T.C.
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SOSYAL BİLİMLER ENSTİTÜSÜ
İKTİSAT ANA BİLİM DALI
İKTİSAT (İNG) BİLİM DALI

MONETARY, MACROPRUDENTIAL POLICIES AND
HOUSING CYCLES: EXPLORING THE NEXUS IN TURKEY

Yüksek Lisans Tezi

UMURCAN POLAT

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ADVISOR: PROF. DR. ALİ SUUT DOĞRUEL

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ABSTRACT

Given the pro-cyclicality of the financial cycles on the business cycles, it is of importance to analyze whether the use of the traditional monetary policy instruments along with the prudential responsibilities result in the prevention of unsustainable financial cycles e.g., housing cycles. Still, there is not enough empirical evidence regarding the exploration of the nexus between housing variables and monetary – macroprudential policy rules. Observing the developments in housing market in Turkey, that is, the simultaneous increase in both house prices and residential investments in the last decade, the nexus between housing market and macro economy deserves a further investigation.

Accordingly, a new Keynesian DSGE model is estimated with Turkish data for a period 2010-2014 using Bayesian techniques in this thesis. Results reveal that arguments for a monetary policy regime that produces aggregate price stability will, as a byproduct, tend to promote stability of housing markets don't fully hold in the estimation. It can also be stated that the monetary policy rules with existing prudential policy instruments may not result in prevention of further housing “bubbles”. The Variance-shock decomposition analyses show that demand and supply shocks dramatically determine the cycles of the real housing prices and residential investment whereas the monetary policy shocks and shocks in central bank's inflation target do not explain the volatility of the housing variables.

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ÖZET

Finansal çevrimlerin iş çevrimleri üzerindeki aynı yönde olan etkisi göz önüne alındığında, geleneksel para politikası araçlarının, ihtiyati tedbirlerle birlikte konut dalgalanmaları gibi finansal çevrimlerin önlenmesinde kullanılıp kullanılamayacağının incelenmesi önemlidir. Ancak henüz konut değişkenleri ve para politikası-ihtiyati politikalar arasındaki bağa ilişkin yeterli ampirik bulgu bulunmamaktadır. Bu açıdan, Türkiye’deki son on yılda yaşanan konut fiyat ve yatırımlarındaki eş zamanlı artış şeklinde gözlemlenen konut piyasasına ilişkin gelişmeler, konut piyasası ve makro ekonomi arasındaki ilişkinin araştırılmasını daha değerli kılıyor.

Yukarıdaki bilgiler ışığında, bu tezde Bayesyen yöntemler kullanılarak, Türkiye için 2010-2014 dönemlerini kapsayan bir *yeni Keynesyen DSGE* modeli tahmin edilmiştir. Çalışmada toplam fiyat istikrarını sağlamak için kullanılan para politikası rejimlerinin ikincil bir sonuç olarak konut piyasalarının istikrarını sağlayacağına ilişkin görüş gözlenmemiştir. Ayrıca, halihazırdaki para politikasının ve varolan makro ihtiyati tedbirlerin ileride oluşabilecek konut balonlarının önlenmesinde yetersiz olduğu görülmüştür. Varyans ve şok dekompozisyon analizleri, reel konut fiyatları ve konut yatırımlarının döngülerini belirlemede talep ve arz şoklarının önemli bir yer tuttuğunu, buna karşın para politikası ve enflasyon hedeflemesi şoklarının konut değişkenlerindeki dalgalanmaları etkilemediğini göstermiştir.

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LIST OF ABBREVIATIONS

BoE: Bank of England

IMF: International Monetary Funds

CBT: Central Bank of Turkey

BIS: Bank for International Settlements

BRSA: Banking Regulation and Supervision Agency

LTV: Loan-to-Value

DTI: Debt-to-Income

DSGE: Dynamic Stochastic General Equilibrium

MCMC: Markov Chain Monte Carlo

BGG: Bernanke, Gertler and Gilchrist model

GDP: Gross Domestic Product

i.i.d: Independent and Identically Distributed

1. INTRODUCTION

Financial sector has important pro-cyclical effects on real economy which itself relies heavily on the former to function properly. In furtherance of this pro-cyclical, the global financial crisis of 2008-2009 revealed the severe macroeconomic consequences of the financial imbalances-instabilities. Since the eruption of the last global financial crisis stability of the financial sector issue has been analyzed further for its relevance with monetary policy and is still at the hearth of policy discussion among both policymakers and academicians. The debate essentially revolves around whether the policy rules of interest rate in a price stability oriented monetary policy framework should be extended to deal with financial stability objectives as of dealing with the asset prices by using some instruments to counter systemic risks resulted from the financial sector. In other words, the arguments are mainly made for whether the use of prudential policy instruments along with the monetary policy responsibilities – in separated or integrated form - result in the prevention of unsustainable asset cycles e.g., housing boom-bust cycles.

Before the crisis, an excessive credit growth and a boom episode in housing variables in most countries were encouraged by a combination of the loose monetary and weak regulatory policies. The boom episode was then turned into a bust side over the business cycle which resulted in economies to slow down. An extensive consensus took place that the origin of the global financial crisis is related to housing booms and busts. Accordingly, observing the deep recession episodes, effectiveness of a post-bust policy intervention has been intensively criticized.

In the aftermath of the global financial crisis, arguments for integration of prudential policies within the central banks have been made further. Main argument is that the central banks could use the policy rate to prevent the occurrence of imbalances in the financial sector together with the provision of price stability. Accordingly, using the short-run policy rates,

central banks can respond to asset price changes to reduce probability of occurrence of financial imbalances in the future at the expense of deviations from targeted level of inflation and output today. However, arguments for separation of monetary and financial responsibilities under coordinated or non-coordinated bodies suggest that financial regulatory authorities should deal with prudential issues to strengthen banking supervision and financial stability being separate from monetary authority.

Asking for a more preventive-proactive policy framework, certain macro-prudential policy tools as of loan-to-value ratio that directly limit risky lending by a restriction on borrowing upon the value of the housing assets have been utilized. Hence forth, many countries have adopted policy instruments particularly of loan-to-value cap for the sake of prevention of housing bubbles in the post-crisis episode. However, there is not enough empirical evidence regarding how effective the monetary policy tools are in prevention of these unsustainable financial cycles and how much the effectiveness of those tools differs when some macro-prudential policies are accessorially considered, which is also valid for the case of Turkish economy.

