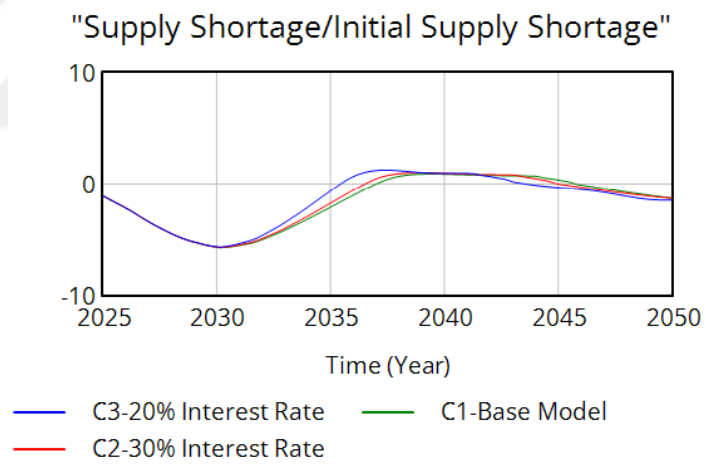


Figure 8.5. Supply Shortage/Initial Supply Shortage for Scenario 1.

Effect of Supply Shortage on Project Start Rate

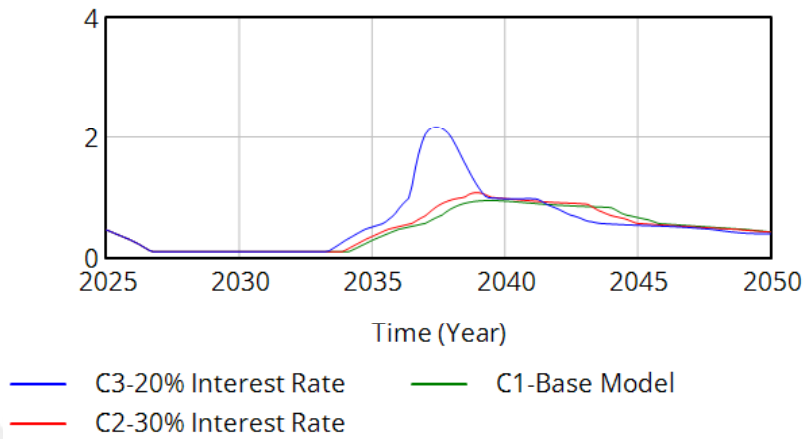


Figure 8.6. Effect of Supply Shortage on Project Start Rate.

Project Start Rate

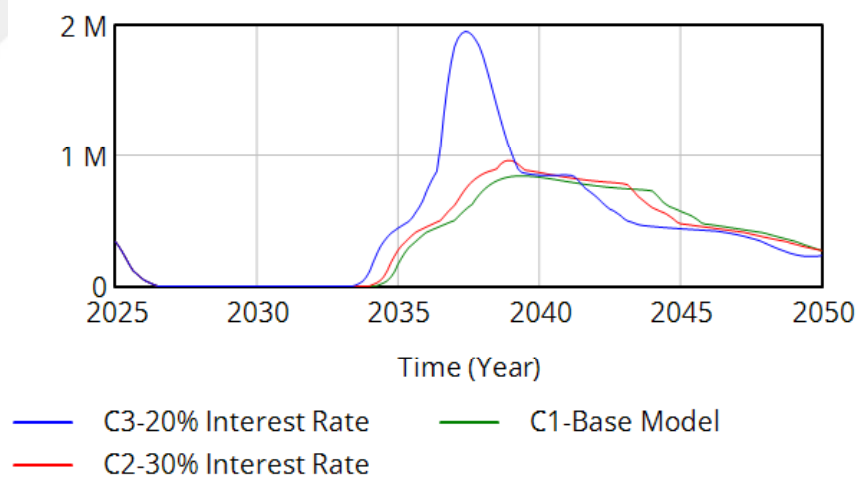


Figure 8.7. Project Start Rate for Scenario 1.

Because of the increasing sales demand in the 3rd case (C3) after 2030, there is more supply shortage and there is additional need for new constructions in the market. According to the *Effect of Supply Shortage on Project Start Rate* effect function given in section 5.3.1, this effect boosts the project start rate when the supply shortage at a specific time increases beyond the initial supply shortage. Between 2030-2040, *Supply Shortage/Initial Supply Shortage*

increases and exceeds 1 in the 3rd case. Thus, *Project Start Rate* increases and reaches almost 1.9 million in 2037.

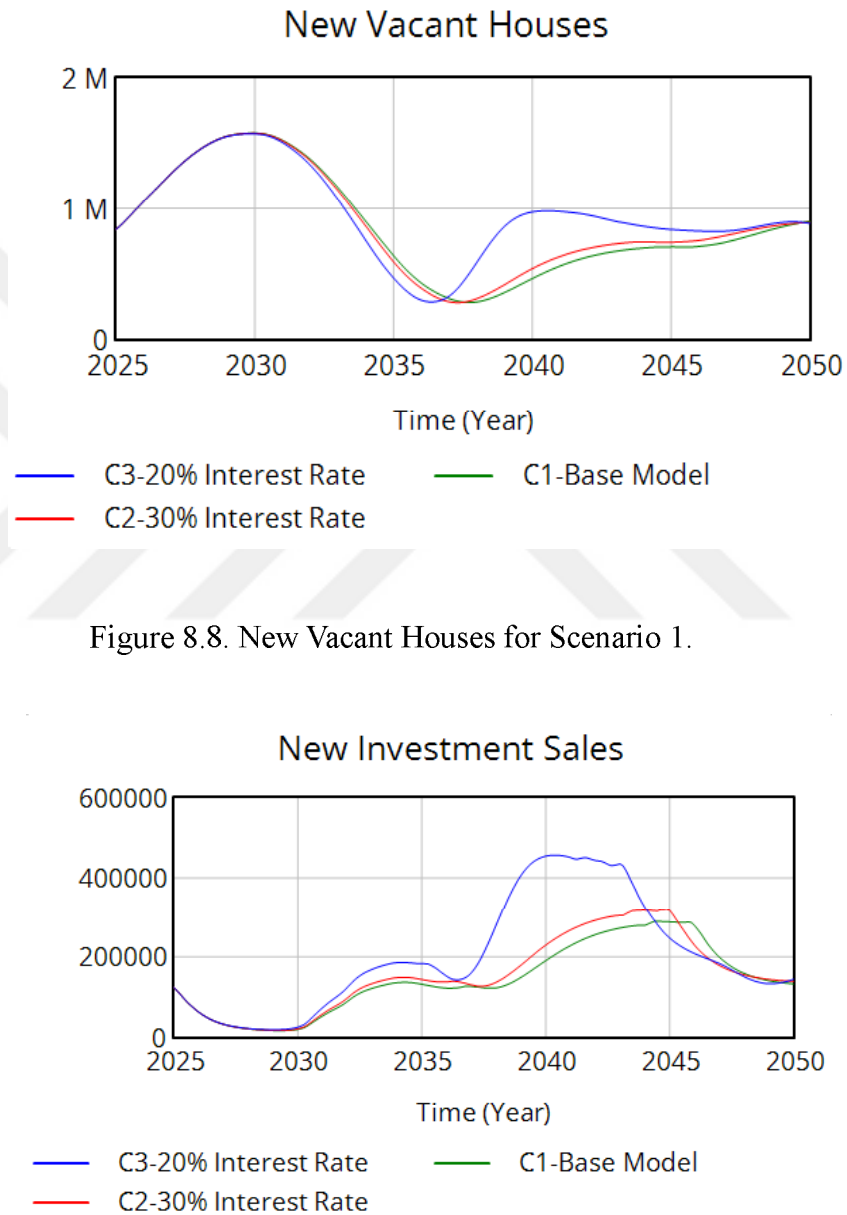


Figure 8.8. New Vacant Houses for Scenario 1.

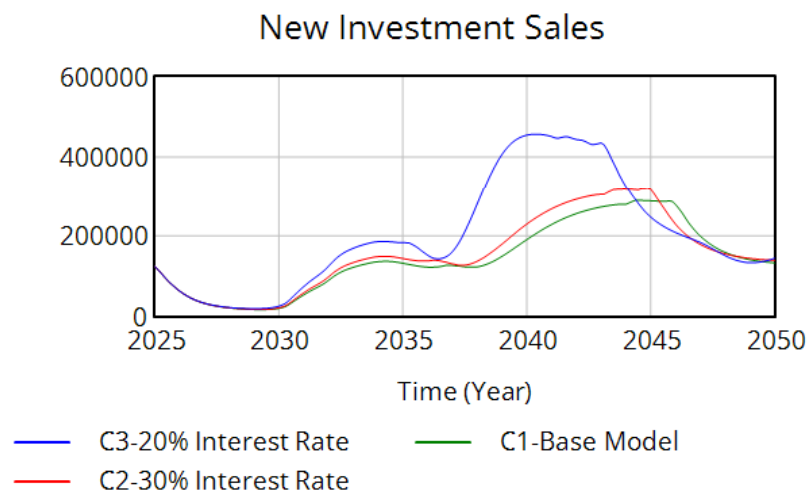


Figure 8.9. New Investment Sales for Scenario 1.

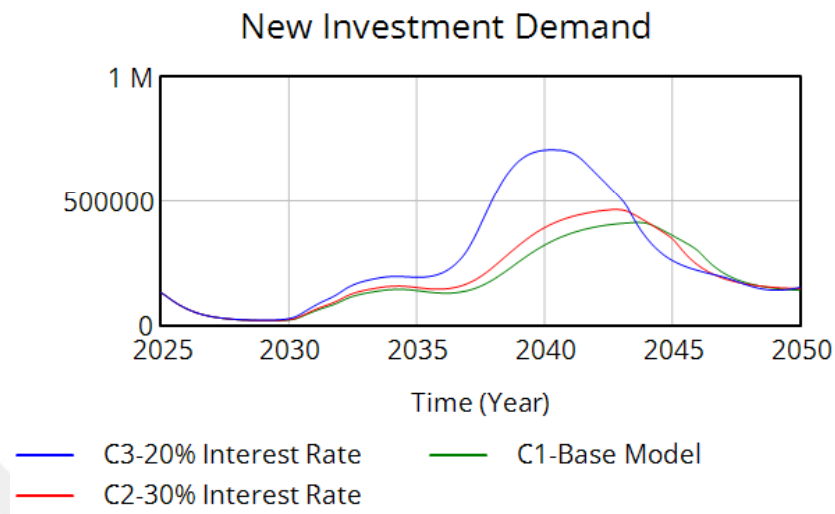


Figure 8.10. New Investment Demand for Scenario 1.

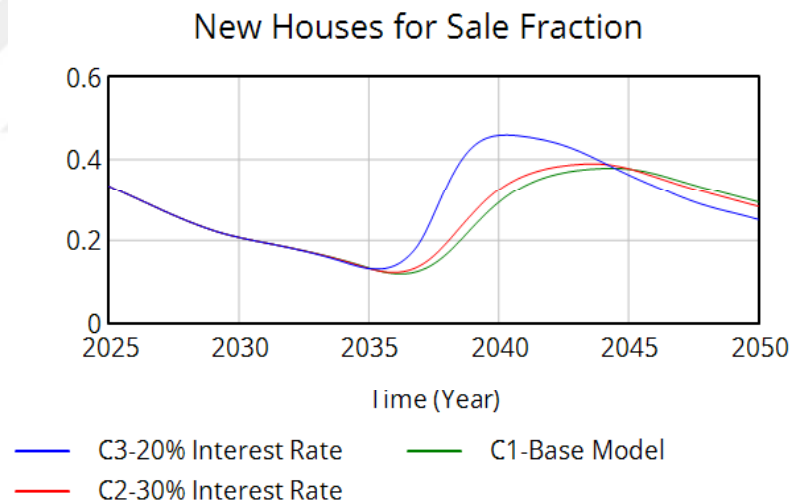


Figure 8.11. New Houses for Sale Fraction for Scenario 1.

