Modeling of Real Estate Price Oscillations in Istanbul

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The purpose of this study is to develop an understanding of the dynamics of the real estate market in Istanbul. As a result of the unavoidable delays in perception of the real estate market state and construction of new buildings, the market variables are strongly oscillatory. A system dynamics model is constructed to understand the reasons of oscillations in real estate prices in Istanbul from the perspective of some major construction company. The model includes dynamics created by factors effecting the speed and size of the construction side and sales. The model focuses on the economic balance aspects of the problem and pays less attention to the dynamics of demand creation, the effects of costs and interest rates. Different policies are tested to improve the current oscillatory behavior. This model can serve as a simulation basis for foreseeing the reaction of the market to changes in the structure and inputs.

Keywords: System dynamics, real estate, oscillation

1. Introduction

Real estate markets are among the most unstable and cyclic asset markets, exhibiting large amplitude cycles of 5 -20 years. Real estate constitutes a large fraction of the total wealth in any economy, generates a significant fraction of banking activity and debt, and strongly affects the job market. Consequently, real estate booms are often accompanied by periods of intense speculation involving expansion of credit and banking activity, stimulating the local and even national economy. When the bubble bursts, the resulting bad loans, defaults, and unemployment can throw an entire region into recession or even depression. Additionally the increase in population growth also makes the market even harder and more complex. With adaptive or backward-looking expectations, developers estimate future house prices based on past trends in house prices. A positive demand shock causes prices to rise. Even with new construction, prices continue to rise since expectations are formed by past movements in prices. Prices peak when so much construction occurs that the stock overshoots its target. At this point, prices decline. This process sets off a repeating cycle in prices, construction, and the stock of houses.

Within this dynamic environment, the constructor companies face a great risk of loss (or has a chance of profit) due to the oscillatory behavior of the prices. If they just react to the prices and start their projects by doing so, they may have unsold houses in bust times or no house in boom times. Therefore, they should foresee the future demand and start their projects before the demand arrives.

There has been a considerable immigration to Istanbul in the last few decades, which has created significant demand for houses. Like it is the case in all other big cities, the house supply has been increased in Istanbul. This study involves a dynamic model of the demand

* Supported by Boğaziçi University Research Fund no. 06HA305

and supply side of the real estate market in Istanbul, and uncovers the reasons of price fluctuations that are critical to the hypothetical constructor company under consideration. The model considers the supply-demand balance, profit expectations of the constructor company, the delays in building the houses, estimating excess demand, price and profits together with other constructor firms' decisions in the market. The study continues with a sensitivity analysis of the variables involved in the model.

1.1. Perspective

The model is built from the perspective of a hypothetical real estate construction company operating in Istanbul and has a large enough market share to influence the market. For that reason, the model focuses on the economic decision making process of the company, which considers the competitors as a whole and the economic dynamics of the market. The demand side and the purchasing power of the customers are modeled in less detail.
The main aim of the model is finding out the structural causes of the oscillating profits due to imbalance between supply and demand. The stakeholders of the problem are the construction companies and the potential customers. The policies presented in the paper are expected to contribute to the decision making process of a hypothetical construction company.

1.2. Time Horizon

The time unit of the model is selected to be years since the major time delays and the rates of changes are measured in terms of years. The time horizon is 40 years between 1980 and 2020. The motivation for selecting a range of 40 years is to be able to observe a few real estate cycles. The reason for extending the horizon to future is to see the effect of interest rate, which is assumed to decrease with mortgage application.

1.3. Reference Modes

The real estate prices in a city shows oscillatory behavior due to the reasons explained above. In Figure 1 below, the typical change of real estate prices are shown.

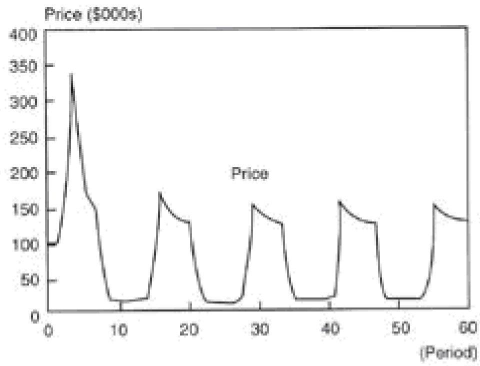

Figure 1. Typical behavior of real estate prices (DePasquale and Wheaton, 1996)

Unfortunately, there is no organized data about the real estate sales price records of Istanbul. As an estimator of the prices, the rents can be used since they usually go in parallel and show very similar behavior. The average rents in Istanbul between 1985 and 2004 in prices of December 2004 are shown in Figure 2.

Even with the deflated prices, the rent values have a trend component. In order to observe the oscillations in real rents, we detrended the data. The detrended rents are shown in Figure 3.

1.4. Model Boundary

The model includes the following elements of the real estate market:

- The houses for sale and under construction
- The demand for houses
- The current and customer price
- The profit and its effect on the construction start rate of the company and the competitors

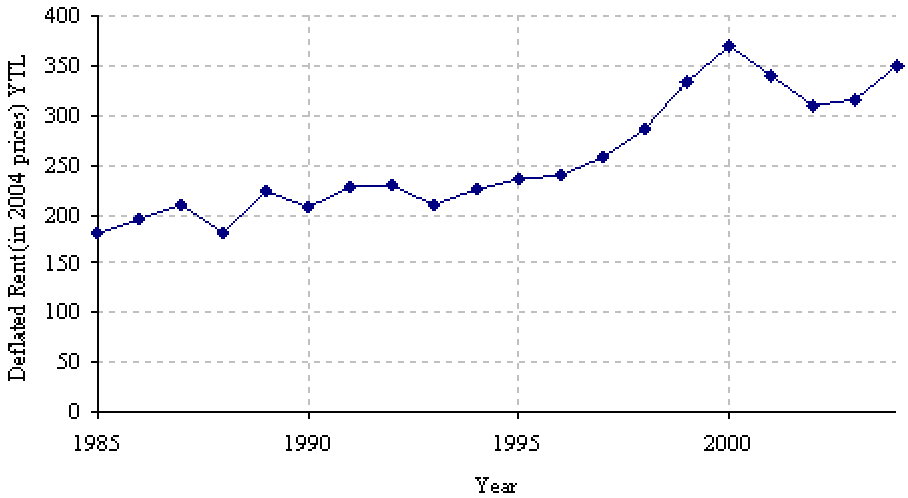

Figure 2. Average rents in Istanbul in 2004 prices

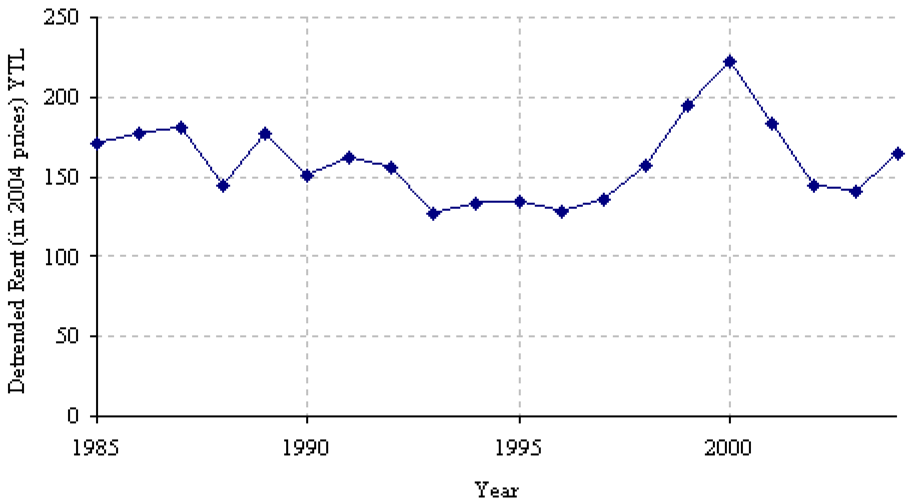

Figure 3. Detrended average rents in Istanbul in 2004 prices

The model does not include the dynamics of the demand creation. The population increase rate is taken as an external input to the model and any effect of housing on migration is excluded. Also, the effect of interest rates on customer purchasing power is modeled by a single variable. The cost is taken to be an input that changes with time. Moreover, the effect of national economy on the constructor companies is not considered.

2. Dynamic Hypothesis

The real estate prices show oscillatory behavior. The reason behind that is the loops effecting the price. The demand-price balance loop balances the demand by the increased price, which is created by the excess demand. That is, when the demand increases, the price swells, which in turn decreases the demand. Another major loop is the supply-price balance loop. When the price increases, the constructions increase. Then, the supply will boost and the prices will fall down. Also, the negative loop between demand and supply exists in the model. When the demand increases, the supply will increase and thus the demand falls down.

Apart from these major loops, there are some minor loops in the model. These are price adjustment loop and sales-demand balance loop.

The causal relationships the feedback loops existing in the model are shown in the causal-loop diagram in Figure 4.