Observing the developments in housing market in Turkey, that is, the simultaneous increase in both house prices and residential investments in the last decade and acknowledging the pro-cyclicality of housing market on macroeconomic fundamentals, the nexus between housing market and macro economy deserves a further investigation. Accordingly, main aim of this paper is to explore the main dynamics of housing variables and the nexus between housing market and monetary-prudential responsibilities for Turkish economy observing those developments in the housing market. Using a rich variety of shocks, it is analyzed whether the shocks hitting the economy result in unsustainable cycles in house prices and residential investments that in turn can create unfavorable effects on Turkish economy through e.g., deteriorations in consumption and credit mechanisms. In this study, it is also investigated whether the implementation of some macro-prudential policy instruments determined by financial authorities in Turkey is useful in prevention of abovementioned cycles in housing market.

To draw main dynamics of housing variables and see how effective the monetary policy tools are in prevention of these unsustainable housing cycles along with how much the

effectiveness of those tools differs when some macro-prudential policies are accessorially considered, DSGE model of Iacoviello and Neri (2010) is estimated with Turkish data for a period 2010-2014 using Bayesian estimation techniques. This model is chosen mainly for its detailed description of modeling economy where the housing market is well-defined within a multi-sector structure, that can enable us to draw precise conclusions regarding the housing market dynamics for Turkish economy. The model developed by Iacoviello and Neri (2010) is strictly followed in this study without considerable modifications. Rigidities in the model economy such as the investment adjustment costs, price rigidity in consumption sector, wage rigidity in both housing and consumption sectors and imperfect competition mechanism are preserved in our study that all together enable us to better observe various business cycle facts of the economy. It is seen from the results that presumptions for a monetary policy regime that produces aggregate price stability will, as a byproduct, tend to promote stability of housing markets don't fully hold in our estimation. Given the inflation targeting policy framework aiming at the price stability, it can be argued that the tighter monetary policy along with existing prudential policy instruments may not result in prevention of further housing "bubbles". From the variance decomposition analysis, it is reached that demand and supply shocks dramatically determine the cycles of the real housing prices and residential investment whereas the monetary policy shocks and shocks in central bank's inflation target do not explain the volatility of real house prices too much. Also, historical shock decomposition analysis shows that demand and inflation target shocks had played an important role in generating the variance of policy rate and shifts in the monetary authority's inflation target have positively contributed to volatility of nominal interest rate with the early periods of 2014 though there had been an opposite relationship between these two in the previous periods. Besides, sensitivity analysis reveals that tighter macro-prudential policy rules with a lower loan-to-value ratio do not significantly change the volatility of the housing variables.

The remainder of the paper is organized as follows. Section 2 provides a theoretical and conceptual framework that includes an explanation of monetary and prudential policies together with housing cycles, a literature review and corresponding policy framework in Turkey. Section 3 briefly introduces the benchmark models. Then, in Section 4, the model economy is introduced. Section 5 describes estimation methodology and data set. Then, the results are given in Section 6. In Section 7, some conclusions are drawn.

2. THEORETICAL AND CONCEPTUAL FRAMEWORK

2.1. PRUDENTIAL POLICIES AND HOUSING BOOM-BUST CYCLES

Macro-prudential policy is not a new concept in reconsideration of the financial imbalances regarding its instruments, objectives and relations with the monetary policy. Crockett (2000) marks out precisely micro- and macro-prudential dimensions of financial stability referring broadly macro-prudential objective as limiting systemic risk and micro-prudential one as limiting idiosyncratic risk of individual institutions. He also ensures a complementary role of the macro-prudential dimension to the micro-prudential approach. Borio (2003) also provides a comparison between macro- and micro-prudential perspectives given essentially in terms of the objectives and model used to describe the risk. In Borio (2003, p.2), the objective of a macro-prudential approach is defined as the limitation of the risk of the episodes of financial distress with remarkable losses in terms of the real output for the economy as a whole and the risk factor is modeled as endogenous to characteristics of the portfolio or more generally to the behavior of the financial system. However, that of micro-prudential approach is to limit the risk of episodes of financial distress at individual institutions, regardless of their effects on the whole economy assuming a modeling of risk that taken as exogenous. In the pre-crisis episode, despite the remarks on emphasis of the macro-prudential objectives as pointed out above, there was still not a literature on macro-prudential policy that is close arriving at a consensus regarding the objectives due a considerable extent to the fundamental lack of understanding of systemic risk and pro-cyclicality of financial system. Borio et al. (2001) point out that financial developments have potential for extreme swings in economic activity and a complete breakdown in the normal linkages between savers and investors that pave the way for concerns that the financial system is excessively pro-cyclical, unnecessarily amplifying swings in the real economy. Crowe et al. (2013) demonstrate that of the 46 systemic banking crises for which real estate price data is available, more than two-thirds followed boom-bust patterns in housing market prices. In a similar vein, they state that 35 out of 51 boom-bust cycles were followed by a crisis, although only about 15 percent of stock market boom-bust cycles provoked systemic banking crisis and all of

these stock market bubbles were accompanied by real estate boom-bust episodes. As Galati and Moessner (2011, p.3) state, regarding this episode, there was a failure to appreciate how aggressive risk-taking by different types of financial institutions supported a massive growth in balance sheets in the financial system within an environment of robust macroeconomic performance and low interest rates. They also highlight the *overconfidence* in the self-adjusting ability of the financial system which ignored the probability of a system-wide risk of financial sector and the *underestimation* of the consequences of the accumulation of growing stocks of debt and leverage. Such a phase of accumulation of debt and leverage in both industrialized and emerging economies evolved out of credit markets and specifically of the booming period of housing sector and asset prices. The aforementioned accumulation processes were exacerbated and complemented by the micro-prudential policy tools concentrating on idiosyncratic risks of individual institutions and by insufficient recognition of the booming of financial imbalances and their further consequences on the real activity.