As a result of increasing new constructions, new vacant houses increase and new home sales rise in the 3rd case (C3). From Figure 8.10 and 8.11, it is seen that in the C3 there is a significant increase in New Investment Demand until 2040 which increases New Investment Sales. *New Investment Demand* is calculated by the multiplication of *Perceived Investment Oriented Housing Demand* and *New Houses for Sale Fraction*. From figure 8.2, we can see that

Perceived Investment Oriented Housing Demand increases significantly in the 3rd case due to the falling CBRT Interest Rate. From the figure 8.11, it can be seen that New Houses for Sale Fraction increases more in the 3rd case due to the increasing new constructions and new vacant houses.

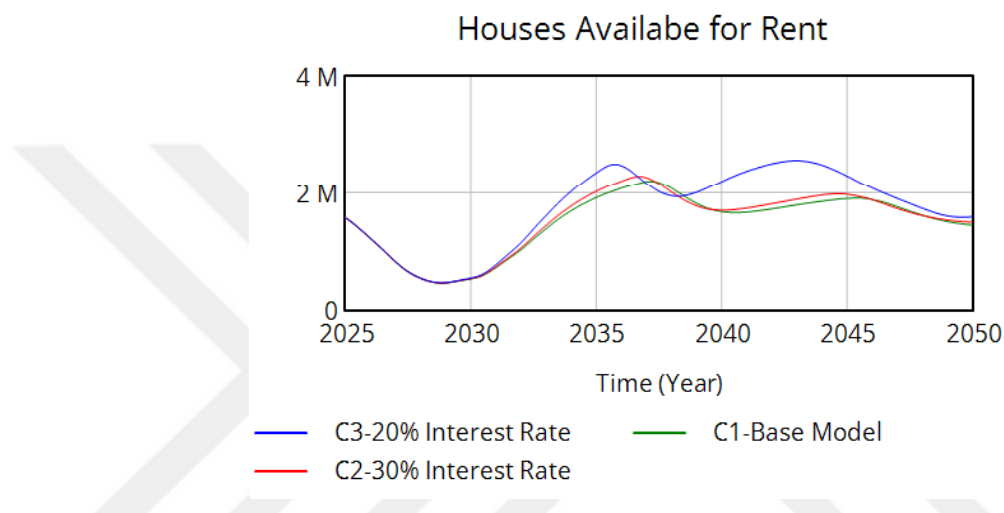


Figure 8.12. Houses Available for Rent for Scenario 1.

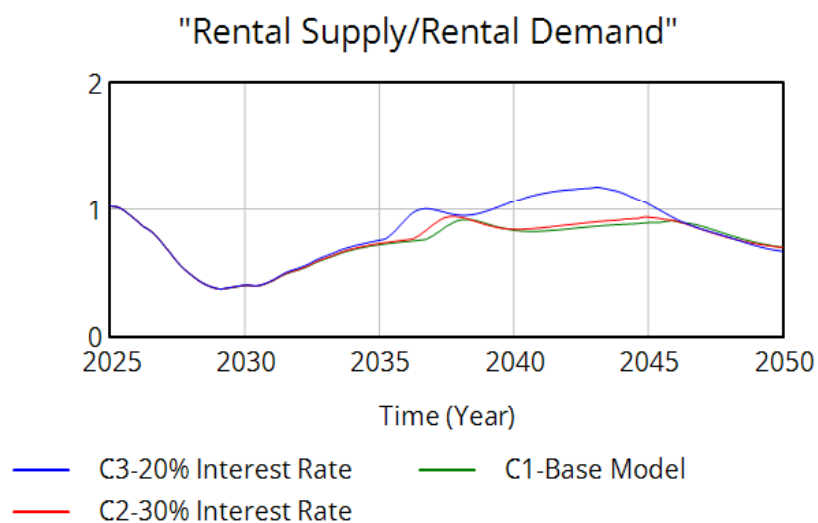


Figure 8.13. Rental Supply/Rental Demand for Scenario 1.

Increasing New Investment Sales causes more available houses for rent in the market in the 3rd case as seen in figure 8.12. Around 2040, New Investment Sales rises which creates additional rental supply in the market.

In the figure 8.14 below, *Perceived Average Rental Price* grows exponentially when the implemented interest rates are kept at 50% and declined to 30% after 2024. However, this behavior changes after 2040 if the interest rates are declined to 20%. After 2040, Houses Available for Rent (Total Supply for Rent) increases and exceeds 2 million in the 3rd case. As a result, Rental Supply/Rental Demand becomes more than 1 and rental prices start to decline after 2040 as in figure 8.14.

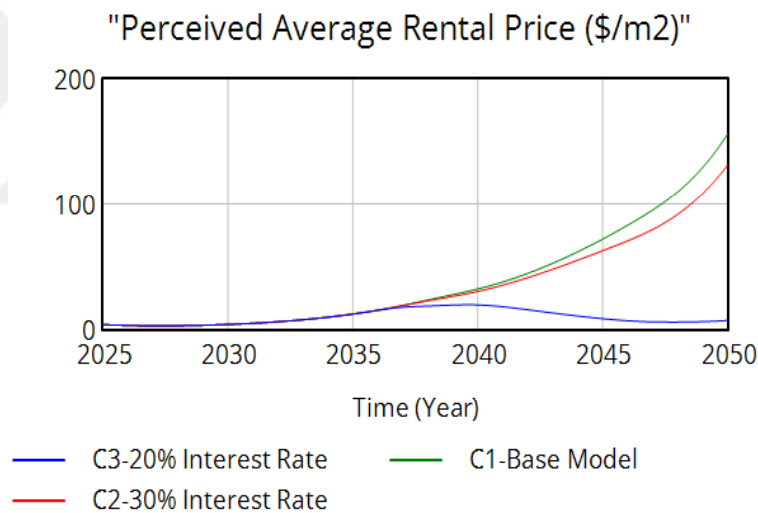


Figure 8.14. Perceived Average Rental Price for Scenario 1.

From figure 8.5, it is seen that total demand for sale increases more in the 3rd case, which reduces Sales Supply/Sales Demand as in figure 8.15. Consequently, Average Sales Price increases more in the 3rd case.

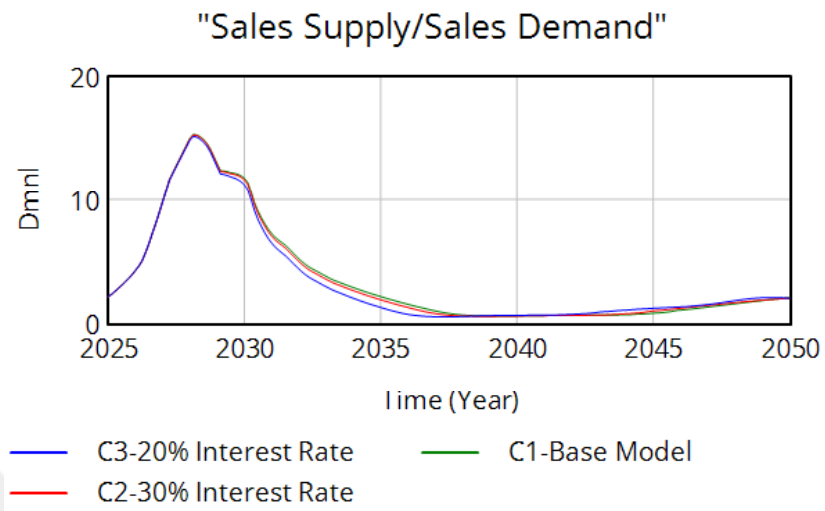


Figure 8.15. Sales Supply/Sales Demand for Scenario 1.

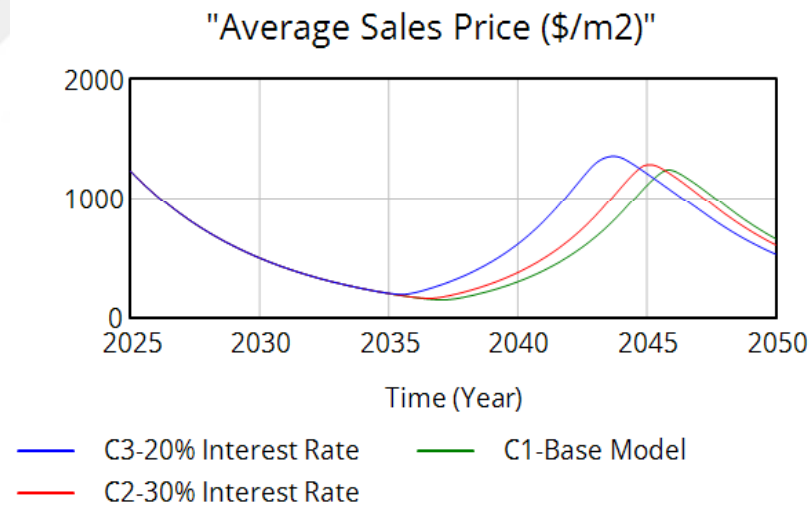


Figure 8.16. Average Sales Price for Scenario 1.

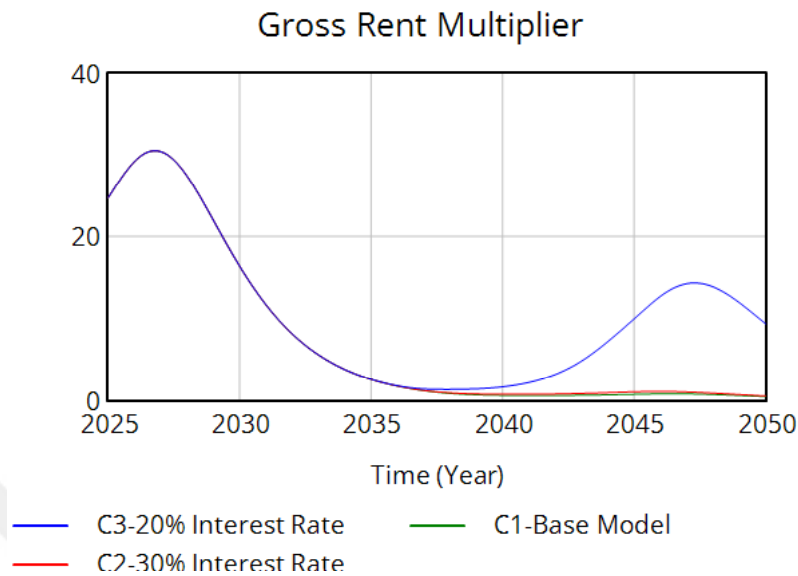


Figure 8.17. Gross Rent Multiplier for Scenario 1.