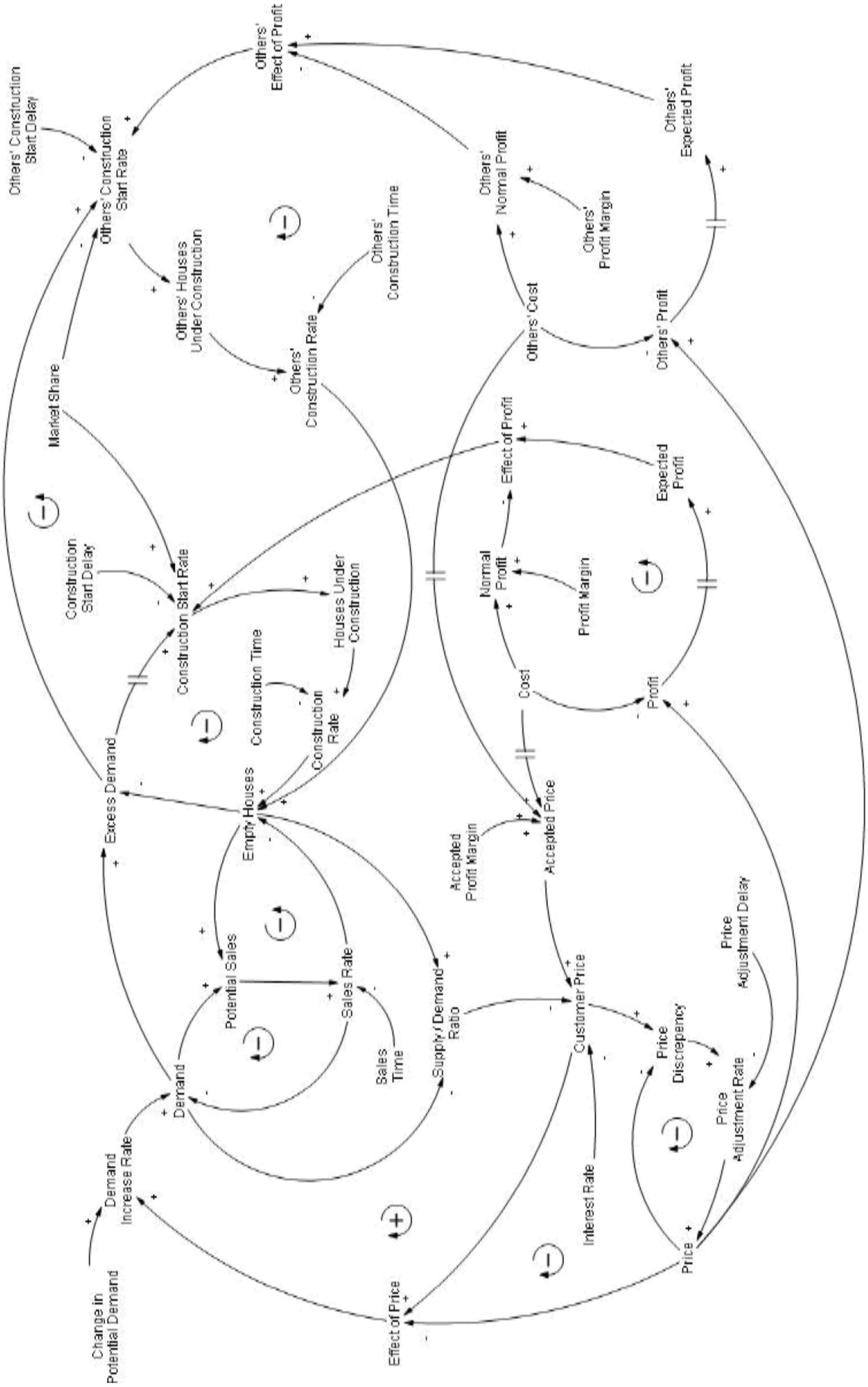

Figure 4. Causal loop diagram of the model

2.1. Model Logic

In the model, there are nine stocks and their related flows. The major stocks of the model are Price, Demand, Empty Houses, Houses under Construction and Others' Houses under Construction. The other four stocks (Estimated Cost, Estimated Excess Demand, Expected Profit, and Others' Expected Profit) are the "OUT" s of the first order information delays of the model. The stock-flow diagram of the model is shown in Figure 5.

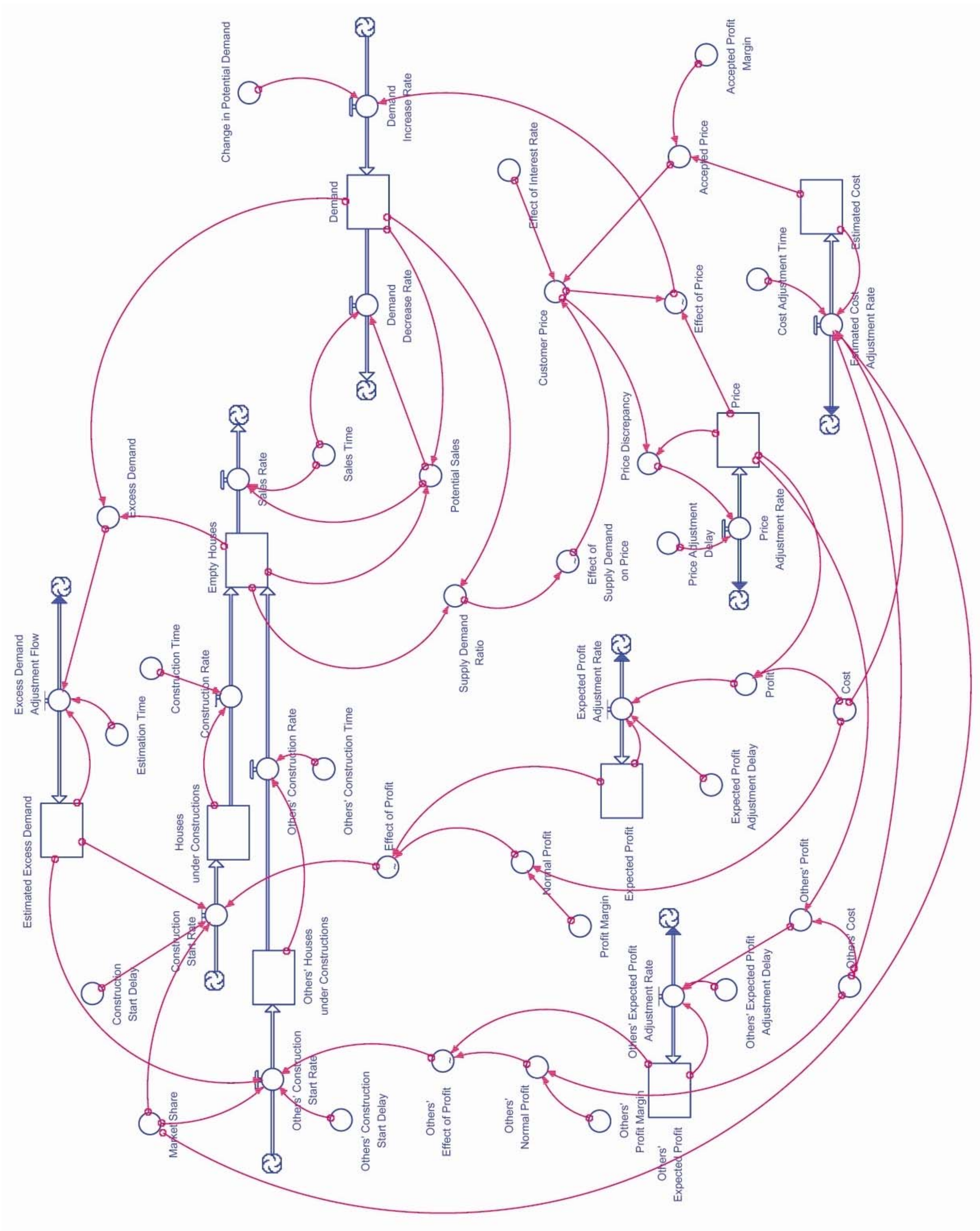

Fig. 5. Stock-Flow diagram of the model

Price (YTL[†]): The current average house price value.

Demand (houses): Demand shows the number of empty houses demanded that is caused by increasing population, at the current price. Demand is taken to be a stock since it is accumulated in time and decreased by the sales. Its flows are demand increase rate and demand decrease rate. Its initial value indicates the demand at the beginning of the year 1980. Since no data can be found about this initial value, other data are used to guess the initial value. Considering the fact that the number of households arriving to Istanbul is 47,845 (TURKSTAT, 2006) and the initial values of empty houses is around 20,000, a demand of 25,000 is selected as the initial demand value.

Empty Houses (houses): This is the number of houses available for sales. It increases with constructions and decreases by sales. The initial value of 20,000 represents the number of houses for sale at the beginning of 1980. The value is found by using the extrapolated number of houses under construction in Istanbul in 1978 and 79 and considering the fact that the constructions turn into empty houses in 1.5 years on the average.

Houses Under Construction (houses): This is the stock of houses that are being constructed by the hypothetical construction company. For calculating the initial value, first the ratio of constructions to the total houses is found using the number of year 2000 and it is assumed that ratio (1.28%) is constant. Then, the number of houses in year 1980 (900,000) is multiplied by this ratio and total number of houses under construction is obtained. Then, this value is multiplied by the market share of company and the initial value of 3,460 is found.