The financial crisis has emphasized the need for a new macro-prudential policy framework to prevent the build-up of systemic financial risks (Lim et al, 2013). In the post-crisis episode theoretical reconsiderations of the macro-prudential policies regarding objectives, implementation and effectiveness of the macro-prudential policy instruments have inclusively been contributed. As a policy framework countercyclical measures are defined to cope with the boom-bust cycles in the sense that as stated by Brunnermeier et al. (2009, p.xvi) one critical objective of macro-prudential regulation must be to act as a countervailing force to the natural decline in measured risks in a boom and the subsequent rise in measured risks in the subsequent collapse-bust. Galati and Moessner (2014) distinguish principally two forms of effectiveness regarding the macro-prudential policy, which are achieving the intermediary goals of macro-prudential policy as of the credit growth and achieving the ultimate goal of providing financial stability and thereby macroeconomic stability. In achieving for those intermediary and ultimate goals, a literature on the macro-prudential policy with a wide variety of instruments has been contributed. Referring to IMF (2011 a), Galati and Moessner (2014) provide the framework and taxonomy of instruments of macro-prudential policy. They distinguish the macro-prudential tools in provision for credit, leverage and asset price booms as follows: time-varying loan-to-value ratio, debt-to-income ratio, loan-to-income caps, countercyclical capital buffers, dynamic provisioning etc. These aforementioned policy

instruments that work through the balance sheets of agents are utilized to create a countercyclical mechanism in prevention the pro-cyclicality of the financial sector on real sides of economies.

The boom episode featured by a combination of excessive credit and augmentation in the real estate sector was then turned into a bust side over the business cycle that triggered economies to slow down. It paved the way for an extensive consensus that the origin of the global financial crisis is related to housing booms and busts and that policy actions should concentrated on institutional arrangements associated with these cycles. This makes necessary the understanding the dynamics regarding the characteristics of housing boom-bust cycles and the ways through which these boom-bust cycles may threaten the financial system and macroeconomic stability.

Debates regarding the dynamics of the real estate boom-busts and the relationship between asset price bubbles and monetary policy are not new. Brunnermeier et al. (2009, p.xii) summarize the episodes of boom-busts as follows: In the up-phase of the economic cycle, price-based measures of asset values rise, price-based measures of risk fall and competition among banking sector to increase that jointly results in occurrence of high leverages. When the boom ends, asset prices fall and short term funding to institutions with uncertain and impaired assets dries up, causing forced sales of assets which drives up their measured risks, ultimately the boom episode turns to bust. It had prevailed long before financial crisis has occurred. Arguments revolved around how aggressive monetary authorities should respond to the asset price bubbles and differed mainly in two groups as Bernanke (2002) conceptualized with lean-against-the-bubble strategy with a more moderate policy action where central banks use monetary policy to target the economy, not asset markets and aggressive-bubble-popping with a more activist policy framework where central banks raises policy rates proactively to eliminate potential bubbles in asset prices. However, Bernanke (2002) finds proactive approach to bubbles as problematic and states that if we intend to use monetary policy as the instrument, monetary authority cannot reliably identify bubbles in asset prices and even if it could identify real estate booms, monetary policy is far too blunt a tool to use effectively against them. Concerning the pre-crisis episode, along these lines, main policy tenet in most economies was defined as waiting for the bust and fixing

distortions rather than to attempt to prevent the bubbles. Two assumptions are made in provision of such a policy framework: the assumption that it is so difficult to identify unsustainable booms in real time and that the distortions associated with avoiding from a boom outweigh the costs of cleaning up after a bust (Crowe et al., 2011, p.3). However, observing a bust cycle that triggered a deep recession episode, effectiveness of a “post-bust policy intervention” (Crowe et al. 2011, p.4) on prevention of emerging costs has been intensively criticized. Asking for a more preventive-proactive policy framework and identification of unsustainable bubbles that is, “price misalignments relative to economic fundamentals” (ibid), macro-prudential policy tools distinguish to reduce the risks-imbalances related to real estate sector. Hence forth, many countries have made provisions against financial imbalances by defining new institutional arrangements or improving the existing ones. Countervailing force of macro-prudential policy tools are mostly suggested to be rule based. Loan-to-value (LTV henceforth) ratio that directly limits risky lending by a restriction on borrowing upon the value of the housing assets enhances resilience to risks from real estate sectors. The LTV rule as a macro-prudential instrument to fill the policy gap comes first among the policy instruments in reducing systemic risk resulted from boom-bust cycles in housing markets. In discussion of housing finance systems in emerging and newly industrialized economies, in IMF (2011) it is shown that LTV ratios on new loans in the name of restraining booms in mortgage credit and real estate prices or increasing resilience to occurrence of bust episode, vary widely across countries and that in the pre-crisis episode, a number of Asian (emerging) countries had used LTV caps, while implementation of LTV limits in advanced economies has been relatively rare, introduced after the onset of global financial crisis. In spite of the possibility of liquidity constraints for potential borrowers and thus of potential trade-offs between financial stability benefits and economic activity (BoE, 2011), empirical evidence shows that many countries- both industrialized and emerging- have adopted this policy instrument in the post-crisis episode (Lim et al. 2013). In this regard, IMF provides a survey on macro-prudential policy instruments over 42 member countries and found that “more than a third of the countries recently implemented an LTV limit, while almost two thirds considered it as a possible policy tool” (IMF, 2011, p. 129).

2.2. LITERATURE REVIEW

“Confidence in combining inflation-targeting-cum-flexible-exchange-rate regimes with isolated micro-prudential regulation as a means to guarantee both macroeconomic and financial stability has been shattered by the scale and synchronization of the asset price booms and busts that preceded the global financial crisis. It has now become clear that if monetary policy makers and prudential regulators are to succeed in achieving stability, there can be no complacency regarding asset price cycles.”

Otaviano and Cavallari (2013, p.1)

In consideration of literature review regarding the dynamics of the real estate or asset price booms-bust cycles through its integration with monetary policy rules and macro-prudential regulation, it arises that the literature primarily hashes out two challenges: of so-called “lean versus clean debate” and of how to integrate housing and asset prices into monetary policy function and/or financial regulation. A large literature -both theoretically and empirically- has studied these two challenges.¹

Considering the pre-crisis episode, as Taylor (2007) underlies, monetary policy has been much more responsive since the early 1980s to inflation and real GDP gaps compared to earlier periods. Higher and more predictable responses of interest rate rule within the Taylor rule framework for occurrence of low and stable inflation had reduced housing boom-bust cycles and large swings in interest rates that caused volatile housing.