To summarize the outcomes of this scenario, we can state that there are 3 loops that are important and mainly responsible for these outcomes. The first one is B1 Sales Supply-New Houses Stock Loop. Sales Supply-New Houses Stock Loop dominates when total demand for sale increases in the 3rd case. With increasing sales demand, supply shortage increase, new constructions begin, and new vacant houses increase. As a result, total sales supply rise and supply shortage diminishes after 2040 which closes the loop.

Another loop that is working is B2 Supply Shortage-Total Sales Demand loop. In the 3rd case supply shortage increases more compared to the other cases. It is observed that with increasing new constructions, new vacant houses and new investment sales increased more after 2035 in the 3rd case. After new investment sales increases, houses available for rent increased more as in figure 8.12. Since the total rental supply increased, average rental price began to decrease after 2040 as seen in figure 8.14. Because of the decrease in average rental prices, rent multiplier increases after 2040 as in figure 8.17. As a result, essential and perceived investment-oriented demand decreases after 2040. In turn, total sales demand decreases as well as supply shortage decreases.

Figure 8.7 displays the project start rate change through years and it is interesting that in the 3rd case (C3) project start rate increases sharply between 2036 and 2038, makes a peak in 2038 and falls sharply until 2039. In 2038, the supply shortage exceeds initial supply shortage which makes the ratio in the figure 8.5 above 1. Project start rate is increased when this ratio exceeds 1, otherwise it declines. The rapid increase in project start rate can be explained by the threshold of the effect function which is given in figure 5.14. Around 2038, this ratio approaches to the threshold which is 1.

There is an additional mechanism that interacts with B1 and B2 loops when we lower interest rates below 30%. Perceived average rental price in 2036 is 15.22 \$/m², 18.7 \$/m² in 2038 and 19 \$/m² in 2039. After 2039, it begins to decrease as explained in the discussion above. This reduction in rental prices contributes to the dominance of B7 loop (Average Rental Price-Rental Supply Loop) after 2039. When rental prices begin to decline, gross rent multiplier increases as in figure 8.17. Investment oriented housing demand decreases as in figure 8.2 as well as total demand for sales decreases. As a result, supply shortage falls and less projects are initiated after 2040.

B1, B2 and B3 loops explain the main dynamics through years, both loops are triggered to work by emergence of supply shortage. 3rd case (C3) is different from base model and 2nd case. There is a critical point in CBRT Interest Rate beyond which rental market dynamics change. When CBRT falls below 30%, we do not observe exponential growth in the perceived average rental price as in the figure 8.14. It can be concluded that interest rates below 30% can make a difference in the market such that the reduction in interest rate determines how B6 and B7 Average Rental Price-Rental Supply loops will work. If CBRT Interest Rate falls below a certain critical point, we can observe more stable rental price dynamics rather than exponential growth until 2050.

8.2. Policy Analysis

8.2.1. First Home Campaign

In this section, a recent policy which is under revision is implemented to the model after 2024. Initiatives aim to enhance housing accessibility to boost the housing sector. An opportunity for households who dream of owning a house in Turkey is being discussed. Low-interest housing loan opportunity is an important development for citizens who will own a home for the first time. The details of the campaign will be determined by the end of 2024. This campaign is called “My First Home” which is a housing project that provides government support to citizens who want to own a home for the first time [51]. Government aims to facilitate house ownership by this policy. This policy is implemented into the model by intervening with the essential housing demand.

In the base model, there is a normal essential ratio which is constant and 0.15. It is estimated that in the base model 15% of the households who are tenants decide to buy a house to reside in. We investigated what happens if this ratio increases linearly until 2030 and then goes back to normal ratio.

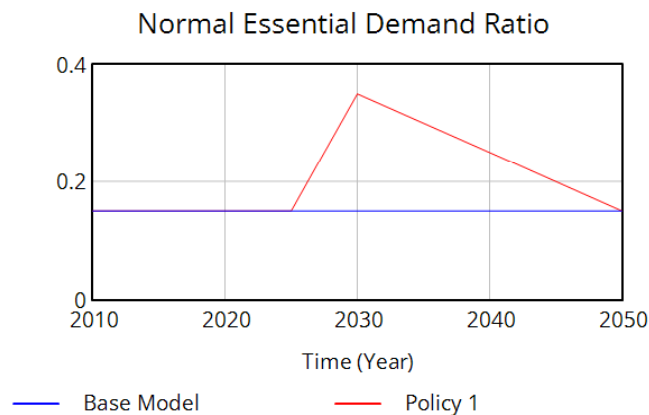


Figure 8.18. Change of normal essential demand ratio for policy 1.

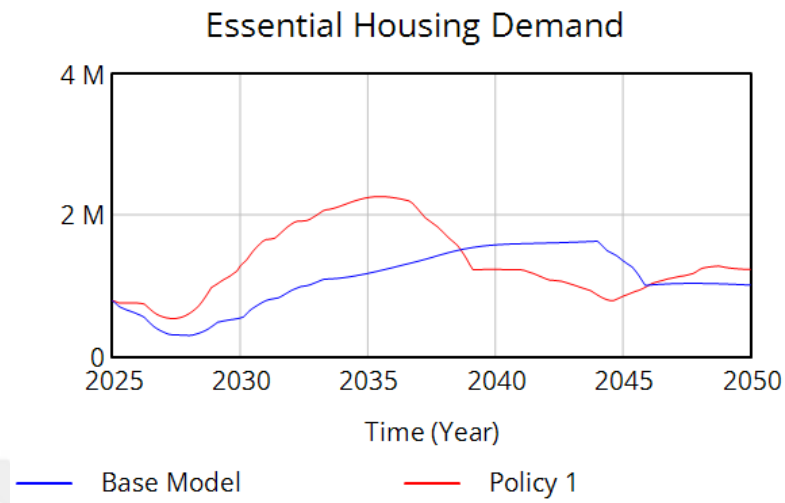


Figure 8.19. Essential housing demand for policy 1.

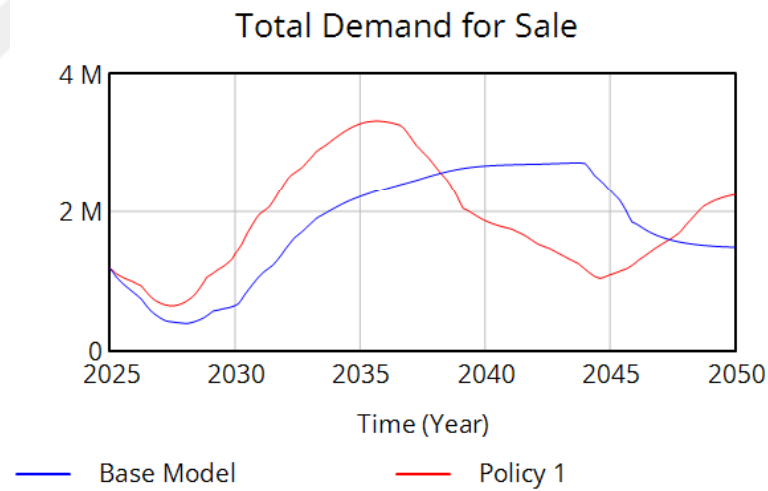


Figure 8.20. Total demand for sale for policy 1.

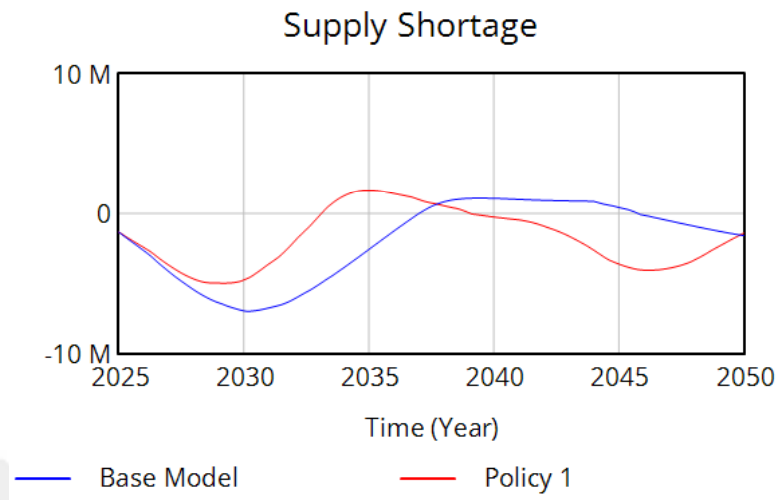


Figure 8.21. Supply shortage for policy 1.

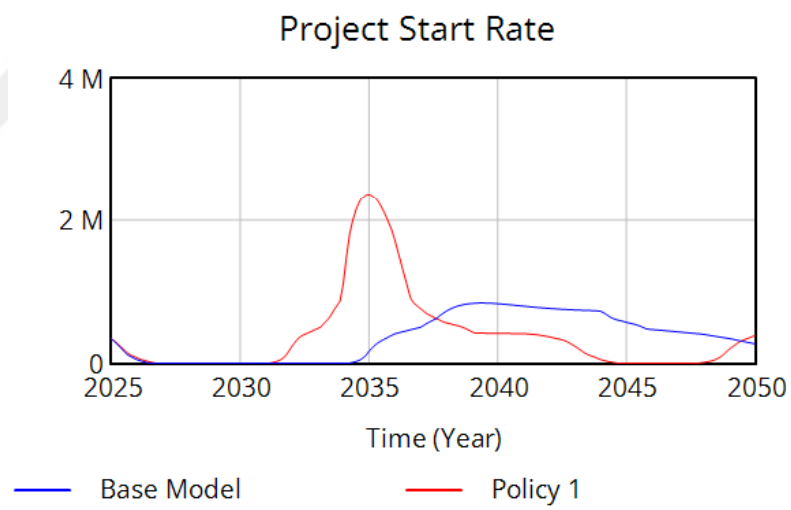


Figure 8.22. Project start rate for policy 1.

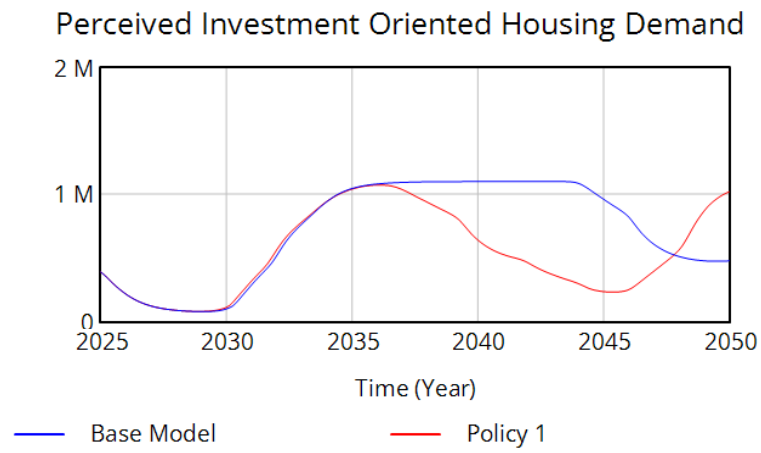


Figure 8.23. Perceived investment-oriented housing demand for policy 1.