Others' Houses Under Construction (houses): This is the stock of houses that are being constructed by the other construction companies. The initial value is found similar to the initial value of Houses Under Construction.

Estimated Cost (YTL): It is a first order information delay stock that represents the estimation of customers about the real construction costs of houses.

Estimated Excess Demand (houses): It is a first order information delay stock that represents the estimation of construction companies about the real excess demand.

Expected Profit (YTL): This is the information delay stock of estimation of profits from construction projects of the company.

Others' Expected Profit (YTL): This is the information delay stock of estimation of profits from construction projects of all other companies.

The demand in the model is determined according to the change in potential demand in Istanbul. This change creates an increase in demand together with the effect of price. The stock of awaiting demand is decreased by the house sales. The sales occur when both empty houses and the demand is available. The ratio of empty houses to the demand gives the supply / demand ratio, which indicates the balance between supply and demand. The supply / demand ratio has an effect on the customer price. That is, when there is excess supply, the prices that customers are willing to pay will decrease and vice versa. The price that customers are willing to pay is also affected by the interest rate and the accepted price. Accepted price is

[†] Turkish currency

the price that customers agree to pay under normal supply / demand and interest rate conditions. It is assumed that, this is 1.1 times the perceived cost of building a house (which is a smoothed version of the average building cost in the market), a 10% profit margin is considered to be normal. Customer price enters an information delay structure and turns into the market price gradually. The difference between the current market price and the customer price creates the effect of price that affects the demand increase rate. This closes the balancing loop between the demand and the price.

The supply side of the model is identical for the hypothetical company under consideration and the other firms as a single entity. The market price also has an effect on the supply side of the model. The cost (which is taken to be an external input that changes with economic conditions) and the price determine the profit of the hypothetical firm and the other firms. Since it is not possible to know the exact profit that can be obtained, an information delay is used to represent the estimation of the profit by the firms. In addition to expected profit, the firms have a normal profit that depends on the cost of the company and the profit margin policy. The difference between the normal profit and the expected profit determines the effect of profit. The firms aim to meet the estimated excess demand for houses by starting new constructions according to their market shares. On doing this, they are affected from the profit. If they have higher profit than the normal profit, their willingness to meet the excess demand increases. The new projects turn into constructions, which become empty houses after a construction delay. Due to the effect of supply / demand ratio on price, a loop is created between the supply and the price.

There is a third loop between the supply and demand. The difference between the empty houses and the demand is the excess demand. This excess demand cannot be known accurately and it is estimated by the construction firms by an information delay structure. As explained above, this estimated excess demand turns into new constructions and the new houses for sale. This decreases the excess demand, which closes the balancing loop.

3. Model Behavior

Figures 6-13 show the behavior of selected variables of the base model. The demand value reaches maximum when its flows are equal. The demand increase rate is dependent on the Change in Potential Demand, which shows an increase until year 1992 and a decrease thereafter, and on the effect of the price. The oscillation of demand increase rate comes from the oscillation of the price effect and the increase-then-decrease trend comes from the net population change rate. The demand decrease rate (which is equal to sales rate) increases with a delay, which comes from the construction delay. When it hits the demand value, since it is not possible to have sales more than demand, it follows the pattern of demand. It is also limited by the empty houses stock. This situation is illustrated in Figure 7.

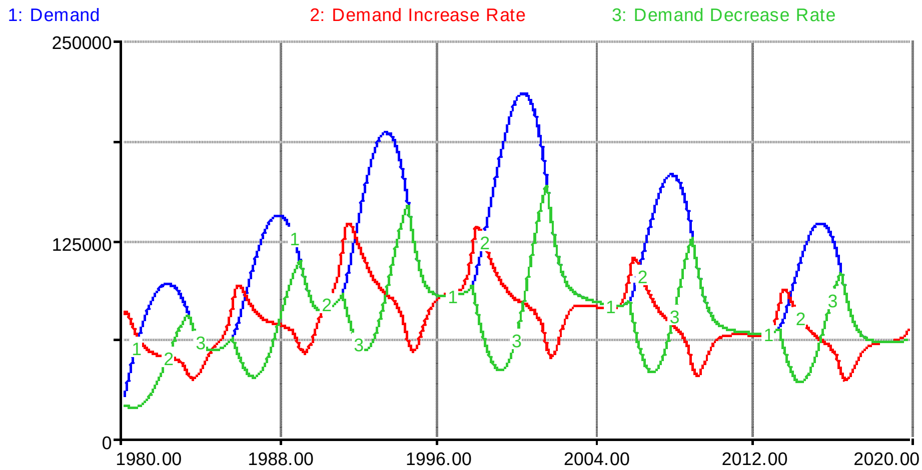

Figure 6. Outputs of the model

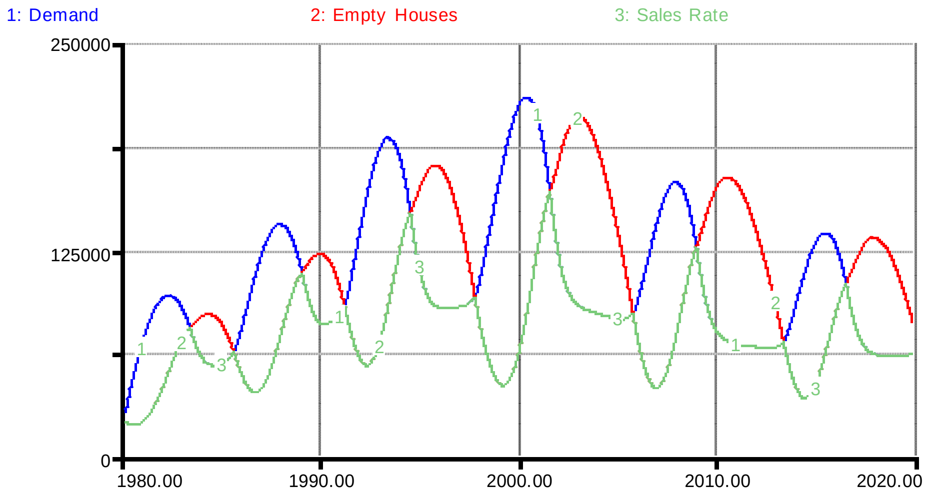

Figure 7. Outputs of the model (continued)

The construction rates of the hypothetical company and the other companies show similar behavior. The slight difference comes from the difference of construction times. The behavior pattern of the construction rate translates into the Empty Houses with a delay.

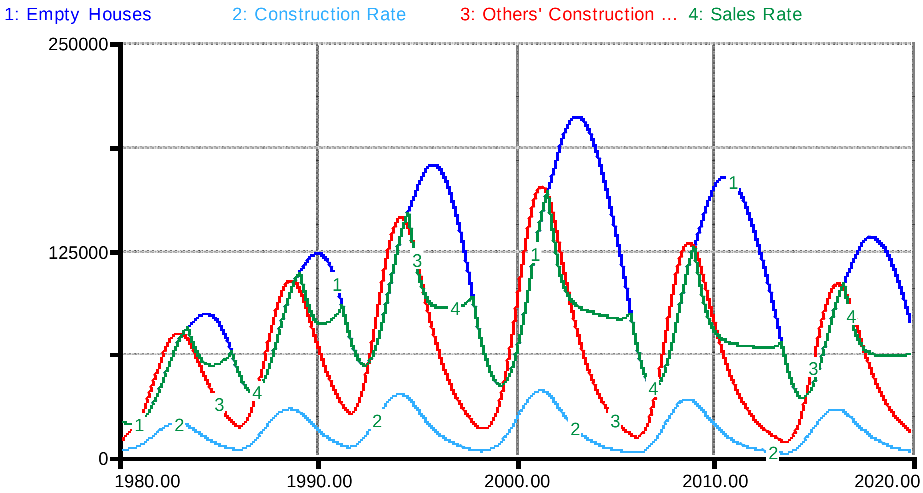

Figure 8. Outputs of the model (continued)

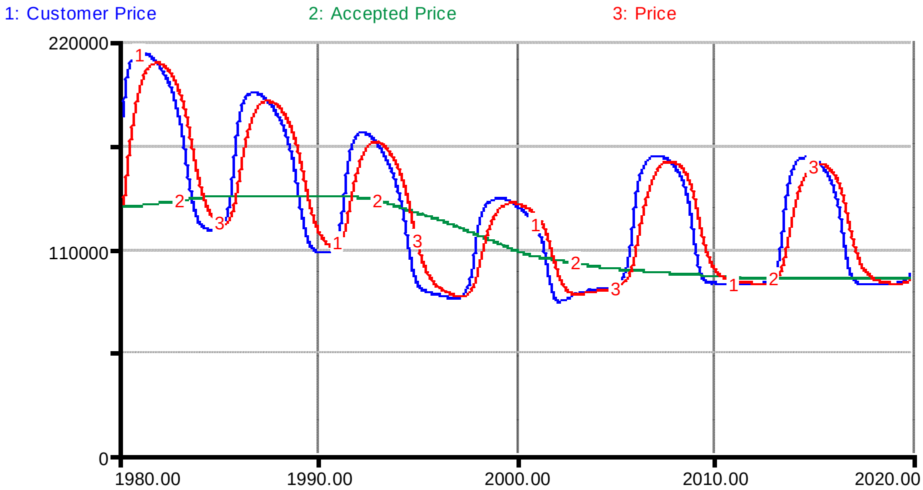

Figure 9. Outputs of the model (continued)

The main reason behind the oscillation of prices is the delay in starting new houses, which increases the price in that period, and the excess supply when these houses are finished, which decreases the price. The price follows the customer price with a delay, as it is seen from Figure 9. Figure 10 shows the change in customer price and the variables that have effect on this behavior. The oscillation comes from the effect of supply/demand ratio. The first decreasing trend comes from increasing interest rates. The decreasing cost of building that occurs between 1992 and 2005 contributes further to the decrease in customer price between these years. The latter increase in price comes from the expected decrease in interest rates due to mortgage application. The relative scale of the customer price with respect to the accepted price is related to whether the effect of interest rates is above or below 1.