In the post-crisis episodes, the abovementioned considerations have dramatically been criticized. Blanchard et al. (2010, p.11) state that the policy rate is a poor tool to deal with many financial system imbalances, such as excess leverage, excessive risk taking, or apparent deviations of asset prices from fundamentals. They argued that a higher policy rate to deal with excessively high asset price will result in cost of a larger output gap leading the

¹ For a review of different arguments on relationship between monetary policy and asset prices, see Lansing (2008).

central bank to face a difficult task of a trade-off within its traditional policy framework. Hence they argued that macro-prudential policy as of a rule on loan to value ratio can be defined to address specific financial system imbalances. Besides, Quint and Rabanal (2013, p.4) stated that the conventional monetary policy is too blunt of an instrument to address the imbalances within financial sector or overheating in one sector of the economy i.e. housing sector. In the pre-crisis episode, criticisms about traditional price-stability oriented monetary policy framework together with financial regulations-supervisions that mostly focused on individual institutions and ignored their macroeconomic implications, particularly of probability of systemic risks arising from financial sectors, promptly deepened in the post-crisis episode.

Bernanke and Gertler (2000) explore the policy rules in moderating the disruptive effects of asset market disturbances, modeling an extended version of the small-scale macroeconomic model developed by Bernanke, Gertler and Gilchrist-BGG model (1999) - by allowing for exogenous bubbles in asset prices. The latter model which is detailed later, defines a financial accelerator mechanism recognizing and modeling financial frictions, i.e., there is possibility of problems of information, incentives and enforcements. Bernanke and Gertler (2000) is of importance for representing macroeconomic interpretations of credit-market frictions and of alternative monetary policy rules in the presence of bubbles in asset prices without taking macro-prudential financial regulatory bodies into consideration. They reach the main conclusion that flexible inflation-targeting policy framework provides an effective, unified solution for achieving both macroeconomic fundamentals' stability and financial stability, for which they adduce empirical evidence using reaction functions for the Federal Reserve and Bank of Japan. Beside to this conclusion, under alternative monetary policy functions, they argued for an aggressive "inflation targeting" policy framework in which whether policy also responds independently to asset prices is not neither necessary nor desirable (Bernanke and Gertler, 2000, p.45-46). In a similar vein, Bordo et al. (2000) investigate the historical association between financial and aggregate price stability state that "despite the influence of regulation and other institutional factors...a monetary policy regime that produces aggregate price stability will, as a byproduct, tend to promote stability of financial system" (Bordo et al., 2000, p.27).

In contrast to those arguments, Borio and Lowe (2002) mainly argue that financial imbalances can arise in a low and stable inflation policy environment and that though identifying financial imbalances *ex ante* can be difficult, historical episodes of asset boom-bust cycles in conjunction with rapid credit expansions have often resulted in financial and economic instabilities *ex post*. They state that it may not be the unanticipated changes in inflation of goods and services *per se* in occurrence of financial problems and rather be the changes in asset prices that build-up the financial imbalances. Regarding the argument of probability of co-existence of low inflation and financial imbalances, one reason is the positive relationship between favorable supply-side developments as of technological improvements, which put downward pressure on prices and optimistic assessments of risk. Another reason they put forward is that obviating the need to tighten monetary policy to prevent probable asset bubbles, though the signals for unsustainable asset price movements are observed, can allow the build-up of financial imbalances to proceed further (*ibid*, p.1-2). In order to demonstrate the performance of aggregate asset price index and of its components – equity prices, residential real estate and commercial real estate - Borio and Lowe (2002) also provide an empirical analysis belonging a dozen of industrial economies for a period of 1960 to 1999. They reach certain results, most significant ones of which are that equity prices are the most volatile, followed by commercial and residential property, that aggregate asset price index is mostly affected by residential property prices given the typical weights in the series, and that it is not difficult to realize a relation between large swings in asset prices and subsequent distresses in financial systems and real economies.

Also, they suggest that despite to the difficulties in foreseeing of financial imbalances *ex ante*, historical boom-bust cycles provide some evidence in favor of useful measures to show that monetary policy can also respond to such imbalances and that cooperation between monetary and prudential authorities is essential. They analyze whether or not a boom episode in asset prices, investment and credit gives a remarkable signal for occurrence of a financial and economic crisis. To this end, they define a threshold value for each of the indicator series and identify a credit boom as a period in which the ratio of credit to GDP deviates from its trend to a certain amount that can be said to signal an imminent bubble. The same is provisioned for asset and investment booms, so that they define credit gap, asset price gap, investment gap. Taken individually, they state that the credit gap is

clearly best indicator, which has the lowest noise to signal ratio and appears to predict the largest number of crisis. Also, considering combinations of indicators, they state that a credit gap of 4 percentage points, an asset price gap of 40 percent and an investment gap of zero yield the best combination of indicators for assessing signals. This empirical evidence, they argue, reveals that useful ex-ante indicators of financial imbalances can be constructed. In these early contributions to the literature on the asset prices and monetary policy where there was no consideration on (macro) prudential policy instruments in elimination of the financial imbalances, bubbles in the asset prices were constructed as exogenous in the models, so that bubbles randomly move being independent of any monetary policy action. Mendicino and Punzi (2011, p.58) point out that in these models, “the conduct of monetary policy rules cannot influence either the occurrence or magnitude of boom-bust cycles in asset prices”. Accordingly, on policy implication in these models, it can be concluded that it is not necessary for central banks to pay attention to boom-bust cycles in asset prices if financial imbalances do not disturb the inflation targeting policy framework.

In Gelain and Lansing (2014), some monetary and macro-prudential policy instruments are analyzed for exploring their contribution in reducing excess volatility of housing prices and household debts in a DSGE model in which expectations are modeled as a weighted average of a fully-rational rule of forecasting and a moving-average rule of forecasting, named as hybrid expectations model. As a bounded-rational forecasting approach, adaptive learning is used with an exponentially-weighted moving average of past observed values of the object. Then two models - hybrid and fully-rational - are evaluated for their implications on provision of a realistic economic model that gives the links between asset prices, credit expansion and real economic activity, they state that “standard DSGE models with fully-rational expectations have difficulty in producing large swings in house prices and household debt that resemble the patterns observed in many industrial countries over the past decade” (Gelain and Lansing, 2014, p.2). Comparing the models with rational expectations and hybrid expectations, they find that the volatilities of housing prices and household debts in the hybrid expectations model are nearly 1.5 times larger than those in the rational expectations model, providing a better match to the observed volatilities in the data as of U.S. economy. However, in consideration of the housing preference shocks, the hybrid expectations model cannot capture the volatilities of U.S. housing prices accurately. Also,

being an important relationship, the co-movement of housing prices, household debt and real production is not captured in the hybrid expectations model, which was significantly observed in the data.