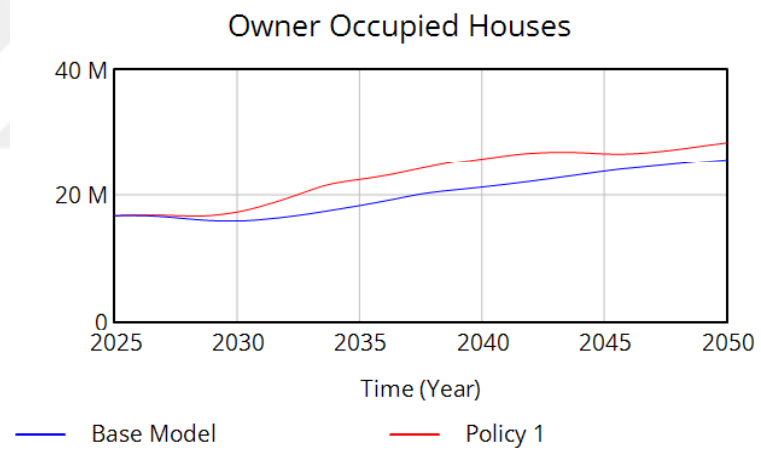


Figure 8.24. Owner occupied houses for policy 1.

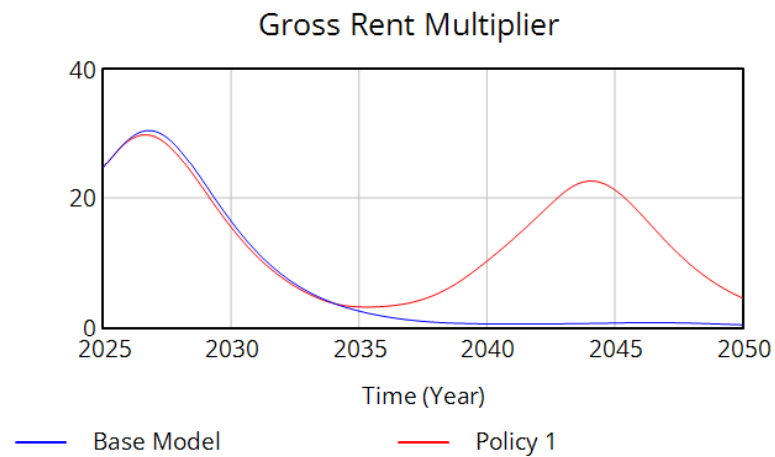


Figure 8.25. Gross Rent Multiplier for policy 1.

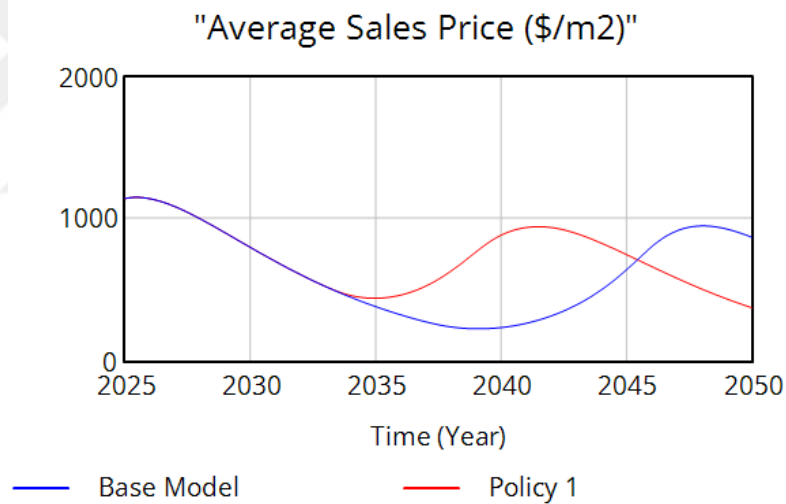


Figure 8.26. Perceived average sales price for policy 1.

For this policy, we can see from the above figures that essential housing demand increases after 2024, supply shortage increases, and new projects begin earlier compared to base model. Households prefer to purchase houses to reside in rather than purchasing them for investment with the emergence of this policy. Essential housing demand starts to increase after 2028. Because demand for sale increases, demand supply imbalance work in the way to increase sales prices after a delay. Gross rent multiplier begins to rise after 2035 due to the changes in

prices as seen in figures 8.26 and 8.29.

From figure 8.25, we see there is more houses purchased for residing as a result of the policy. Since rental prices start to fall after 2035, it is not favorable to purchase a house for investment, on the other hand it is favorable to sell your own property and rent a house to reside since rent multiplier is increasing. It is seen that housing prices rise rapidly with this policy since more households can afford to purchase property. The rapid increase in house prices also increases the rent multiplier rapidly, and this time, people living in their own homes decide to sell their houses and look for a house to rent. In this case, houses start to increase in the secondhand house market after 2040 as in the figure 8.28.

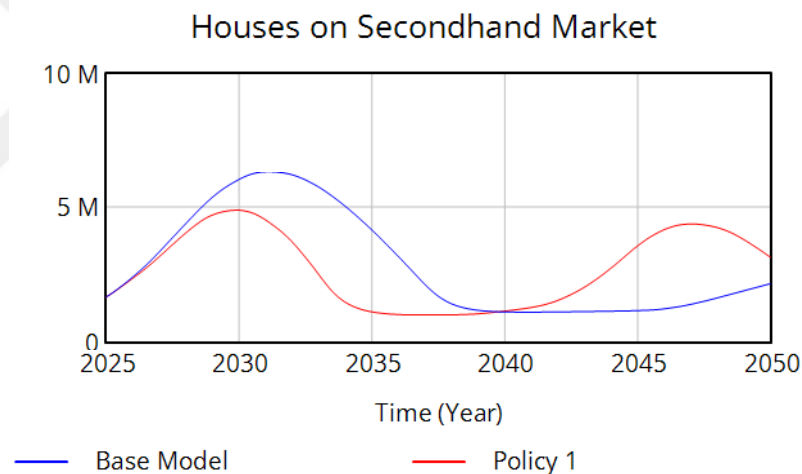


Figure 8.27. Houses on secondhand market for policy 1.

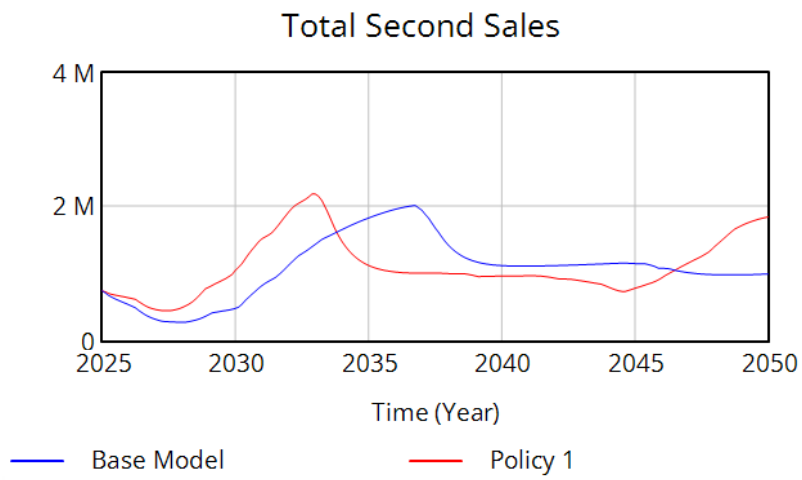


Figure 8.28. Total second sales for policy 1.

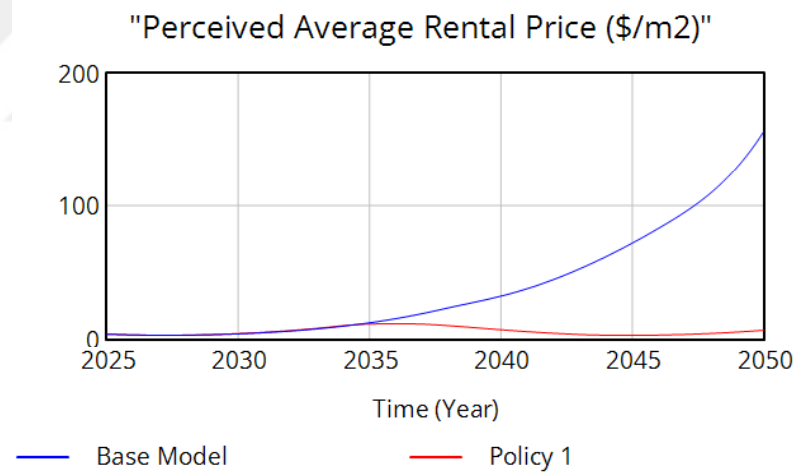


Figure 8.29 Perceived Average Rental Price for policy 1.

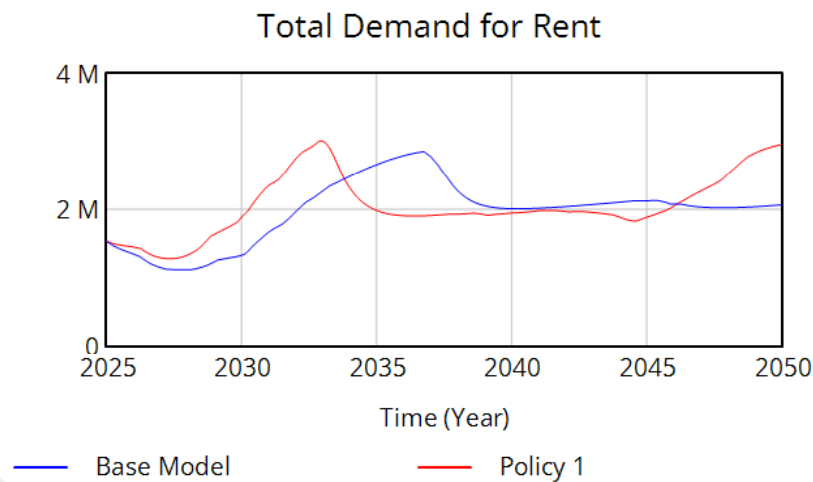


Figure 8.30 Total demand for rent for policy 1.

To sum up, between 2024 and 2030, a rapid increase in the demand for housing is implemented to model for demonstrating the effect of policy on essential demand. Households who were not homeowners previously took advantage of low-interest housing loans. More households become homeowners between 2024 and 2040. After 2040, some of the households who own a house decide to put their houses on sale and look for rental houses. Average sales price of houses is relatively high and rental price of houses are decreasing thus households head towards renting. Due to this decision, houses on secondhand market increase considerably after 2040. As explained before, in secondhand houses stock there are houses occupied by the owner of the house who intends to sell it and there are also those houses which are advertised by the owner of the house while tenants are residing in. In both scenarios, the assumption is made such that the family continues living in the house when it is advertised, and when the house is sold, families leave. From the figure 8.28, we see that total second sales are decreasing, and thus houses on the secondhand market grow since those houses cannot be sold.

In the base model, average rental price of houses increased exponentially until 2050 as shown in figure 7.8. There was a problem with rental house supply shortage. By this policy, households can afford to purchase a house and sales demand increases. Since sales demand increases, average rental prices begin to decrease. The demand for rent decreases where rental

supply increases.

8.2.2. Project Real Estate Fund

Real estate investment funds are the funds that offer investors the opportunity to invest in real estate projects and benefit from the returns of these projects. Housing projects are normally under the scope of real estate investment funds in Turkey. Lately, it has been said that the scope of these funds will be broadened. The regulations will pave the way for investing in more real estate projects. With this development, real estate projects for which construction permits have not yet been obtained and which are still in the project phase will also be included in the scope of the funds [52]. As a result of the expansion of the real estate investment funds, there will be a positive contribution to the project start rate flow in our model, which will accelerate the new project launches.