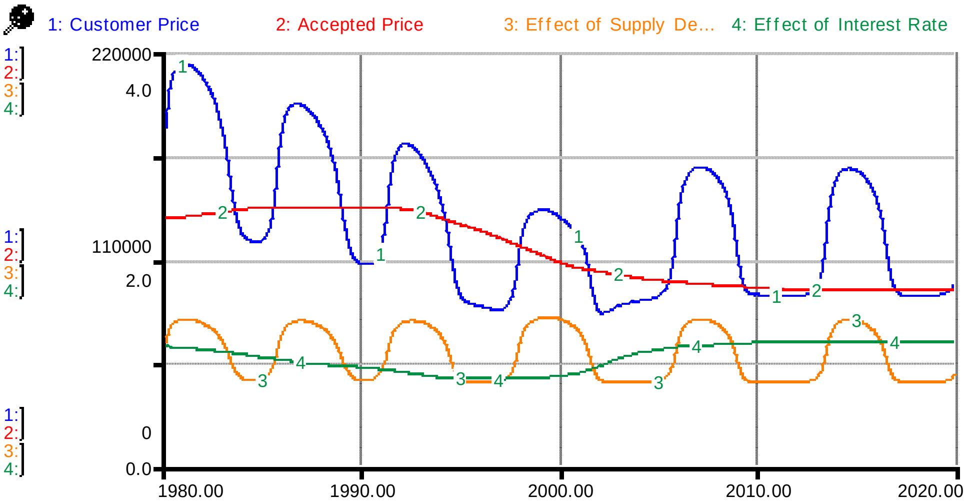

Figure 10. Outputs of the model (continued)

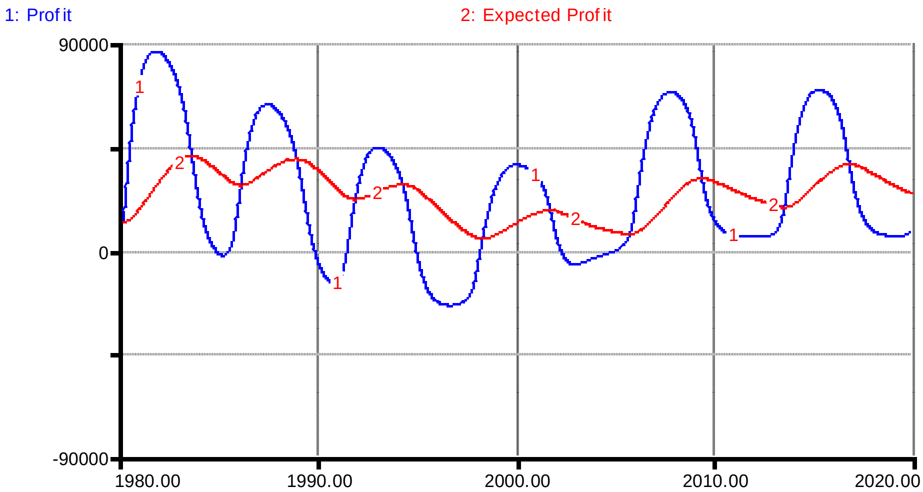

Figure 11. Outputs of the model (continued)

Profit follows the behavior of the price in general. It is also affected from the decrease in cost. Expected profit is the smoothed version of the profit.

The construction start rate behavior is repeated in houses under construction stock with a delay. The construction rate follows the sale pattern with its stock. The same is valid for others' construction start rate, construction rate and houses under construction.

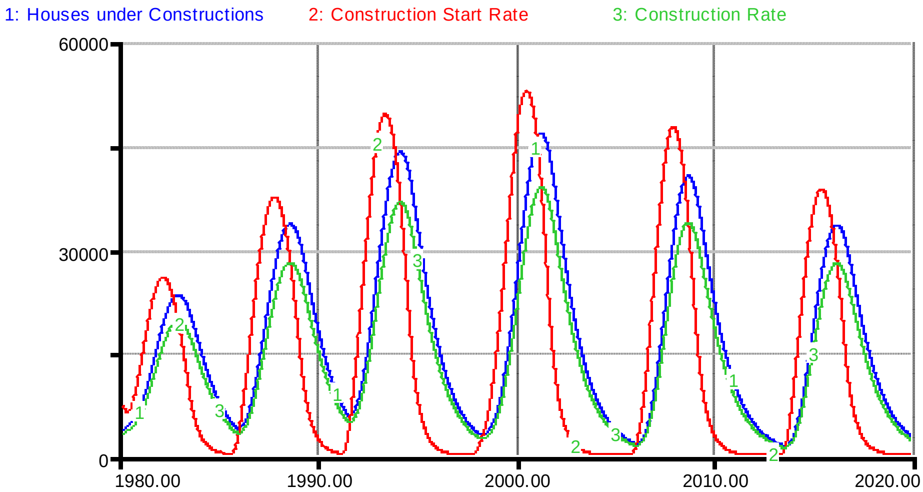

Figure 12. Outputs of the model (continued)

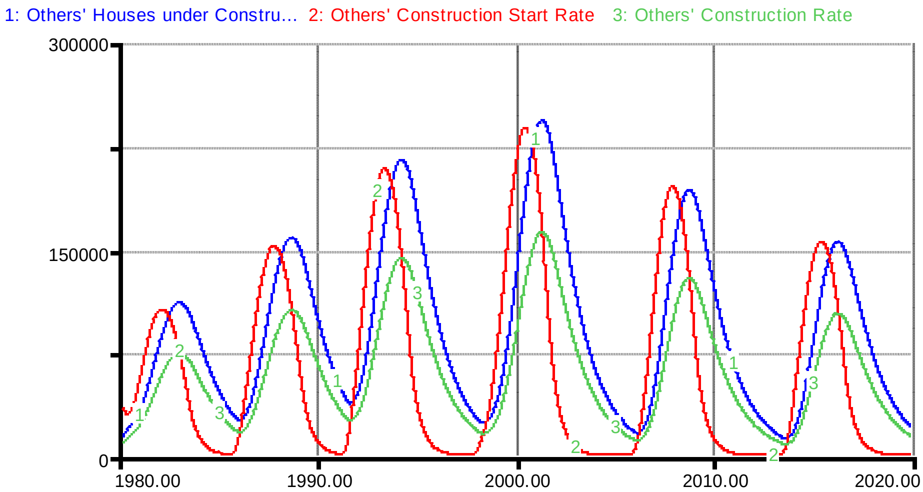

Figure 13. Outputs of the model (continued)

4. Verification

Verification is checking the model constructed against the mental conceptualization of the relations in the system. Before going further in the analysis, one should be sure that the model is error-free and accurate translation of conceptual model. For verifying the model, the equations and relations are checked to avoid careless programming and mathematical errors. After being confident that the model does what is intended, and an analysis for achieving *dt* accuracy is performed. For doing this, the minimum delay time in the model is considered. The *dt* is halved until there is no further behavioral change. The final *dt* is selected to be 0.0125.

5. Validation

System dynamics models are always constructed with respect to a purpose. Therefore a model cannot simply be categorized as correct or false but is can be evaluated in a continuous scale of validity. Therefore, although there are some formal tools developed for validating system dynamics models (Barlas, 1996), still subjective judgment of model is unavoidable. Validation of system dynamics models are carried out under two main headings, namely structure validity and behavior validity. Structure validity is assuring that model structure is in agreement with the relations existing in real life. Structural validity can either be direct or indirect. Direct structure tests assess the validity of model structure by direct comparison with knowledge about real system structure while indirect structure tests evaluate the validity of the structure indirectly, by applying certain behavior tests on model-generated behavior patterns (Barlas, 1996). Behavior validity, on the other hand, measures if the model and real system produce the same behavioral patterns.

5.1. Structure Validity

5.1.1. Direct Structure Tests

Structure Confirmation Test: For this test, the effect of formulations and equations are compared against the real system and it is tried to create valid formulations. In the formations, information about the real system is gathered using the reliable information sources on the Internet and existing literature (Genta, 1989, Born and Pyhrr, 1994, Waddell and Ulfarsson, 2003, Case and Quigley, 1991) on similar subject.