In evaluation of the policy tools, they point out that an interest rate rule of the central banks that responds to either house price booms or credit expansion provides some benefits under rational expectations as of lower volatilities for household debt, stock prices and consumption but benefits are limited to reduced volatility in household debt under a model of hybrid expectations. Additionally, under such policy tools, inflation volatility improves in both models, which is essentially very contrary to the inflation-targeting policy framework. Regarding the macro-prudential policy, they consider two instruments: imposition of a more restrictive loan-to-value rule by tightening the lending standards and a modified (or generalized) collateral constraint, in which debt-to-income constraint is used by placing an important weight on borrower's wage income. In implementation of loan-to-value ratio, they state that "a reduction in the loan-to-value ratio from 0.7 to 0.5 substantially reduces the volatility of household debt under both expectations regimes, but output volatility is magnified" (ibid, p.6). However, they find the latter macro-prudential policy tool as more effective in prevention overall excess volatility in the model and argue that it is a more prudent lending criterion due to mainly the reason that it is less affected by distortions from excessive up-cycles in asset prices.

Lambertini et al. (2010) identify four peaks in real house prices in U.S (1973:3, 1979:4, 1989:2, and 2006:2) over the period 1965:1 and 2009:2 and show the characteristics on how the relationship between housing market boom-bust episodes and a number of macroeconomic variables had prevailed, which is of importance in exploring the nexus between housing market and monetary policy. Using the empirical evidence they point out that real housing prices and main macroeconomic fundamentals as of real personal consumption, real private non-residential business investments, hours worked are positively correlated. They mainly point out the pro-cyclicality of real housing prices on macroeconomic fundamentals where aforementioned peaks in real housing prices were followed by macroeconomic recessions. They also reach the conclusion that real loans grow during the boom episode, generally peak at the beginning of the recession and fall during the bust

episode in housing prices. Crucially, based on abovementioned empirical evidence, they argued that inflation and nominal interest rate are less correlated with real house prices during boom-bust cycles and reproducing the hypothesis that “housing booms were accompanied by low inflation and interest rate” (Lambertini et al., 2010, p.13), which is very contrary to arguments in Bordo et al. (2000) who argue that a monetary policy regime providing low and stable inflation will, as a byproduct, tend to promote stability of financial system.

They also examine the housing sector boom-bust cycles driven by changes in expectations about future macroeconomic developments.² They define a model with endogenous boom-bust cycles building on a “news shock” mechanism where public signals to household expectations determine the business cycle fluctuations. Boom episode is generated through the public signals, followed by bust episode if these signals do not come true ex post. The primary result they reach is the importance of changes in expectations as a mechanism to raise boom-bust cycles in the housing prices and investment. They extended the model developed by Iacoviello and Neri (2010) by introducing expectations of future macroeconomic developments. First, they state that in the presence of nominal price and wage rigidities, expectations on or news about future productivity result in boom-bust cycle dynamics in housing market and then business cycle fluctuations if expectations generate procyclicality. Second, beside to the news about the productivity, expectations on other sources, such as housing demand and monetary policy can generate cycles in the housing market only if agents expect a future increases in prices in housing sector, providing the housing demand and household indebtedness to rise. Accordingly, expectations about policy rate can generate boom-bust cycles in housing market if they are supported by the co-movements in consumption, investment, hours etc. Third, they state that if expectations on future expansionary monetary policy are not fulfilled, regarding the policy rate or inflation target, a boom-bust cycle and a macroeconomic recession can arise.

Lambertini et al. (2011) identify a modeling of expectations driven boom-bust cycles following Lambertini et al. (2010) and provide a consideration of the roles of monetary and macro-prudential policy in leaning against boom-bust episodes. They provide an active LTV

² For a more recent work in the literature, see Kanık and Xiao (2014), who analyze the possibility that a housing market boom-bust cycle can arise when public beliefs are driven by news shocks and that how monetary policy should respond to a news-driven fluctuations.

rate as a macro-prudential policy tool that responds counter cyclically to variables of financial imbalances such as credit growth. They find that a strong counter-cyclical response to credit expansion through a lower LTV rate directly counters the boom in housing market and stabilizes the credit aggregates without increasing the volatilities of inflation and GDP caps. In a similar vein, Rubio and Carrasco-Gallego (2013) consider a macro-prudential rule on the LTV rate that responds to credit expansion in reconsideration of the impact of monetary and prudential policies on the business cycles and welfare. They evaluate the implication of monetary and macro-prudential policy rules over stability of financial sector and welfare, when they behave in coordinated or non-coordinated way. In both cases a welfare improving result for the society, especially in the policy action of non-coordination, is realized. Given a positive housing demand and supply-side shock, they find that the macro-prudential authority that uses a lower ratio of LTV cap can moderate the credit bubbles in the name of provision of financial stability.

Crowe et al. (2013) acknowledge that identifying unsustainable asset bubbles with certainty is difficult. However, focusing on episodes involving sharp rises in amount of credit and leverage can serve as signal for this identification, where highly levered real estate markets had a prominent place. In consideration of distinguishing “bubbles” as the “price misalignments relative to economic fundamentals” (Crowe et al. p.305) from sustainable movements in prices, they address main risks as originated from increased leverage in both the real- in particular, housing and construction sector- and financial markets. Accordingly, they define two main, non- mutually exclusive policy objectives: one is preventing real estate booms and the associated leverage build-up at household and banking sectors altogether and other is ameliorating real estate busts by increasing the resilience of the financial system to such busts (ibid). With an empirical analysis using a sample of 19 advanced economies, regarding the pre-crisis period, they do not observe a correlation between the changes in house prices and interest rates or other measures of monetary instruments and also state that monetary policy can reduce the risk of an unsustainable boom episode, but with a possible cost of a larger output gap and the associated higher unemployment rate. In evaluation of the macro-prudential policy tools regarding their effectiveness on prevention of unsustainable boom-bust cycles, acknowledging the limitation that macro-prudential policy frameworks are still in their infancy they focus on three specific sets of measures: capital requirements, that is,

risk weights that change with the real estate cycle, dynamic provisioning, that is, the rule to increase banks' loan loss provisions during the boom episode and the LTV or debt-to-income ratio (DTI), that is, the cyclical tightening/easing of loans for borrowers.