For this policy, an effect is added to the formulation of the project start rate which boosts new projects:

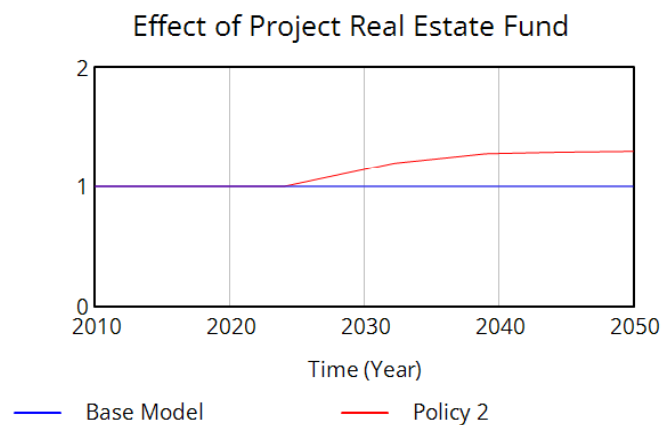


Figure 8.31 Effect of Project Real Estate Fund for policy 2.

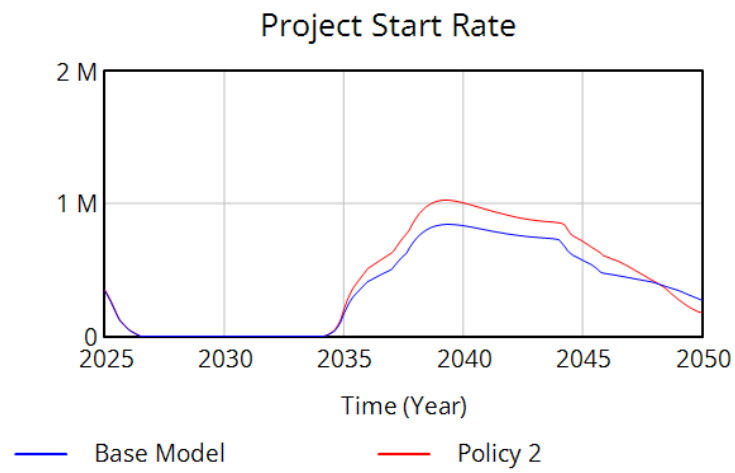


Figure 8.32 Project Start Rate for policy 2.

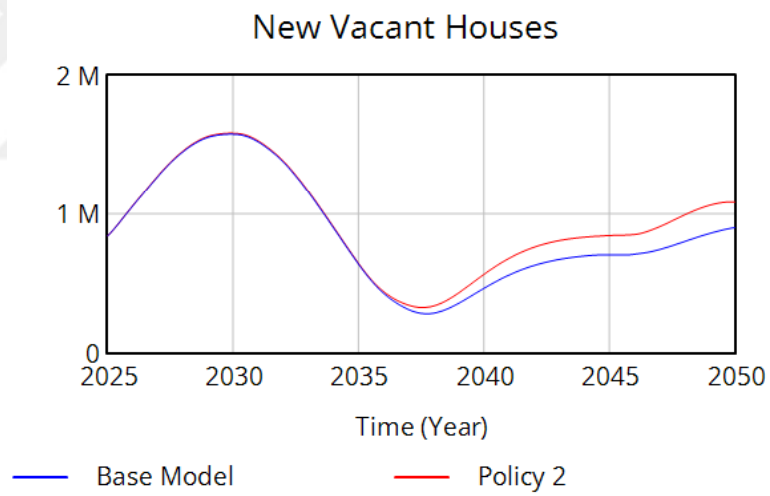


Figure 8.33 New Vacant Houses for policy 2.

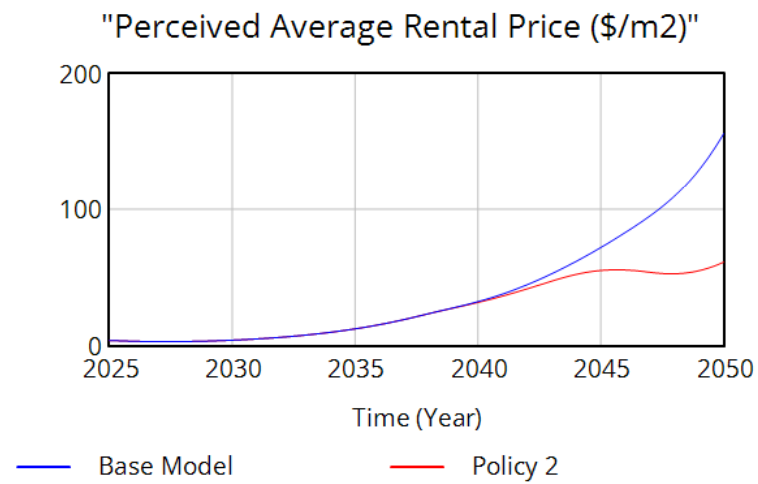


Figure 8.34 Perceived Average Rental Price for policy 2.

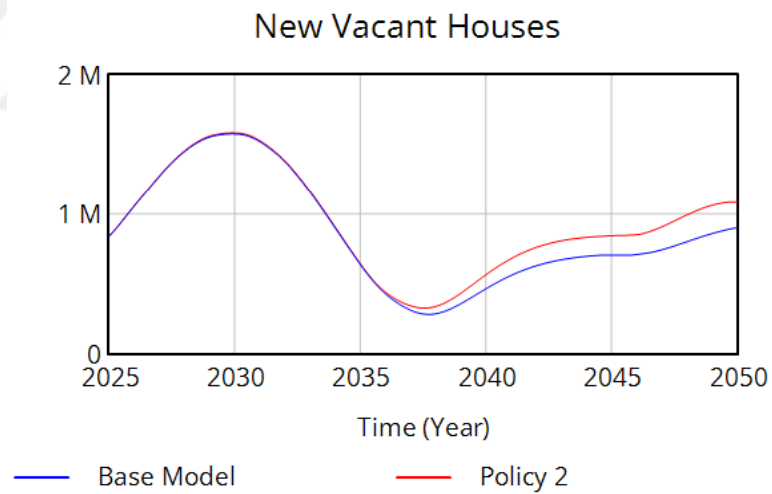


Figure 8.35 New Vacant Houses for policy 2.

From the figure 8.34, we can interpret that by boosting new projects with funds, the rise trend of average rental price can be prevented. As in figure 8.35, there are more available houses for sale with the implementation of this policy. Housing supply is enhanced by accelerating new projects. Houses available for rent (rental supply) have also increased. With this policy, each time unit approximately 200 000 more projects are initiated after 2035, and this gap starts to

shrink after 2045. If we look at the figure 8.34, we can observe that the average rental price of a house is 150 \$/m² in 2050 and after policy it is 61 \$/m². By initiating around 200 000 more projects each year regularly, we can reduce the average rental price of a house by almost 60% which is a significant result.



9. RESULTS AND CONCLUSIONS

The housing sector in Turkey carries significant importance both socially and economically. It creates employment opportunities and enhances economic growth through several activities related to construction and real estate trade. Turkey's real estate market creates attractiveness for both domestic and international investors. With urbanization and consistently increasing population, Turkish housing market faces with additional housing units. Thus, the housing sector is very important to address the diverse housing needs of the household.

This model is built to address the underlying mechanisms that drive the oscillations in sales and rental prices in a housing market where basic structures are based on Turkish housing market. A Turkey-inspired housing model is constructed to obtain a base behavior between 2010 and 2024. Extreme conditions tests are done to determine whether the model remains reliable when subjected to extreme scenarios. After the model is found that it is an adequate representation of a common housing market, simulations for the 2025-2050 period are conducted to understand the behavior of the market with the base parameters. Those simulations are done in section 7 under Base Run. The aim of the base run is to construct a model that resembles the Turkish housing market in terms of key variables such as sales price, rent price, demand and supply and observe what problems will emerge in the long run. In the literature the demand of investors and the dynamic of secondhand market is not studied in detail. In this model, we include those concepts to create a realistic overview of the market. According to the results, we conclude that investors' actions and secondhand house market are very important in changing market dynamics such that rental prices are subject to change with respect to investor decisions.

It is known from the literature that housing markets show oscillatory behavior with a few years of cycle periods. If we run the model until 2050, we can observe cycles occurring. Especially prices make boom and busts in some periods due to the demand and supply imbalance occurring in the market. As a result of booms and busts, the demand in the market can shift from rental housing demand to sales housing demand or vice versa.

According to the base model simulations, between 2024 and 2030, we found that increase in sales demand depends on a critical sales price value which is under 1000 \$/m². This critical price is reached in 2030, after an increase in sales demand is observed. There is a shortage of rental supply such that rental demand is not met. As a result, rental price increases exponentially.

Between 2030 and 2050 in the base model simulations, there is demand for secondhand houses. When those houses are sold, households that were previously residing in those houses needs to find a house which means there is additional housing demand that arises. Since current rental supply is not adequate, rental price of houses grows until 2050. As a summary, there are rental supply shortage and increasing rental price problem after 2025 which may seem to persist until 2050. To address these problems and give recommendations, scenario and policy analysis are conducted. Moreover, the base run simulation demonstrates that both the sales and rental markets are heading towards conditions that cannot occur in real life. In these situations, the market will react in ways we have not known until today. Looking ahead, this market may reach a point where we may notice some social behaviors or market reactions that we are not aware of today. Therefore, we should be cautious when using this model for future predictions.

In the scenario analysis, we have found that CBRT interest rates are critical in affecting rental prices in the market. It is not enough to decrease inflation and interest rates to reduce rental prices. There is a critical point below which we can observe rental prices decrease. In the scenario analysis, we have found that reducing interest rate to 20 % is enough to prevent rental price increase through years, however 30 % interest rate is still high such that rental price continues to grow.

In policy analysis, a policy which is under consideration in Turkey is implemented by simply affecting the constant essential demand ratio. This policy is called “First Home Campaign”. This constant essential demand ratio is increased for a 6-year period after 2024. After, the ratio comes back to 0.15 as in the base model. With this policy, more households can afford to buy houses, so sales demand has increased. House ownership gained importance, rental demand falls as a result rental prices decrease. The second policy is called “Project Real Estate

Fund”. By this policy, new projects are initiated, and rental supply is boosted. Thus, the increase in average rental prices is stopped around 2045. By introducing around 200 000 more projects each year regularly, we can reduce the average rental price of a house by almost 60% in 2050 by this policy.

All in all, in the model we included the effect of secondhand houses, investors and their demands, and rental prices to examine the dynamics of each separately. The relations between the new houses, secondhand houses and rental houses enriches the causal loops that are inherent in the housing sector. In terms of what the trend in prices will be, the simulation shows us that there will be oscillations in prices and that there is not constantly increasing or decreasing price trend between 2024 and 2050. The balancing feedback loops that are introduced in section 5, determine the direction of changes in the system variables. Those feedback loops inherently resist changes only in one direction. When a change happens in the market, they counteract this shift by initiating a change in the opposite direction, successfully dampening fluctuations and directing the system back toward stability. Outcomes of scenario and policy analysis give insights into how to increase rental supply and prevent the increase of average rental prices in the long run. Those results and recommendations can be important, and corrective actions can be applicable for Turkey since the applied scenario and policies reflect what is being spoken in Turkey contemporarily.