Parameter Confirmation Test: This test involves conceptual and numerical confirmation of parameters in the model. Since the initial conditions of 1980 are not available and no direct data about most of the parameters are available, several resources are utilized to have meaningful estimates of the parameters. The resources referred include web sites of Turkish Statistics Foundation (TURKSTAT, 2006) and Istanbul Metropolitan Municipality (IBB, 2005) for demographic and economic parameters, newspaper archives and real-estate related supplements and magazines, personal communication with related people for construction-related parameters and historical values.

Direct Extreme Condition Test: The relations between the variables are evaluated one by one to see the behaviors under extreme conditions of related variables. When the linearity of relationship is violated under some conditions of related variables, graphical effect formulations are preferred. The effect formulations can be seen in the Appendix.

Dimensional Consistency Test: The units of left and right sides of the equations are evaluated and it is verified that there is no variable that has no real life meaning.

5.1.2. Indirect Structure Tests

Extreme Condition Test: When there is no initial demand and the increase in demand is zero, the houses under construction are completed and no new houses are constructed. The price is only affected from changes in cost and interest rates.

Another extreme condition test shows the behavior when the supply/demand ratio is always zero. In this case, prices go up to maximum possible price, which is 1.5 times the accepted price, adjusted for the interest rate. The number of houses still oscillates since the companies monitors the excess demand and build houses with a delay. The price has no negative effect on the construction and only the supply-demand balance behavior is observed.

When there is no construction delay, then all newcomers can get and empty house immediately and there won't be any discrepancy between demand and supply. Thus, the price will not oscillate and follow the behavior of customer price, which is a function of the cost. Also, the construction start rate will follow the demand increase rate and the houses under construction will be very low.

Behavior Sensitivity Test: In this part, the parameters are tried to be determined to which the model is sensitive.

Construction delay: Since the main cause of the oscillations in the system is the time delay between starting and completing the houses and the mismatch between the demand and the supply, it is thought that the model is sensitive to the value of construction delay. Figure 14 shows the behavior of some important variables when the construction delay is 1/3 of its original value. As it is expected, the frequency of oscillations increase and the amplitude decrease.

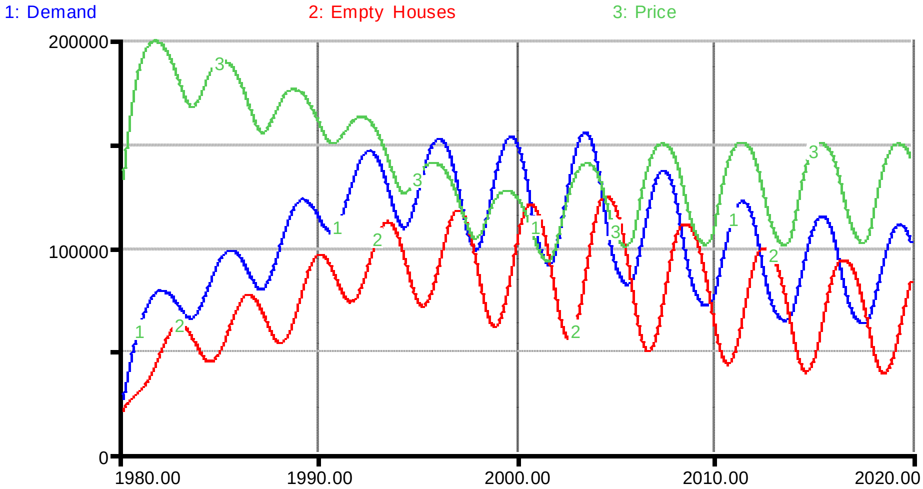

Figure 14. Sensitivity to change in Construction Delay

Effect of Supply/Demand on Price: When the effect of supply/demand on the price is changed such that it takes more than extreme values in tails, the amplitude of oscillations in price increase. The behavior of price is given in Figure 15. Other variables show similar behaviors due to the behavioral change in price.

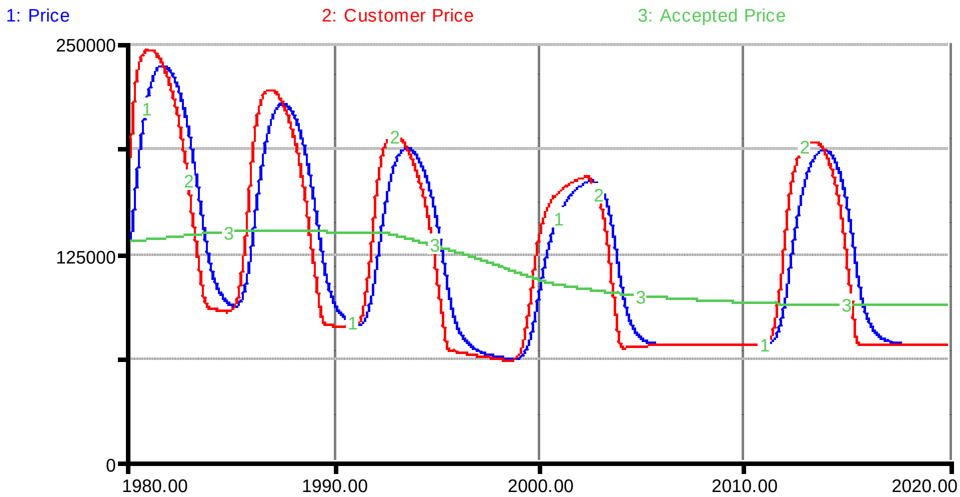

Figure 15. Sensitivity to change in Effect of Supply/Demand Ratio

Estimation Time of Excess Demand: When the estimation time of excess demand is increased to 5 years, the firms become late in perceiving the excess demand and the construction start rate change less frequently. This affects the empty houses and supply/demand ratio similarly, and the frequency of price oscillations is decreased. The results are presented in Figure 16.

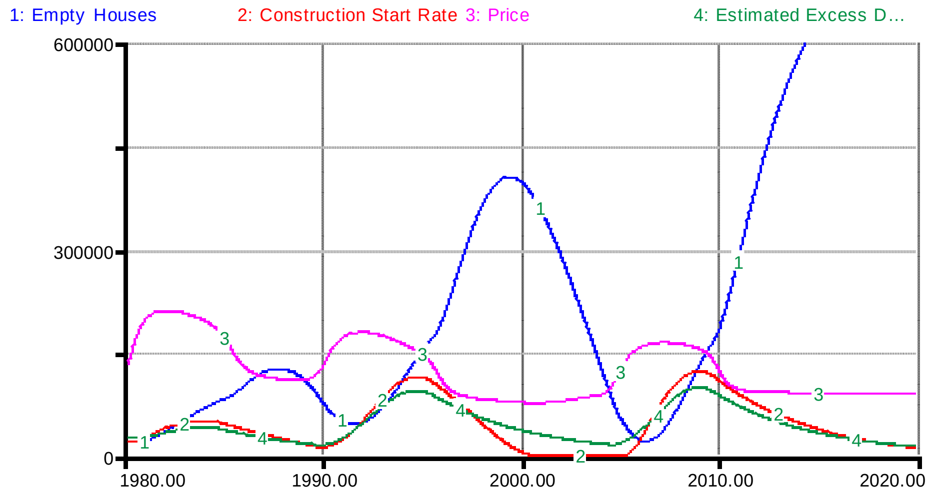

Figure 16. Sensitivity to change in Estimation Time of Excess Demand

5.2. Behavior Validity

Unfortunately, there is no real estate sales record in Istanbul. On the other hand, it is known from the literature that the real estate prices oscillate. The real estate prices in the dynamic model oscillates, which shows that the general behavior of the model is valid. The frequency of oscillations is 6-7 years, which is consistent with the values in the literature (5-20 years) and the observations from real life. The normalized versions of detrended real rents and detrended simulation output for the house prices are in agreement regarding their behaviors. There are some differences between the two time series, which is not very critical from the behavioral perspective.

6. Policy Analysis

6.1. Policy 1: Construction Companies Consider Houses under Construction

In this policy, the construction companies estimate the houses under construction and start new construction projects for the remaining excess demand. For doing this, an information delay structure with a delay time of 0.5 years for the total houses under construction is built. The construction start rate equations became:

```
Construction_Start_Rate = (Estimated_Excess_Demand -
  Estimated_Houses_Under_Construction) * Effect_of_Profit * Market_Share /
  Construction_Start_Delay
Others'_Construction_Start_Rate = (Estimated_Excess_Demand -
  Estimated_Houses_
Under_Construction) * Others'_Effect_of_Profit * (1- Market_Share) /
Others'_Construction_Start_Rate
```

where

```
Estimated_Houses_Under_Construcion (t) =
  Estimated_Houses_Under_Construction (t-dt) + (HUC_Adjustment_Rate) * dt
```

```
INIT Estimated_Houses_Under_Construction = 17300
HUC_Adjustment_Rate = (Houses_under_Construciton +
  Others'_Houses_Under_Construction - Estimated_Houses_Under_Construction)
  / HUC_Estimation_Time
HUC_Estimation_Time = 0.5
```

This policy prevents the excess supply that is due to ignoring houses under construction when starting new projects. For that reason, the oscillations are avoided as it can be seen in Figures 17-20. The house under construction stay at lower levels at all times. Since the construction companies subtract the number of houses under construction, which are started to be built to meet previous excess demand, the supply stays below the demand as seen in Figure 18. Since there is always an excess demand, the sales rate is equal to empty houses / sales time. The excess demand makes the prices increase. In that way, the profits increase. However, in real life such high profits may not persist since the excess demand can be met somehow.