The empirical evidence on effectiveness of the abovementioned policy measures is mixed, as summarized in Table 2.1, where a summary of some country experiences on the effects of various policy instruments to real estate and credit boom episodes is given. In the case of limits on LTV or DTI, for instance, Crowe et al. (2013) state that containing leverage through a limit on LTV can reduce the risks associated with declines in house prices and thus reduce amount of defaults, but with a cost of rationing sensitive groups out of the markets for credit. There exist a number of countries that adopted this policy rule long before the global financial crisis as of Hong Kong monetary authority (HKMA), which has operated an LTV policy rule to mitigate the housing cycles since 1994. Wong et al. (2011) point out that LTV cap has helped the Hong Kong banking sector for prevention of the unsustainable booms in real estate markets during the past two decades.

Table 2. 1: A summary of policy responses to real estate and credit booms -country cases

POLICY MEASURE	TO ADDRESS	USED IN	EFFECT
MONETARY POLICY			
Monetary tightening	Rapid credit growth and/or real estate boom	Croatia, Iceland, Latvia, Ukraine; Australia, Israel, Korea, Sweden	Not always effective, capital flows and currency switching risk are major limitations
Maintaining a flexible and consistent FX policy	Rapid credit growth	Poland, Romania	FX-denominated credit growth slowed down in Poland but not in Romania
MACROPRUDENTIAL POLICY			
Higher/differentiated capital requirements or risk weights by loan type	Rapid credit growth and/or real estate boom	Bulgaria, Croatia, India, Poland, Norway	Not always effective, some side-effects of shifting the risk elsewhere in the system
Tighter/differentiated loan classification and provisioning requirements	Rapid credit growth and/or real estate boom	Bulgaria, Croatia, Greece, Israel, Ukraine	Limited effect
Dynamic provisioning	Resilience to cyclical downturn/bust	China, Colombia, India, Spain, Uruguay	So far so good, difficulty in calibrating the extent of losses based on historical data
Tightening eligibility requirements, e.g., limits on loan-to-value ratios	Real estate boom	China, Hong Kong SAR, Korea, Malaysia, Singapore; Sweden	Short-lived effect on prices and mortgage activity

Source : Crowe et al. (2013). For more details on particular country cases, see Crowe et al. (2011) and Se (2013)

2.3. MACROPRUDENTIAL POLICY FRAMEWORK IN TURKEY

A particular emphasis, especially in the post-crisis episode, has been given to dynamics of housing prices and residential investment in Turkey. As Gelain and Lansing (2014) point out, seemingly-plausible arguments that aim to justify the dramatic rise in the asset prices in the pre-crisis episode, as particularly of the U.S. economy during the mid-2000s, were predicated on the justification that a bubble did not exist and that macroeconomic fundamentals were driving force for sustainable run-up in housing prices. In a similar vein, such a justification has been provided for the case of Turkey as well. However, acknowledging the pro-cyclicality of housing market boom-bust episodes on macroeconomic fundamentals, as pointed out before, monetary authorities in Turkey recognized that some of the shocks to the economy may result in unsustainable boom-bust cycles in house prices and residential investments that in turn can create unfavorable effects on Turkish economy through e.g., deteriorations in consumption and credit mechanism. Accordingly, given that the primary goal of the Central Bank of Turkey is the price stability within an inflation-targeting policy framework, some macro-prudential policy instruments have been implemented in an attempt to provide the stability of both financial markets and real activity, particularly concentrated in aftermath of the global financial crisis of 2008-2009. Following the main policy objective of limiting the build-up of system-wide (systemic) financial risk and set of instruments as described IMF report (2011), monetary and macro-prudential authorities in Turkey defined the prudential type instruments to deal specifically with systemic risk as the core instruments of macro-prudential policy. The LTV rule arises one of the primary policy instruments. The main instruments can be grouped in two: one is the instruments for explicitly and specifically monitoring the systemic risk; and the other is the operational instruments as of capital buffers, improving the capital adequacy ratios in sectorial base and loan-to-value or income-to value ratios. (IMF, 2011 and CBT, 2014). However, it should be noted that macro-prudential instruments defined by these financial regulatory institutions i.e., the Banking Regulation and Supervision Agency (BRSA), are not used as a substitute for actions provided by CBT but they are utilized having a secondary role.

Conforming with the abovementioned monetary policy framework, BRSA in Turkey defined some *pro-active* macro-prudential tools to help the prevention of the unsustainable housing boom-bust cycles and thus financial instability. Accordingly, as one of the primary tools, BRSA determined a loan-to-value ratio of 0.75 for residential credits and of 0.50 for commercial credits in 2010 so that macro-prudential authority imposed some rules on leverage and credit constraints featuring a relatively tighter policy tenet for the sake of sustainable financial cycles and business cycles in Turkey.

3. BENCHMARK MODELS

In this section, four DSGE models that incorporate the housing market dynamics and financial frictions into (monetary and macro-prudential) policy framework will be outlined. There is a growing literature on incorporation of financial frictions into macroeconomic models, which mainly contributed through two different approaches: financial accelerator mechanism due to Bernanke (1999) and collateral constraints due to Iacoviello (2005). Accordingly, in consideration of the New Keynesian models that incorporate the financial frictions through the financial accelerator mechanism, first, the work developed by Bernanke, Gertler and Gilchrist (1999) will briefly be introduced. Then to demonstrate how housing market dynamics are included in financial accelerator framework, a model developed by Aoki et al. (2004) will be outlined. In analysis of the latter approach of collateral constraints, the pioneering works of Iacoviello and Neri (2010) and Kannan et al. (2012) are summarized to demonstrate how rule based macro-prudential policy instruments and monetary policy rules are brought together to analyze housing boom-bust cycles. The model developed by Iacoviello and Neri (2010) is decided on as the benchmark model of the thesis.