REFERENCES

1. Sterman, J.D., *Business Dynamics: System Thinking and Modeling for a Complex World*, HD30. 2 S7835 2000, USA, 2000.
2. Wheaton, W. C., Real Estate “Cycles”: Some Fundamentals. *Real Estate Economics*, Vol.27, No.2, pp. 209–230, 1999.
3. Aoki, K., Proudman, J., & Vlieghe, G., House Prices, Consumption, and Monetary Policy: A Financial Accelerator Approach. *Journal of Financial Intermediation*, Vol. 13, No.4, pp. 414–435, 2004.
4. Guo, J., & Wang, J., Housing Price Research Based on System Dynamics Model. *IOP Conference Series: Earth and Environmental Science*, Dali, China, p.12, 2021.
5. Tunçsiper, Çağatay & Akgündüz, Kadir, Türkiye’de Konut Piyasası ve Hedonik Fiyatlama Modeli Bağlamında İstanbul/Eyüp Örneği, Vol. 20, No. 4, pp. 428-446, 2022.
6. Ebru, Ç., & Eban, A., Determinants of House Prices in Istanbul: A Quantile Regression Approach. *Quality & Quantity*, Vol. 45, No.2, pp. 305–317, 2009.
7. Turkey Habitat III National Report., [https://webdosya.csb.gov.tr/db/habitat/editordosya/file/TURKEY_HABITAT-III_NATIONAL_REPORT_\(english\).pdf](https://webdosya.csb.gov.tr/db/habitat/editordosya/file/TURKEY_HABITAT-III_NATIONAL_REPORT_(english).pdf), accessed on August 20, 2024.
8. Ayan, E., Eken, S. Detection of Price Bubbles in Istanbul Housing Market Using LSTM Autoencoders: a District-based Approach, *Soft Computing*, Vol. 25, pp. 7957–7973, 2021.
9. Kenny, G., Modelling the Demand and Supply Sides of the Housing Market: Evidence from Ireland. *Economic Modelling*, Vol. 16, Vol.3, pp. 389–409, 1999.

10. BETAM sahibindex Kiralık Konut Piyasası Görünümü: Ocak 2024, 2024, <https://betam.bahcesehir.edu.tr/2024/01/sahibindex-kiralik-konut-piyasasi-gorunumu-ocak-2024/>, accessed on October 26, 2024.
11. BETAM sahibindex Kiralık Konut Piyasası Görünümü: Ocak 2023, 2023, <https://betam.bahcesehir.edu.tr/2023/01/sahibindex-kiralik-konut-piyasasi-gorunumu-ocak-2023/>, accessed on October 26, 2024.
12. BETAM Kiralık Konut Piyasası Görünümü: Ocak 2022, 2022, <https://betam.bahcesehir.edu.tr/2022/01/kiralik-konut-piyasasi-gorunumu-ocak-2022/>, accessed on October 26, 2024.
13. BETAM Konut Piyasası Görünümü: Ocak 2021, 2021, <https://betam.bahcesehir.edu.tr/2021/01/konut-piyasasi-gorunumu/>, accessed on October 26, 2024.
14. Mu, L., Ma, J., & Chen, L., A 3-dimensional discrete model of housing price and its inherent complexity analysis. *Journal of Systems Science and Complexity*, Vol. 22, No.3, pp. 415–421, 2009.
15. HIANG, L. K., & Webb, J. R. (2007). Are International Real Estate Markets Integrated: Evidence from Chaotic Dynamics. Technical Report, October 2007. *Hartford: Real Estate Research Institute*.
16. Özbaş, B., Özgün, O., & Barlas, Y., Modeling and Simulation of the Endogenous Dynamics of Housing Market Cycles. *Journal of Artificial Societies and Social Simulation*, Vol.17, No.1, pp.19, 2014.
17. Team, I. Investopedia, How Does Supply and Demand Affect the Housing Market?, 2023, <https://www.investopedia.com/ask/answers/040215/how-does-law-supply-and-demand-affect-housing-market.asp>, accessed on October 25, 2024.

18. Kramer, L. Investopedia, How Does the Law of Supply and Demand Affect Prices?, 2024, <https://www.investopedia.com/ask/answers/033115/how-does-law-supply-and-demand-affect-prices.asp>, accessed on October 25, 2024.
19. Nathanson, C., & Zwick, E., Arrested Development: Theory and Evidence of Supply-Side Speculation in the Housing Market, Vol. 73, No. 6, pp. 2587-2633, 2013.
20. Turkish Statistical Institute, House Sales Statistics, March 2023, 2023, <https://data.tuik.gov.tr/Bulten/Index?p=House-Sales-Statistics-March-2023-49517&dil=2#:~:text=House%20sales%20decreased%20by%2011.5,and%20became%20283%20thousand%20215.>, accessed on October 25, 2024.
21. Timur, M. C., & Kurtbaş, İ., Covid-19 Sonrası Dönemde, Türkiye’de Konut Sektörünün Ekonomi-Politik Analizi. Politik Ekonomik Kuram, Vol. 8, No.2, pp. 516–539, 2024.
22. Yıldırım, M., & İvrendi, M., House prices and the Macroeconomic Environment in Turkey: The Examination of a Dynamic Relationship. Economic Annals, Vol. 62, No. 215, pp. 81–110, 2017.
23. Kutlu, S., Türkiye Konut Fiyatları Dolar Bazlı: OCAK 2010-KASIM 2023 (Güncellendi), 2024, <https://safurekutlu.com/turkiye-konut-fiyatlari-dolar-bazli/>, accessed on October 25, 2024.
24. Akkoç, S., 2018 Kur Şoku ve Türkiye Ekonomisine Yansımaları. International Review of Economics and Management, Vol.11, No.2, pp. 75-96, 2023.
25. Aksoy Khurami, E., & Özdemir Sarı, B, Trends in Housing Markets During the Economic Crisis and Covid-19 Pandemic: Turkish case. Asia-Pacific Journal of Regional Science, Vol.6, No.3, pp. 1159–1175, 2022.

26. Barlas, Y., Özbaş, B., & Özgün, O., (PDF) Modeling of Real Estate Price Oscillations in Istanbul. *Proceedings of 25th International System Dynamics Conference*, Albany, NY, USA, p.23, 2007.
27. TANRIVERMİŞ, Prof. dr. H., & MENDEŞ, M., Konut üretiminde Arz-TALEP Dengesi Kurulamamasının Nedenleri ve Sonuçları. *Kocaeli Üniversitesi Mimarlık ve Yaşam Dergisi*, Vol.8, No.3, pp. 575-596, 2023.
28. AdminRaheelEmaad, Sterlingworth Group Surveys, Understanding the Link between Interest Rates and House Prices – Sterlingworth Group Surveys, 2023, <https://sterlingworthgroup.co.uk/surveys/interest-rates-and-house-prices/>, accessed on May 3, 2024.
29. Hjalager, A.-M., Sørensen, M. T., Steffansen, R. N., & Staunstrup, J. K., Sales prices, Social Rigidity and the Second Home Property Market. *Journal of Housing and the Built Environment*, Vol. 38, No. 4, pp. 2325–2344, 2023.
30. Penn State University Park, Exploring the Dynamics of Earth Systems, Ch 2.3 1st Example: The Bathtub, <https://personal.ems.psu.edu/~dmb53/DaveSTELLA/modeling/ch2.3.html>, accessed on October 27, 2024.
31. Turkish Statistical Institute, BUILDING PERMITS, IV. QUARTER 2011, 2012, <https://data.tuik.gov.tr/Bulten/Index?p=Building-Permits-IV.-Quarter-2011-10762>, accessed on October 25, 2024.
32. Sahibinden, İnşaat Projesinden Alınan Eve Ne Zaman Taşınılabılır? <https://www.sahibinden.com/emlak360/insaat-projesinden-alinan-evlere-ne-kadar-surede-tasinilabilir>, accessed on October 27, 2024.
33. Gazete Duvar, Boşkent, <https://www.gazeteduvar.com.tr/boskent-makale-1562033>, accessed on October 27, 2024.

34. Emlakjet Haber, Türkiye’de Kaç Hane Oturduğu Evde Ev Sahibi?, 2018, <https://www.emlakjet.com/haber/haber/turkiyede-kac-hane-oturdugu-evde-ev-sahibi>, accessed on July 4, 2024.
35. Sabah, Ev Fiyatları En Çok Antalya’da Kiralar İzmir ve Adana’da Arttı, 2010, https://www.sabah.com.tr/ekonomi/2010/07/16/ev_fiyatlari_en_cok_antalyada_kiralar_izmir_ve_adanada_artti, accessed on July 4, 2024.
36. Endeksa, Blog, Bilgi Bankası, Amortisman Nedir ve Nasıl Hesaplanır, 2023, <https://www.endeksa.com/tr/blog/yazi/amortisman-nedir-ve-nasil-hesaplanir#:~:text=Genel%20olarak%20gayrimenkuller%20i%C3%A7in%20s%C3%BCre,s%C3%BCre%2014%20ay%20olarak%20belirlenmi%C5%9Ftir>, accessed on July 4, 2024.
37. Deaton, M., & MacDonald, R. (n.d.). Chapter 2: *Systems Thinking: a New Way to Tackle Problems*. Pressbooks, James Madison University, USA.
38. DiPasquale, D., & Wheaton, W. C., Housing Market Dynamics and the Future of Housing Prices. *Journal of Urban Economics*, Vol. 35, No.1, pp. 1–27, 1994.
39. Immo, A., The Number of Renters in Türkiye Reaches 23 Million, Barnes Türkiye, <https://www.barnes-turkey.com/en/news/2024/the-number-of-renters-in-turkiye-reaches-23-million-267.html>, accessed on October 28, 2024.
40. Turkish Statistical Institute, Survey on Building and Dwelling Characteristics, 2021, December 2022, <https://data.tuik.gov.tr/Bulten/Index?p=Survey-on-Building-and-Dwelling-Characteristics-2021-45870&dil=2>, accessed on October 28, 2024.
41. Kau, James B., and Donald Keenan. “The Theory of Housing and Interest Rates.” *The Journal of Financial and Quantitative Analysis*, Vol. 15, No. 4, pp. 833–47, 1980.

42. Merkez Bankası Faiz Oranları - Investing.com Türkiye. <https://tr.investing.com/central-banks/>, accessed on October 28, 2024.
43. Sutton, K. Buyer's vs. Seller's market: How to Tell the Difference, Assurance Financial, 2024, <https://assurancemortgage.com/buyers-vs-sellers-market/#difference>, accessed on October 28, 2024.
44. Genta, P. J., *Understanding the Boston Real Estate Market: A System Dynamics Approach*, Ph.D. thesis, Massachusetts Institute of Technology. Boston, USA, 1989.
45. Barlas, Y., Formal Aspects of Model Validity and Validation in System Dynamics. *System Dynamics Review*, Vol. 12, No.3, pp. 183–210, 1996.
46. Barras, R., A Building Cycle Model for an Imperfect World. *Journal of Property Research*, Vol. 22, No. 2–3, pp. 63–96, 2005.
47. Zhang, X., Geltner, D., & de Neufville, R., System Dynamics Modeling of Chinese Urban Housing Markets for Pedagogical and Policy Analysis Purposes. *SSRN Electronic Journal*, Vol.57, pp. 476-501, 2018.
48. BBC, Merkez Bankası Faizi Eylül'De yüzde 50'de Sabit Tuttu, BBC News Türkçe, <https://www.bbc.com/turkce/articles/cwyl8ld74d8o>, accessed on October 28, 2024.
49. Ntv, NtvPara Haberleri, Bankalarda Faiz Indirimi Fiyatlaması, 2024, <https://www.ntv.com.tr/galeri/ntvpara/bankalarda-faiz-indirimi-fiyatlamasi,BizAWb4BxkGslQRC4Swe2A/AzIkCACme06dmLmYwGmP5g>, accessed on October 15, 2024.
50. Nicholas Apergis, "Housing Prices and Macroeconomic Factors: Prospects within the European Monetary Union," *International Real Estate Review*, *Global Social Science Institute*, vol. 6, No.1 , pp. 63-74, 2003.