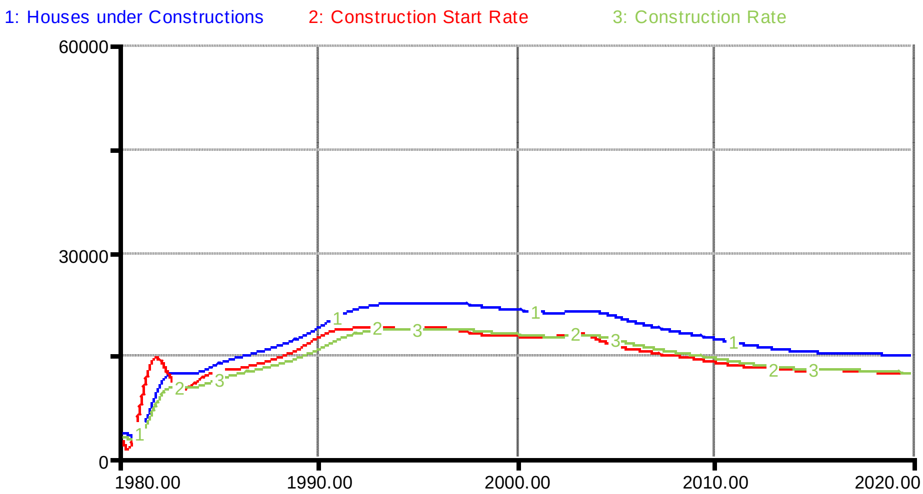

Figure 17. Outputs of Policy 1

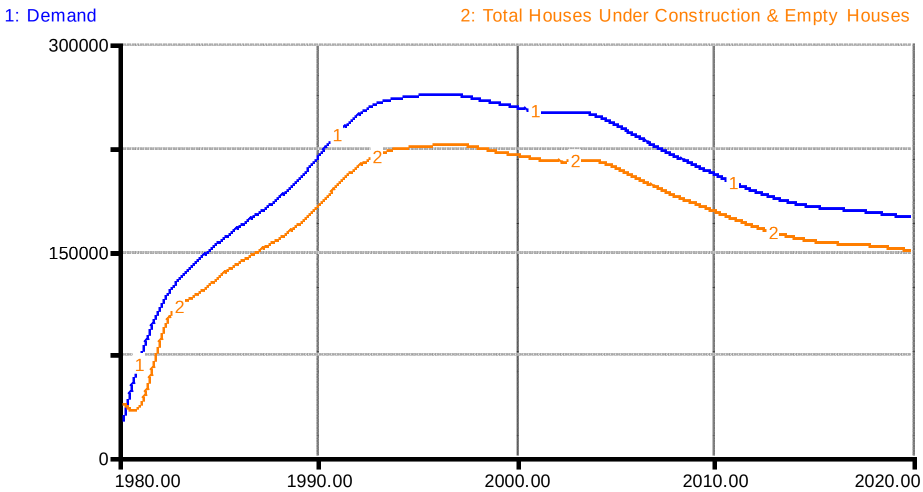

Figure 18. Outputs of Policy 1 (continued)

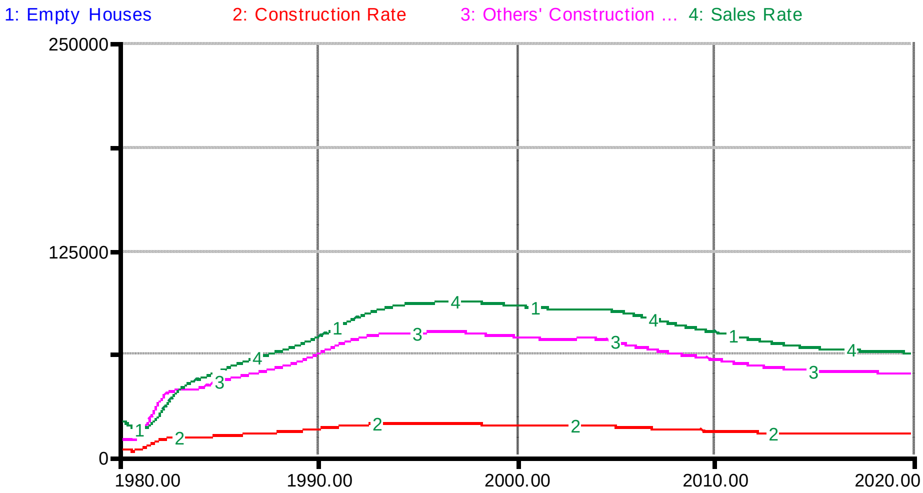

Figure 19. Outputs of Policy 1 (continued)

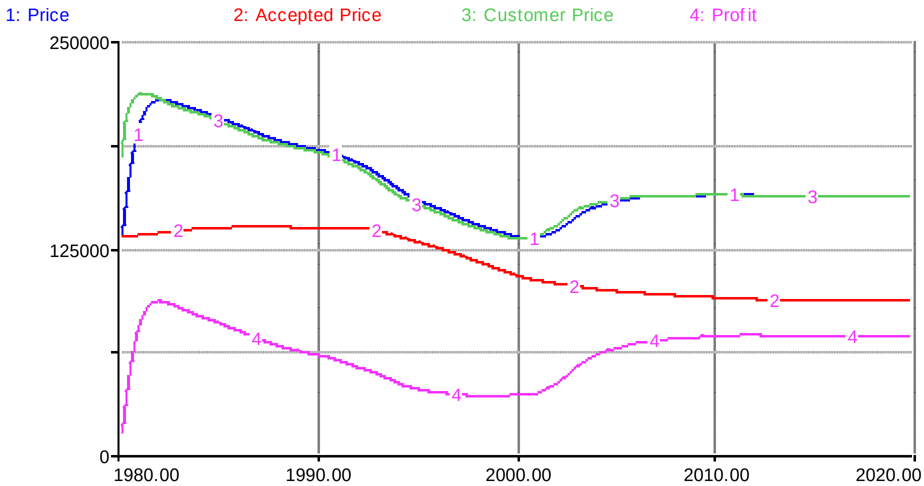

Figure 20. Outputs of Policy 1 (continued)

6.2 Policy 2: Construction Companies Forecast the Demand

In this policy, the construction companies forecast the increase in demand by an information delay structure and start their constructions accordingly. The equations are:

```
Forecasted_Demand (t) = Forecasted_Demand (t-dt) +
  (Forecasted_Demand_Adjustment_Flow) * dt
INIT Forecasted_Demand = 25000
Forecasted_Demand_Adjustment_Flow = (Change_in_Potential_Demand -
  Forecasted_Demand) / Forecasting_Time
Forecasting_Time = 1
Construction_Start_Rate = Forecasted_Demand * Effect_of_Profit *
  Market_Share / Construction_Start_Delay
Others'_Construction_Start_Rate = Forecasted_Demand *
  Others'_Effect_of_Profit * (1 - Market_Share) /
  Others'_Construction_Start_Delay
```

This policy creates a smoother behavior in terms of the variables. Since the construction companies do not stop or start building houses according to the supply / demand balance, there is continuous construction. The excess demand indirectly affects the construction start rate, by decreasing the price, and thus the profit, to a very low value, which wipes out the willingness to start new projects. Figures 21-26 give results for this policy. As the Figures indicate, the frequency of oscillations is lower but it ignores the effect of short term demand changes on the construction start rate.