The pro-cyclicality of financial markets in real economic activity was extensively investigated in the literature over the last two decades, in which the financial accelerator mechanism has an important place. Based on the work developed by Bernanke and Gertler (1989), BGG (1999) develop a standard dynamic new Keynesian model, modified to allow for financial accelerator effects. In the model construction, households and business firms have a priori role. The BGG model differs from the precedent standard dynamic new Keynesian models in that it assumes the existence of credit-market frictions, as of the problems of information and thus these financial frictions result in a financial accelerator role on certain dynamics. In BGG (1999) model key mechanism occurs within the link between the external finance premium, which defined as the difference between the cost of funds raised externally and opportunity costs internal to firms and net worth of potential borrowers, which defined as the sum of liquid assets plus collateral value of illiquid assets less outstanding obligations. (BGG, 1999, p.1345) In BGG model, a relevance between business firms' borrowing costs and their net worth arising due to asymmetric information between

lenders and borrowers is described, postulating that the external finance premium that depends inversely on borrowers' financial condition, rises when the firms' leverage increases. Accordingly, financial frictions make external finance more costly than internal finance. "A borrowing firm with more internal equity can offer more collateral to lenders. Thus, procyclical movements in the financial condition of potential borrowers translate into countercyclical movements in the premium for external finance, which in turn magnify investment and output fluctuations in the BGG model" (Bernanke and Gertler, 2000, p.17). In consideration of the shocks to economy, beside to the direct effects on output, consumption, employment etc., the shocks that increase the net worth of the economic agents results in an indirect effect through the increased credit worthiness of the borrowers and thus the reduced the external risk premium. This indirect effect is assumed to prompt the mentioned shocks to have more ever-lasting and stronger effects on macroeconomic fundamentals, which is what financial accelerator mechanism provides. With a tightening in monetary policy, for instance, the return on capital is reduced, causing a decline in the net worth of the economic agents. This increases the leverage and thus external finance cost. Accelerator effect arises due to ever-reducing the demand for capital and corresponding value of capital.

Aoki et al. (2004) develop a general equilibrium model based on the financial accelerator mechanism of BGG to analyze mainly the effects of monetary policy shocks on housing boom-bust cycles, housing investment and consumption in an environment of credit market frictions. They also demonstrate the effects of a change in the financial markets that lowers the cost of external finance of additional borrowing considering the housing assets. Although their model does not take a macro-prudential policy rule into account, Aoki et al. (2004) provide meaningful propositions regarding the nexus between the housing sector dynamics and monetary policy actions. In their model, because home is used as the collateral that reduces the costs of agents in financing housing investment and consumption, they give a priori role for house prices. They apply the BGG model that relates the cost of business firms' external finance to their net worth considering imperfections in credit markets, to the housing sector. They state that BGG model paves the way for a suitable platform to build a model where house prices, housing consumption and investment can be described in a general equilibrium framework. Being similar to mechanism of (indirect) financial accelerator effects in BGG model, developments in the imperfect credit markets, such as the changes in the

collateral and net worth, accelerate the effects of the shocks to economy. They summarized those effects, stating that “a positive shock to economic activity causes a rise in housing demand, which leads to the rise in house prices and so an increase in homeowners’ net worth. This decreases the external finance premium, which leads to a further rise in housing demand and also spills over into consumption demand”. (Aoki et al. 2004, p.416).

In consideration of modeling the household credit channel within a general equilibrium framework, they represent households as being a composite of two behavioral types: consumers and homeowners, which make the analysis simpler, without discrediting the financial accelerator mechanism. It is assumed that homeowners finance their funds to purchase houses from housing producers using both their net worth and borrowings from financial intermediaries. When they borrow from financial intermediaries, as in the case of business firms in BGG model, such an external finance results the homeowners in paying a premium caused by financial frictions i.e. information asymmetries. Homeowners rent those houses to consumers. Consumers consume goods and rent the housing services from the homeowners. Aoki et al. interpret the homeowners as firms who are owned by households. Households use their housing equity to finance their consumption and housing investment. When the house prices go up, households face a decision problem of whether to increase consumption today or reduce the future external finance premium, keeping the transfer payments and consumption constant, which is determined in accordance with the target level of net worth and consumption. They introduce price stickiness in consumption goods assuming the Calvo (1983) staggered price setting. Also, house prices are assumed to be a function of q -theory of investment with adjustment costs. Monetary policy is assumed to be determined by a Taylor-type rule.

In consideration of how financial accelerator mechanism works in their modeling economy, they mainly find that with a positive shock to the economy, a rise in the housing demand occurs, which leads to a rise in house prices and homeowners’ net worth and thus a decrease in the external finance premium. This results in a further increase in housing demand and consumption. Hence, “as in BGG, credit-market frictions amplify shocks to the economy” (ibid, p.429).

As stated by Monacelli (2009, p.242), new Keynesian models, featuring price stickiness and imperfect competition as central building blocks, have recently become an important instrument for the analysis of business cycles and monetary policy. However, most of these models ignore the importance of housing sector in business cycles. In the pioneering work developed by Iacoviello and Neri (2010), following the modeling framework of Iacoviello (2005), incorporation of financial frictions into macroeconomic models is made through the approach of collateral constraints. They investigate the housing market spillovers -sources and consequences of fluctuations in the housing market- by providing evidence from an estimated DSGE model in a closed economy framework. Observing the experience of the U.S housing market dynamics, which shows rapid growth in the housing prices and residential investment, particularly in the early periods of last decade, the ideas concerning the pro-cyclicality of housing markets, as one of the driving forces of business cycles rather than just a reflection of progress in the real activities, have been increasingly contributed. To justify these ideas, Iacoviello and Neri (2010) state that it is important to answer two questions: first, what is the nature of the shocks that hit the housing market? Second, how effective or big are the spillovers from the housing market to the macroeconomic fundamentals? By developing a DSGE model of the U.S. economy, in which the price and quantity sides of the housing sector are defined in detail and estimating it using Bayesian methods, they study the shocks and frictions that can explain main mechanisms of housing prices and residential investment in U.S. economy.