51. Takvim.com.tr, İlk Evim Kampanyası Ne Zaman Başlayacak, Başvuru Şartları Neler? 2024, <https://www.takvim.com.tr/ekonomi/2024/02/18/120-faizli-konut-kredisi-basvuru-ekrani-2024-ilk-evim-kampanyasi-ne-zaman-baslayacak-basvuru-sartlari-neler-2000000-tl-taksit-geri-odeme-tablosu>, accessed on September 18, 2024.

52. Ateşli, D. E., Proje Gayrimenkul Yatırım Fonları Konut Sektörünü Nasıl Etkileyecek?, 2024, <https://emsal.com/proje-gayrimenkul-yatirim-fonlari-konut-sektorunu-nasil-etkileyecek/>, accessed on September 30, 2024.



APPENDIX A: MODEL EQUATIONS

```
(001) "Average Rental Price ($/m2)"= INTEG (
```

Net Change of Average Rental Price,

2.6)

Units: \$/m²/Year

```
(002) "Average Sales Price ($/m2)"= INTEG (
```

Net Change of Average Sales Price,

650)

Units: \$/m²/Year

(003) CBRT Interest Rate = WITH LOOKUP (

Time,

$[(0,0)-(2025.06,66.2736)],(2010,6.25),(2011,6.25),$
 $(2012,5.75),(2013,4.5),(2014,10),(2015,7.5),(2016,8),(2017,8),(2018,24),$
 $(2019,11.25),(2020,17),(2021,14),(2022,9),(2023,35),(2024,50))$

Units: **undefined**

(004) Construction Finish Rate=

Construction in Progress/Construction Time

Units: Houses/Year

(005) Construction in Progress= INTEG (

Project Start Rate-Construction Finish Rate,

1.4e+06)

Units: Houses

(006) Construction Time=

3

Units: Year

(007) "Effect of Demand-Supply Imbalance on Rent Price" = WITH LOOKUP ("Rental Supply/Rental Demand",

([(0,0)-(1.46615,1.08683)],(0.513291,0.799163),(0.599636,0.790795),(0.670403,0.78),(0.730736,0.727833),(0.804654,0.631916),(0.871848,0.497707),(0.937489,0.338912),(1.03876,-0.723849),(1.07393,-0.8),(1.11858,-0.866109),(1.25718,-0.916653),(1.40634,-0.96728)))

Units: **undefined**

(008) "Effect of Demand-Supply Imbalance on Sales Price" = WITH LOOKUP ("Sales Supply/Sales Demand",

([(0,0)-(1.79586,0.664142)],(0.490051,0.469456),(0.599512,0.466109),(0.648161,0.457741),(0.706844,0.436318),(0.758352,0.38569),(0.800834,0.340686),(0.843532,0.282008),(0.883441,0.233808),(0.916553,0.178117),(0.964381,0.0728033),(1.00391,0.0100418),(1.08142,-0.148954),(1.14852,-0.189121),(1.20235,-0.203347),(1.31626,-0.24),(1.45655,-0.27),(1.5877,-0.3)))

Units: **undefined**

(009) Effect of Interest Rate = WITH LOOKUP (

CBRT Interest Rate,

([(0,0)-(10,10)],(6,1.25),(10.7762,1.02301),(16.3398,0.834728),(23.5028,0.709205),(30.5138,0.596234),(40,0.55)))

Units: **undefined**

(010) "Effect of New Vacant Houses/Project Start Rate by Shortage" = WITH LOOKUP

(
 "New Vacant Houses/Project Start Rate by Shortage",
 ([(0,0)-(5.8809,1.36576)],(0,1),(1,0.97),(1.76796,0.903766),
 (2.32136,0.715481),(3.03562,0.393305),(4.05208,0.217573),(4.94491,0.154812
),(8,0.0119272)))

Units: **undefined**

(011) Effect of Rent Multiplier on Essential Demand = WITH LOOKUP (

"Perceived Gross Rent Multiplier/Normal Gross Rent Multiplier",
 ([(0,0)-(1.69981,1.16371)],
 (0.605721,1.15481),(0.688214,1.1046),(0.797367,1.02),(0.901558,1.00418),(1
 ,0.960251),(1.12344,0.903766),(1.19496,0.809623),(1.26647,0.76569),(1.35514
 ,0.721757),(1.45526,0.658996),(1.54733,0.493814),(1.63546,0.372521)))

Units: **undefined**

(012) Effect of Rent Multiplier on Investment Oriented Demand = WITH LOOKUP

(
 "Perceived Gross Rent Multiplier/Normal Gross Rent Multiplier",
 ([(0,0)-(1.66919,
 2.09665)],(0.65539,1.65245),(0.702926,1.56485),(0.734859,1.43681),(0.778117
 ,1.2636),(0.841559,1.15481),(0.921449,1.08787),(1,1),(1.05068,0.945607),(1.10003
 ,0.887029),(1.13977,0.76296),(1.18227,0.552301),(1.2459,0.456318),(1.33596
 ,0.355063),(1.45304,0.284184),(1.55352,0.265981)))

Units: **undefined**

(013) Effect of Rental Demand on New Renting = WITH LOOKUP (

"Rental Supply/Rental Demand",
 ([(0,0)-(4.69117,1.07496)],(0.125,0.125),(0.25,0.25),(0.375,0.375
),(0.5,0.5),(0.625,0.625),(0.75,0.75),(0.875,0.846),(1,0.91),(1.125,0.948)
))

Units: **undefined**

(014) Effect of Sales Price on Essential Demand = WITH LOOKUP (
"Average Sales Price (\$/m2)",

((0,0)-(988.041,1.57864)],(501.001,1.2364),(548.928,1.12971),(600.849,1.07322
,(650,1),(702.694,0.935146),(743.631,0.841004),(778.578,0.740586)))

Units: **undefined**

(015) Effect of Sales Price on Investment Oriented Demand = WITH LOOKUP (
"Average Sales Price (\$/m2)",

((0,0)-(1149.69,1.81563)],(438.385
,1.3431),(476.233,1.29289),(516.392,1.17364),(553.46,1.09923),(598.465,1.05621
,(650,1),(714.983,0.947699),(751.933,0.891213),(776.092,0.834728),(806.861
,0.677824),(841.063,0.60251),(880.965,0.589958),(930.25,0.564854),(986.42,
0.546025)))

Units: **undefined**

(016) Effect of Supply Shortage on Project Start Rate = WITH LOOKUP (
"Supply Shortage/Initial Supply Shortage",

((0,0)-(2.75363,5.29715
,(-3.03325,0.1),(-2.04853,0.298382),(-1.04762
,0.468619),(0.0125025,0.569038),(0.500496,0.702929),(1,1),(1.21321,2.03498
,(1.426,2.76151),(1.67841,3.52401)))

Units: **undefined**

(017) Essential Housing Demand=

Effect of Rent Multiplier on Essential Demand*Effect of Sales Price on Essential
Demand

*Houses Rented*Normal Essential Demand Ratio

Units: Houses

(018) FINAL TIME = 2023

Units: Year

The final time for the simulation.

(019) Gross Rent Multiplier=

"Average Sales Price (\$/m2)"/("Perceived Average Rental Price (\$/m2)"*12)

Units: **undefined**

(020) House Owning Rate=

Owner Occupied Houses/Total Occupied Houses

Units: **undefined**

(021) House Renting Rate=

Houses Rented/Total Occupied Houses

Units: **undefined**

(022) Houses Availabe for Rent= INTEG (

Rented Houses Putting up for Rent+Secondhand Investment Sales+New Investment Sales
-Renting,
300000)

Units: Houses

(023) Houses on Secondhand Market= INTEG (

Owned House Putting on Sale+Rented House Putting on Sale-Secondhand Essential
Sales
-Secondhand Investment Sales,
800000)

Units: **undefined**

(024) Houses Rented= INTEG (

Renting-Rented Houses Putting up for Rent-Rented House Putting on Sale,

7.8e+06)

Units: Houses

(025) "Implied Sales Price (\$/m2)"= INTEG (

Net Change of Implied Sales Price,

630)

Units: \$/m2/Year

(026) InfDelay 1=

3

Units: Year

(027) InfDelay 2=

1

Units: Year

(028) InfDelay 3=

2

Units: Year

(029) InfDelay 4=

1

Units: Year

(030) Initial Supply Shortage=

1.22e+06

Units: **undefined**

(031) INITIAL TIME = 2010

Units: Year

The initial time for the simulation.

(032) Investment Oriented Housing Demand=

Effect of Sales Price on Investment Oriented Demand*Effect of Rent Multiplier on
Investment Oriented Demand

*Normal Investment Oriented Demand*Effect of Interest Rate

Units: Houses

(033) Net Change of Average Rental Price=

"Average Rental Price (\$/m2)"*Effect of Demand-Supply Imbalance on Rent Price"
*0.3

Units: **undefined**

(034) Net Change of Average Sales Price=

("Implied Sales Price (\$/m2)"-"Average Sales Price (\$/m2)"/InfDelay 1

Units: **undefined**

(035) Net Change of Implied Sales Price=

"Implied Sales Price (\$/m2)"*Effect of Demand-Supply Imbalance on Sales Price"
*0.6

Units: **undefined**

(036) Net Change of Perceived Average Rental Price=

("Average Rental Price (\$/m2)"-"Perceived Average Rental Price (\$/m2)"/InfDelay 3

Units: **undefined**

(037) Net Change of Perceived Gross Rent Multiplier=

(Gross Rent Multiplier-Perceived Gross Rent Multiplier)/InfDelay 2

Units: **undefined**

(038) New Essential Demand=

Essential Housing Demand*New Houses for Sale Fraction

Units: **undefined**

(039) New Essential Sales=

New Essential Demand*Sales Effect 1

Units: Houses/Year

(040) New Houses for Sale Fraction=

New Vacant Houses/(New Vacant Houses+Houses on Secondhand Market)

Units: **undefined**

(041) New Investment Demand=

Perceived Investment Oriented Housing Demand*New Houses for Sale Fraction

Units: **undefined**

(042) New Investment Oriented Demand=

(Investment Oriented Housing Demand-Perceived Investment Oriented Housing Demand
)/InfDelay 4

Units: Houses/Year

(043) New Investment Sales=

New Investment Demand*Sales Effect 1

Units: Houses/Year

(044) New Vacant Houses= INTEG (

Construction Finish Rate-New Essential Sales-New Investment Sales,
300000)