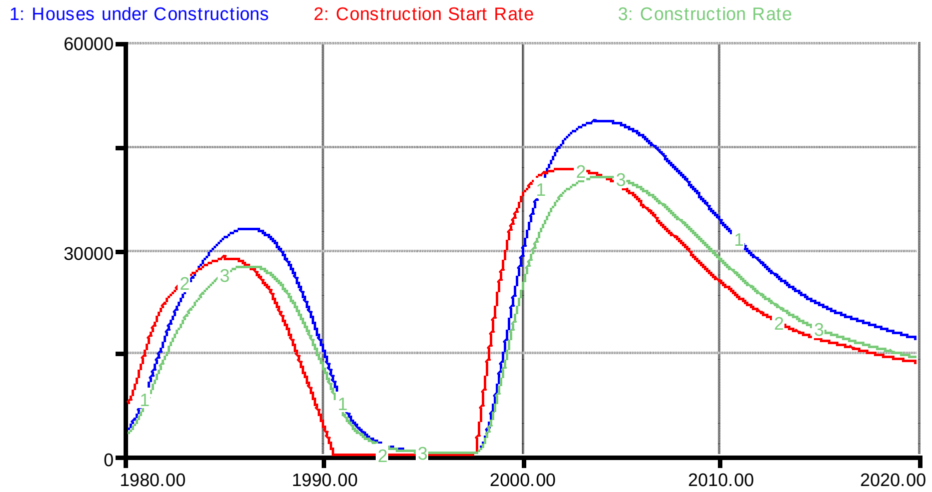

Figure 21. Outputs of Policy 2

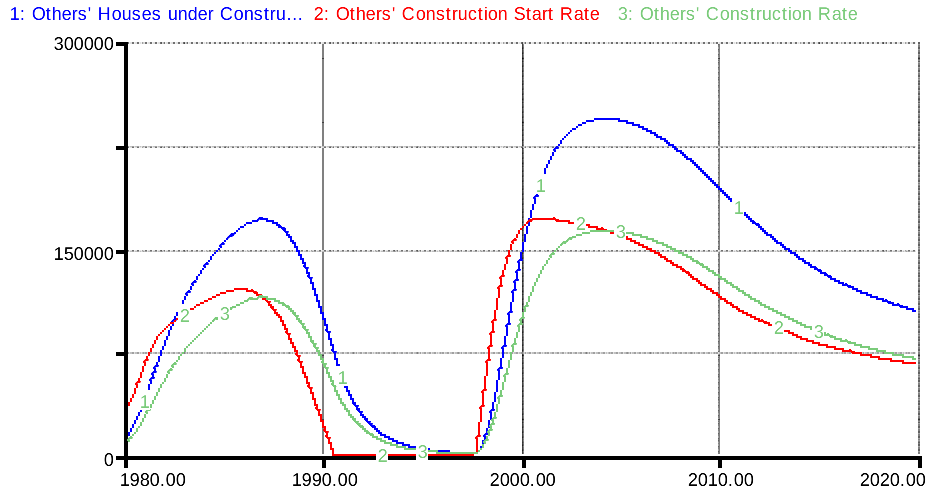

Figure 22. Outputs of Policy 2 (continued)

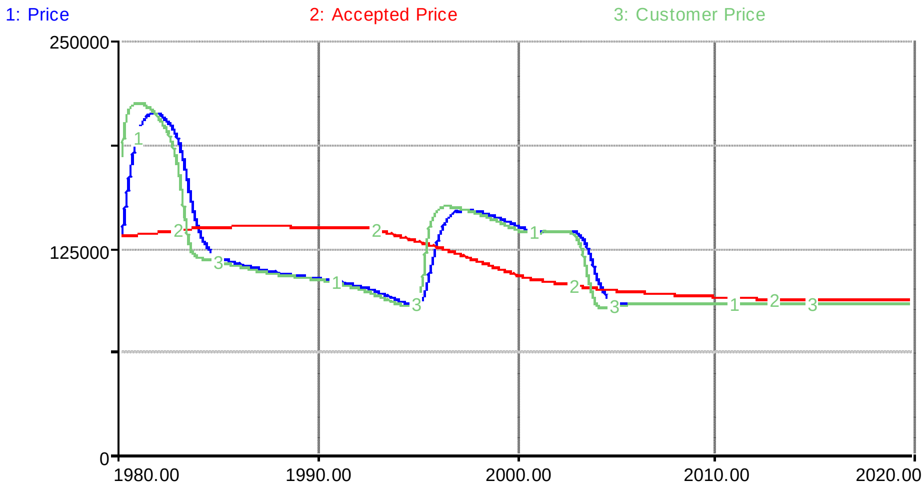

Figure 23. Outputs of Policy 2 (continued)

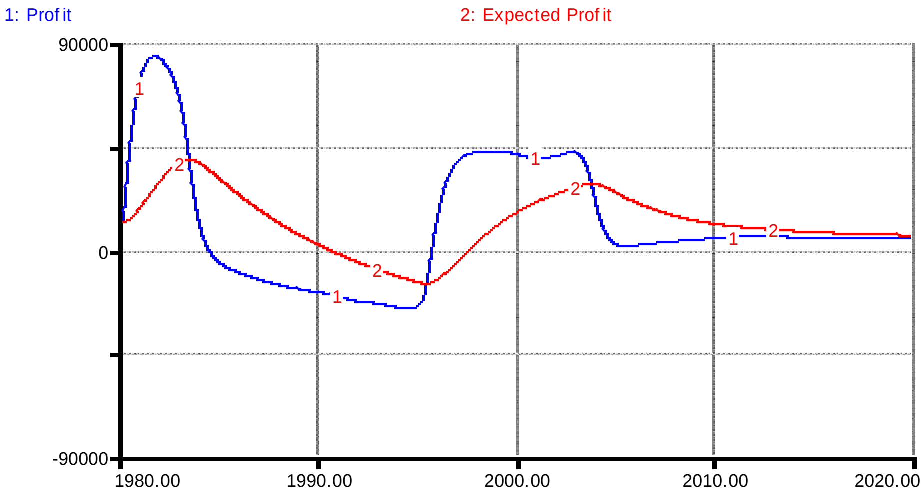

Figure 24. Outputs of Policy 2 (continued)

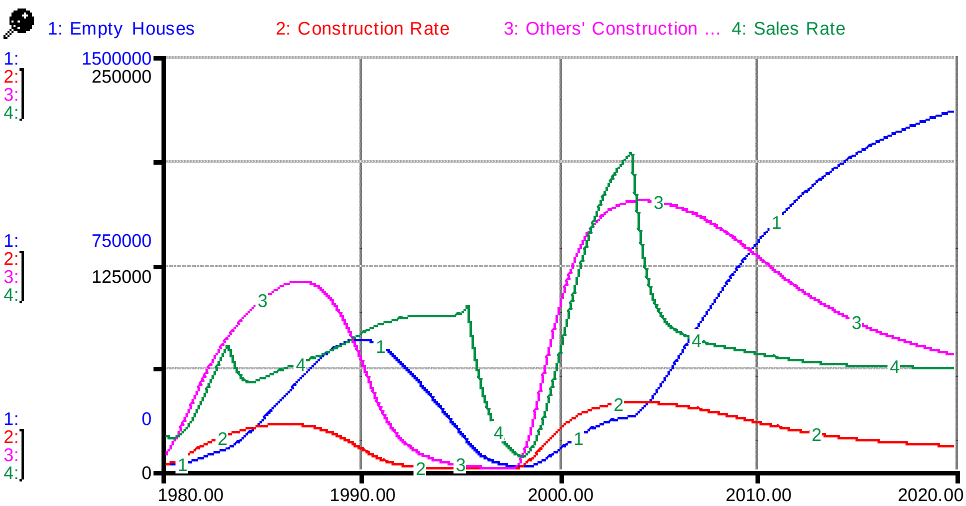

Figure 25. Outputs of Policy 2 (continued)

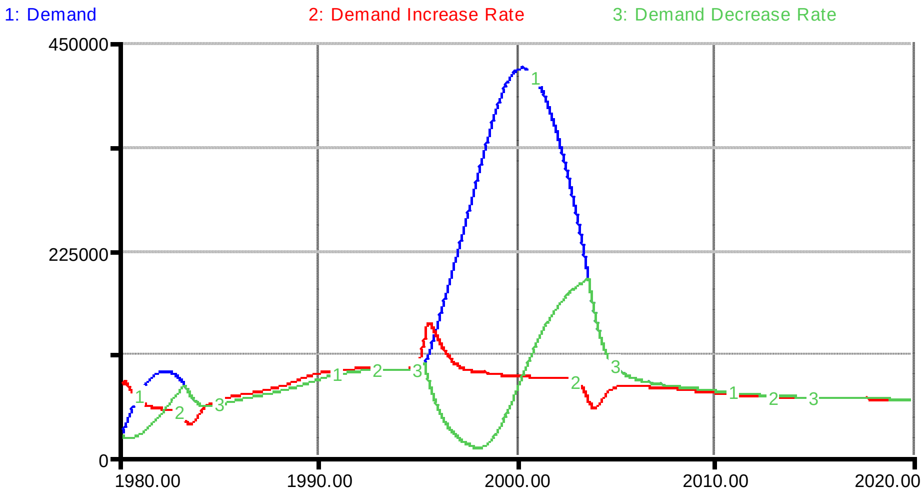

Figure 26. Outputs of Policy 2 (continued)

7. Conclusion

In this study, a dynamic feedback model of real estate prices in Istanbul is built. The model focuses on the economic supply-demand dynamics of the problem and looks from the perspective of a hypothetical construction company. Verification and validation tests show that model offers an adequate representation of the real estate market by considering demand, supply and price sectors. The model can reproduce the dynamics of the fundamental reference modes, oscillations known to exist in the real system. It can explain the reason behind the oscillations in prices: time lags in starting new construction projects and completing them after demand rises. This latter first causes the prices to rise, but a surplus demand occurs for real estate when the constructions are completed, which brings the fall of prices.

The model shows that, if the construction companies can take the houses under construction into account as a whole, they can reduce the price oscillations that present a high risk for most companies. If, further the companies use proper forecasting to sense the future demand, a smoother behavior can be obtained. By performing different scenario analyses, alternative approaches are suggested to prevent the oscillations, which is the main problem of the real estate market.

In further studies, the model can be expanded to include a more sophisticated structure for demand creation, the interactions of the real estate market with the economy in general, the costs and limitations of resources of construction and the effects of interest rates and other investment opportunities on the supply side. For further understanding of the model structure, it is important to determine the variables to which the model is sensitive, by using a more formal experimental design analysis. A complete sensitivity analysis is being carried out to uncover the factors that should be controlled or monitored more carefully to obtain desired real estate price dynamics.

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Appendix

Equations of the model

```
Demand(t) = Demand(t - dt) + (Demand_Increase_Rate - Demand_Decrease_Rate)
  * dt
INIT Demand = 25000
Demand_Increase_Rate = (Change_in_Potential_Demand)*Effect_of_Price
Demand_Decrease_Rate = Potential_Sales/Sales_Time
Empty_Houses(t) = Empty_Houses(t - dt) + (Construction_Rate +
  Others'_Construction_Rate - Sales_Rate) * dt
INIT Empty_Houses = 20000
Construction_Rate = Houses_under_Constructions/Construction_Time
Others'_Construction_Rate =
  Others'_Houses_under_Constructions/Others'_Construction_Time
Sales_Rate = Potential_Sales/Sales_Time Estimated_Cost(t) =
  Estimated_Cost(t - dt) + (Estimated_Cost_Adjustment_Rate) * dt
INIT Estimated_Cost = 120000
Estimated_Cost_Adjustment_Rate = ((Cost*Market_Share+Others'_Cost*(1
  Market_Share))- Estimated_Cost)/Cost_Adjustment_Time
Estimated_Excess_Demand(t) = Estimated_Excess_Demand(t - dt) +
  (Excess_Demand_Adjustment_Flow) * dt
INIT Estimated_Excess_Demand = 25000
Excess_Demand_Adjustment_Flow = (Excess_Demand
  Estimated_Excess_Demand)/Estimation_Time
Expected_Profit(t) = Expected_Profit(t - dt) +
  (Expected_Profit_Adjustment_Rate) * dt
INIT Expected_Profit = 12000
Expected_Profit_Adjustment_Rate = (Profit-
  Expected_Profit)/Expected_Profit_Adjustment_Delay
Houses_under_Constructions(t) = Houses_under_Constructions(t - dt) +
  (Construction_Start_Rate - Construction_Rate) * dt
INIT Houses_under_Constructions = 3460
Construction_Start_Rate =
  Estimated_Excess_Demand*Effect_of_Profit*Market_Share/
  Construction_Start_Delay
Construction_Rate = Houses_under_Constructions/Construction_Time
Others'_Expected_Profit(t) = Others'_Expected_Profit(t - dt) +
  (Others'_Expected_Profit_Adjustment_Rate) * dt
INIT Others'_Expected_Profit = 12000
Others'_Expected_Profit_Adjustment_Rate = (Others'_Profit-
  Others'_Expected_Profit)/Others'_Expected_Profit_Adjustment_Delay
Others'_Houses_under_Constructions(t) =
  Others'_Houses_under_Constructions(t - dt) +
  (Others'_Construction_Start_Rate - Others'_Construction_Rate) * dt
INIT Others'_Houses_under_Constructions = 13840
Others'_Construction_Start_Rate =
  Estimated_Excess_Demand*Others'_Effect_of_Profit *(1-
  Market_Share)/Others'_Construction_Start_Delay
Others'_Construction_Rate =
  Others'_Houses_under_Constructions/Others'_Construction_Time
Price(t) = Price(t - dt) + (Price_Adjustment_Rate) * dt
INIT Price = 132000
Price_Adjustment_Rate = Price_Discrepancy/Price_Adjustment_Delay
Accepted_Price = Estimated_Cost*(1+Accepted_Profit_Margin)
Accepted_Profit_Margin = 0.1
Construction_Start_Delay = 0.4
Construction_Time = 1.2
Cost_Adjustment_Time = 0.5
Customer_Price =
  Accepted_Price*Effect_of_Supply_Demand_on_Price*Effect_of_Interest_Rate
Estimation_Time = 0.5
```

```
Excess_Demand = MAX(0,Demand-Empty_Houses)
Expected_Profit_Adjustment_Delay = 5
Market_Share = 0.2
Normal_Profit = Cost*Profit_Margin
Others'_Construction_Start_Delay = 0.4
Others'_Construction_Time = 1.5
Others'_Expected_Profit_Adjustment_Delay = 5
Others'_Normal_Profit = Others'_Cost*Others'_Profit_Margin
Others'_Profit = Price-Others'_Cost
Others'_Profit_Margin = 0.2
Potential_Sales = MIN(Demand,Empty_Houses)
Price_Adjustment_Delay = 0.5
Price_Discrepancy = (Customer_Price-Price)
Profit = Price-Cost
Profit_Margin = 0.25
Sales_Time = 1
Supply_Demand_Ratio = Empty_Houses/Demand
Change_in_Potential_Demand = GRAPH(TIME) (1980, 47845), (1981, 49656),
  (1982, 52440), (1983, 56958), (1984, 60861), (1985, 64425), (1986,
  67925), (1987, 71946), (1988, 77220), (1989, 85687), (1990, 92706),
  (1991, 95193), (1992, 98160), (1993, 97805), (1994, 97475), (1995,
  96671), (1996, 95497), (1997, 92715), (1998, 91770), (1999, 89928),
  (2001, 87652), (2002, 84412), (2003, 83473), (2004, 81099), (2005,
  78860), (2006, 76488), (2007, 74166), (2008, 73416), (2009, 70676),
  (2010, 68210), (2011, 66240), (2012, 65000), (2013, 63646), (2014,
  62735), (2015, 62870), (2016, 62784), (2017, 62269), (2018, 61176),
  (2019, 60588), (2020, 60588)
Cost = GRAPH(TIME) (1980, 120000), (1984, 125000), (1988, 125000), (1992,
  124500), (1996, 112000), (2000, 96250), (2004, 90000), (2008, 87000),
  (2012, 85000), (2016, 85000), (2020, 85000)
Effect_of_Interest_Rate = GRAPH(TIME) (1980, 1.15), (1981, 1.14), (1982,
  1.12), (1983, 1.10), (1984, 1.07), (1985, 1.04), (1986, 1.02), (1987,
  0.993), (1988, 0.976), (1989, 0.962), (1990, 0.95), (1991, 0.93), (1992,
  0.904), (1993, 0.874), (1994, 0.85), (1995, 0.843), (1996, 0.84), (1997,
  0.836), (1998, 0.84), (1999, 0.85), (2000, 0.864), (2001, 0.895), (2002,
  0.955), (2003, 1.04), (2004, 1.09), (2005, 1.12), (2006, 1.15), (2007,
  1.16), (2008, 1.17), (2009, 1.18), (2010, 1.19), (2011, 1.20), (2012,
  1.20), (2013, 1.20), (2014, 1.20), (2015, 1.20), (2016, 1.20), (2017,
  1.20), (2018, 1.20), (2019, 1.20), (2020, 1.20)
Effect_of_Price = GRAPH(Price/Customer_Price) (0.00, 2.75), (0.167, 2.67),
  (0.333, 2.46), (0.5, 2.16), (0.667, 1.78), (0.833, 1.40), (1, 1.00),
  (1.17, 0.69), (1.33, 0.45), (1.50, 0.285), (1.67, 0.225), (1.83, 0.21),
  (2.00, 0.195)

Effect_of_Profit = GRAPH(Expected_Profit/Normal_Profit) (0.00, 0.00),
  (0.167, 0.25), (0.333, 0.5), (0.5, 0.7), (0.667, 0.83), (0.833, 0.91),
(1, 0.96), (1.17, 0.98), (1.33, 0.99), (1.50, 0.995), (1.67, 0.998), (1.83,
  1.00), (2.00, 1.00)
Effect_of_Supply_Demand_on_Price = GRAPH(Supply_Demand_Ratio) (0.00, 1.49),
  (0.2, 1.44), (0.4, 1.38), (0.6, 1.30), (0.8, 1.18), (1.00, 1.00), (1.20,
  0.89), (1.40, 0.836), (1.60, 0.818), (1.80, 0.809), (2.00, 0.806)
Others'_Cost = GRAPH(TIME)
(1980, 120000), (1984, 125000), (1988, 125000), (1992, 124500), (1996,
  112000), (2000, 96250), (2004, 90000), (2008, 87000), (2012, 85000),
  (2016, 85000), (2020, 85000)
Others'_Effect_of_Profit =
  GRAPH(Others'_Expected_Profit/Others'_Normal_Profit) (0.00, 0.00),
  (0.167, 0.25), (0.333, 0.5), (0.5, 0.7), (0.667, 0.83), (0.833, 0.91),
  (1, 0.96), (1.17, 0.98), (1.33, 0.99), (1.50, 0.995), (1.67, 0.998),
  (1.83, 1.00), (2.00, 1.00)
```