Units: Houses

(045) "New Vacant Houses/Project Start Rate by Shortage"=

New Vacant Houses/Project Start Rate by Shortage

Units: **undefined**

(046) "New Vacant Houses/Total New Demand"=

New Vacant Houses/Total New Demand

Units: **undefined**

(047) Normal Essential Demand Ratio=

0.15

Units: **undefined**

(048) Normal Gross Rent Multiplier=

17.6

Units: **undefined**

(049) Normal Investment Oriented Demand

=900000

Units: Houses

(050) Normal Project Start Rate=

916504

Units: **undefined**

(051) Owned House Putting on Sale=

Owner Occupied Houses*Owned House Putting on Sale Fraction

Units: **undefined**

(052) Owned House Putting on Sale Fraction = WITH LOOKUP (

Gross Rent Multiplier,

[(0,0)-(23.7,0.044356)],

(12,0.0239331),(13.0198,0.02443),(14.1672,0.0254393),(15.0411,0.0264435),(

16.0184,0.0282845),(17.3329,0.0299198),(18.3916,0.0309623),(19.7165,0.032636

),(20.8399,0.0343096),(22.1905,0.0361506),(23.6338,0.0384301)))

Units: **undefined**

(053) Owner Occupied Houses= INTEG (
 Secondhand Essential Sales+New Essential Sales-Owned House Putting on Sale
 ,
 1.12834e+07)

Units: Houses

(054) "Perceived Average Rental Price (\$/m2)"= INTEG (
 Net Change of Perceived Average Rental Price,
 2.66)

Units: \$/m2/Year

(055) Perceived Gross Rent Multiplier= INTEG (
 Net Change of Perceived Gross Rent Multiplier,
 17.6)

Units: **undefined**

(056) "Perceived Gross Rent Multiplier/Normal Gross Rent Multiplier"=
 Perceived Gross Rent Multiplier/Normal Gross Rent Multiplier

Units: **undefined**

(057) Perceived Investment Oriented Housing Demand= INTEG (
 New Investment Oriented Demand,
 1.2e+06)

Units: Houses

(058) Project Start Rate=
 Project Start Rate by Shortage*"Effect of New Vacant Houses/Project Start Rate by
 Shortage"

Units: Houses/Year

(059) Project Start Rate by Shortage=

Effect of Supply Shortage on Project Start Rate*Normal Project Start Rate

Units: **undefined**

(060) "r-average rental prices" = WITH LOOKUP (

Time,

[(0,0)-(2026.87,7.32316)],(2010,2.66),(2014,3.82),(2016,
5),(2019,2.27),(2020,2.2),(2021,2.7),(2022,3.75),(2023,4.38),(2024,4.24))
)

Units: **undefined**

(061) "r-average sales price" = WITH LOOKUP (

Time,

[(0,0)-(2023,2000)],(2010,649),(2011,647),(2012,672),(2013,742
,(2014,751),(2015,730),(2016,764),(2017,687),(2018,670),(2019,510),(2020,
500),(2021,540),(2022,500),(2023,1044)))

Units: **undefined**

(062) "r-construction finish rate" = WITH LOOKUP (

Time,

[(0,0)-(2023,900000)],(2009,469981),(2010,429591),(2011,549920),(2012
,556331),(2013,721501),(2014,766527),(2015,732948),(2016,753426),(2017,820526
,(2018,893544),(2019,734373),(2020,600156),(2021,626505),(2022,632174)))

Units: **undefined**

(063) "r-house owning rate" = WITH LOOKUP (

Time,

[(0,0)-(10,10)],(2010,0.6),(2011,0.596),(2012,0.606),(2013,0.607
,(2014,0.611),(2015,0.604),(2016,0.597),(2017,0.591),(2018,0.59),(2019,0.588

),(2020,0.578),(2021,0.575),(2022,0.567),(2023,0.56)))

Units: **undefined**

(064) "r-households with property" = WITH LOOKUP (

Time,

(([(0,0)-(2017,1.59351e+07)],(2010,1.12834e+07),(2011,1.1627e+07)
,(2012,1.15379e+07),(2013,1.22516e+07),(2014,1.25377e+07),(2015,1.2576e+07
,(2016,1.29851e+07),(2017,1.32194e+07),(2018,1.39215e+07),(2019,1.42631e+07
,(2020,1.44217e+07),(2021,1.45646e+07),(2022,1.47845e+07),(2023,1.47332e+07
)))

Units: **undefined**

(065) "r-new vacant houses" = WITH LOOKUP (

Time,

(([(0,0)-(10,10)],(2013,225000),(2014,450000),(2015,550000),(2016,700000
,(2017,850000),(2018,1e+06),(2019,1.35e+06),(2020,1.4e+06),(2021,1.629e+06
)))

Units: **undefined**

(066) "r-project start rate" = WITH LOOKUP (

Time,

(([(0,0)-(2023,2e+06)],(2010,903000),(2011,645655),(2012,771878
,(2013,837282),(2014,1.01468e+06),(2015,897230),(2016,1.00037e+06),(2017,
1.32312e+06),(2018,663200),(2019,305938),(2020,555337),(2021,709936),(2022
,652677)))

Units: **undefined**

(067) "r-rent multiplier" = WITH LOOKUP (

Time,

(([(0,0)-(10,10)],(2019,13.25),(2020,14),(2021,14),(2022,16.5),(2023
,15)))

Units: **undefined**

(068) "r-total new sales" = WITH LOOKUP (

Time,

((0,0)-(10,10]),(2013,529130),(2014,541550),(2015,598670),(2016,631690
,(2017,659700),(2018,651570),(2019,511680),(2020,469740),(2021,461520),(2022
,460079),(2023,393333)))

Units: **undefined**

(069) "r-total number of households" = WITH LOOKUP (

Time,

((0,0)-(10,10]),(2010,1.9321e+07),(2011,1.9658e+07),(2012,2.0221e+07)
,(2013,2.0625e+07),(2014,2.138e+07),(2015,2.185e+07),(2016,2.2322e+07),(2017
,2.3096e+07),(2018,2.3596e+07),(2019,2.4257e+07),(2020,2.4951e+07),(2021,2.53298e+07
,(2022,2.6075e+07),(2023,2.63093e+07)))

Units: **undefined**

(070) "r-total sales" = WITH LOOKUP (

Time,

((0,0)-(10,10]),(2010,607098),(2011,708475),(2012,701621),(2013
,1.15719e+06),(2014,1.16538e+06),(2015,1.28932e+06),(2016,1.34145e+06),(2017
,1.40931e+06),(2018,1.3754e+06),(2019,1.34873e+06),(2020,1.49932e+06),(2021
,1.49186e+06),(2022,1.48562e+06),(2023,1.22593e+06)))

Units: **undefined**

(071) "r-total secondhand sales" = WITH LOOKUP (

Time,

((-42187.5,0)-(2023.18,1.60781e+06]),(2013,628060),(2014,623830),(2015
,690653),(2016,709767),(2017,749616),(2018,723826),(2019,837047),(2020,1.02958e+06
,(2021,1.03033e+06),(2022,1.02554e+06),(2023,800000)))

Units: **undefined**

(072) "Rental Supply/Rental Demand"=

Total Supply for Rent/Total Demand for Rent

Units: **undefined**

(073) Rented House Putting on Sale=

Houses Rented*Rented House Putting on Sale Fraction

Units: **undefined**

(074) Rented House Putting on Sale Fraction = WITH LOOKUP (

Gross Rent Multiplier,

$[(0,0)-(23.9,0.112049)],(12,0.08)$

, $(13.5729,0.0825126), (15.0155,0.0837766), (16.0757,0.0843085), (17.0887,0.0851064)$
 $, (18.1283,0.0860401), (19.3748,0.0880816), (20.6587,0.0909408), (21.878,0.093447)$
 $, (22.9387,0.0946871), (23.8006,0.0951522))$

Units: **undefined**

(075) Rented Houses Putting up for Rent=

New Essential Sales+Secondhand Essential Sales

Units: **undefined**

(076) Renting=

Total Demand for Rent*Effect of Rental Demand on New Renting

Units: **undefined**

(077) Sales Effect 1 = WITH LOOKUP (

"New Vacant Houses/Total New Demand",

$[(0,0)-(10,10)],(0.125$

, $0.125), (0.25,0.25), (0.375,0.375), (0.5,0.5), (0.625,0.625), (0.75,0.75), (0.875$
 $, 0.846), (1,0.91), (1.125,0.948))$

Units: **undefined**

(078) Sales Effect 2 = WITH LOOKUP (
 "Secondhand Houses/Total Secondhand Demand",
 [(0,0)-(1.35127,1.06106)],(0.125,0.125),(0.25,0.25
),(0.375,0.375),(0.5,0.5),(0.625,0.625),(0.75,0.75),(0.875,0.846),(1,0.91)
 ,(1.125,0.948)))

Units: **undefined**

(079) "Sales Supply/Sales Demand"=
 Total Supply for Sale/Total Demand for Sale
 Units: Dmnl

(080) SAVEPER =
 TIME STEP
 Units: Year [0,?]

The frequency with which output is stored.

(081) Secondhand Essential Demand=
 Essential Housing Demand*Secondhand Houses for Sale Fraction
 Units: **undefined**

(082) Secondhand Essential Sales=
 Secondhand Essential Demand*Sales Effect 2
 Units: Houses/Year

(083) Secondhand Houses for Sale Fraction=
 Houses on Secondhand Market/(Houses on Secondhand Market+New Vacant Houses
)
 Units: **undefined**

(084) "Secondhand Houses/Total Secondhand Demand"=

Houses on Secondhand Market/Total Secondhand Demand

Units: **undefined**

(085) Secondhand Investment Demand=

Perceived Investment Oriented Housing Demand*Secondhand Houses for Sale Fraction

Units: **undefined**

(086) Secondhand Investment Sales=

Secondhand Investment Demand*Sales Effect 2

Units: Houses/Year

(087) Supply Shortage=

Total Demand for Sale-Total Supply for Sale

Units: **undefined**

(088) "Supply shortage/init s.s."=

Supply Shortage/1.226e+06

Units: **undefined**

(089) "Supply Shortage/Initial Supply Shortage"=

Supply Shortage/Initial Supply Shortage

Units: **undefined**

(090) TIME STEP = 0.125

Units: Year [0,?]

The time step for the simulation.

(091) Total Demand for Rent=

(Total Occupied Houses*0.03)+Secondhand Investment Sales+Secondhand Essential

Sales

Units: **undefined**

(092) Total Demand for Sale=

Essential Housing Demand+Perceived Investment Oriented Housing Demand

Units: Houses

(093) Total Houses=

Total Occupied Houses+Total Unoccupied Houses

Units: Houses

(094) Total New Demand=

New Essential Demand+New Investment Demand

Units: **undefined**

(095) Total New Sales=

New Essential Sales+New Investment Sales

Units: **undefined**

(096) Total Occupied Houses=

Owner Occupied Houses+Houses on Secondhand Market+Houses Rented

Units: Houses

(097) Total Sales=

Total Secondhand Sales+Total New Sales

Units: **undefined**

(098) Total Secondhand Demand=

Secondhand Investment Demand+Secondhand Essential Demand

Units: **undefined**

(099) Total Secondhand Sales=

Secondhand Essential Sales+Secondhand Investment Sales

Units: **undefined**

(100) Total Supply for Rent=

Houses Availabe for Rent

Units: **undefined**

(101) Total Supply for Sale=

Houses on Secondhand Market+New Vacant Houses

Units: **undefined**

(102) Total Unoccupied Houses=

Houses Availabe for Rent+New Vacant Houses

Units: Houses