Regarding the first question, they state that slow technological progress in the housing market and the presence of land-as a fixed factor- in the production function explains the upward trend in the real prices in housing sector in U.S economy regarding the period 1965:I-2006:IV. Their results demonstrate that several shocks are needed in explaining the patterns of co-movements in macroeconomic fundamentals. Accordingly, housing demand and technology shocks partly explain-one-quarter of- the volatilities of housing prices and housing investment, which are strongly pro-cyclical, volatile and significantly sensitive to monetary policy shocks. They investigate the monetary transmission mechanism through its effects on both housing prices and residential investment. They find that monetary policy shocks explain nearly 20 percent of the housing market boom-bust cycles in the U.S. data. To answer the second question, they concentrate on the relationship between housing wealth and

non-housing consumption, as one aspect of the spillovers. They show that the housing market spillovers are non-negligible and have become more important over time in the data.

In the modeling economy, there exist four assumptions: 1. a multi-sector structure with housing and non-housing goods and services; 2. nominal rigidities; 3. financial frictions in the housing sector and 4. various set of shocks. On the supply side, they assume sectoral heterogeneity, where the non-housing markets produce consumption and business investment goods using labor and capital; the housing sector produces housing services using labor, capital and land. On the demand side, households consume housing and consumption goods. Also, housing is used as collateral for loans, following Iacoviello (2005). As a macro-prudential policy rule, LTV ratio is defined in the collateral constraint, in which fluctuations in the prices in housing market affect the borrowing capacity of (impatient) households and affects the profitability of producing new housing services. Additionally, different technologies are assumed to be used in production of housing and consumption goods.

Kannan et al. (2012) closely follow the DSGE models developed by Iacoviello (2005), Iacoviello and Neri (2010) and Monacelli (2009) in consideration of how macro-prudential and monetary policy rules should be brought together to prevent the unsustainable housing boom-bust episodes and help macroeconomic stability. They address three questions using a model economy with housing markets: 1) What are the potential gains from reacting to signs of emerging financial problems? 2) Is monetary policy the appropriate tool for reacting to such indicators, or should macro-prudential tools be used? And 3) What are the trade-offs between concentrating on the policy actions for stabilizing the output gap and inflation and attempting to reduce the risk of asset price crashes?

In the modeling economy, households can make choices about how much to consume goods and how much to accumulate housing. Investments of households in housing services are the main vehicles of accumulation of wealth in this modeling economy. For simplicity, it is assumed that the economy is closed and there is no capital in the production of consumption and housing goods. There exist two-sectors and both sectors operate under monopolistic competition and under sticky price mechanism in the short run à la Calvo (1983). Due to assumptions of habit formation and adjustment costs, consumption and

housing investment adjust slowly. As in the model developed by Iacoviello and Neri (2010), households are defined as heterogeneous agents where distinction between borrowers and lenders is made in Kannan et al. (2012). However, unlike the former model, they assume that the lenders cannot provide funds to borrowers directly, but rather financial intermediaries are assumed to take deposits from the lenders and lend to borrowers. In return, they demand a spread that depends on the net worth of the borrowers. Profits of the financial intermediaries are transformed to the lenders who own these financial intermediaries. The determinants of the spread between the lending and deposit rates are the mark-up in the banking sector-the margin banks charge over the funding costs-, leverage of the borrowers-ratio of debt to the value of the housing stock of borrower- where a higher lending rate is charged for a higher leveraged loan, and the macro-prudential instruments of capital requirements and LTV rules imposed by central banks to prevent the unsustainable credit growth. By introducing various determinants of the spread rate, Kannan et al. (2012) aim to provide a more flexible borrowing constraint compared to that in Iacoviello (2005).

Incorporation of presence of the sticky price assumption and the financial frictions into the model makes the analysis of the real effects of monetary policy rules and of the alternative policy regimes possible. Accordingly, in addition to standard Taylor-type policy, they define augmented Taylor-type policy regimes that respond to the lagged nominal credit changes. One important result they reach is that extending monetary policy rule through inclusion of credit market can help counter the financial accelerator mechanism that paves the way for unsustainable credit expansion and booms in house prices. Another result is that considering the bubbles in credit and housing markets driven by the financial and housing demand shocks, implementation of macro-prudential policy instruments that responds to credit expansion will improve the welfare of households. However, when the source of bubbles in housing market is driven by technological progresses, the same instruments that react credit market will result in a decrease in welfare of households. Accordingly, they emphasize the importance of expectations regarding the source of the shock to economy, which in turn determine how monetary and macro-prudential policy regimes are utilized.

In exploration of nexus between housing boom-bust cycles, monetary and macro-prudential policy rules for Turkish economy the modeling economy developed by Iacoviello

and Neri (2010) is decided as the benchmark model for this thesis without considerable modifications to model. The medium-scale macroeconomic model developed by Iacoviello and Neri (2010) includes habit persistence and other rigidities such as the investment adjustment costs, price rigidity in consumption sector, wage rigidity in both housing and consumption sectors and imperfect competition mechanism that all together enable us to better observe various business cycle facts of the economy.

4. THE MODEL

The model developed by Iacoviello and Neri (2010) is used in this paper as the benchmark model without a worth-mentioning modification. The primary reason for choosing the model of Iacoviello and Neri (2010) is its detailed description of an economy where the housing market is well-defined in a multi-sector structure, that can enable us to draw precise conclusions regarding the housing market dynamics for Turkish economy. Also, rigidities in the model economy such as the habit persistence, investment adjustment costs, price rigidity in consumption sector, wage rigidity in both consumption and housing sectors and imperfect competition mechanism are preserved in our study that all together enable us to better observe various business cycle facts of the economy. Descriptions regarding the model economy are mostly in line with the benchmark model. The modeling economy features two sectors – consumption goods sector and housing sector, heterogeneity in households' discount factors and collateral constraints that are tied to the housing prices. The non-housing sector uses capital and labor to produce consumption goods and business capital. The housing sector produces housing services combining business capital, labor and land. There are two types of households: patient (lenders) and impatient (borrowers). Patient households consume, work and accumulate housing. They supply funds to firms and to impatient households and own the productive capital in the economy. Impatient households consume, work and accumulate housing. However, due to their relative impatience, impatient households accumulate only the required “net worth” to finance the down payment of their home. The Figure 4.1 denotes the basic structure of the model economy.

Figure 4. 1: Basic Structure of the Model

Source: Author's calculation

4.1. HOUSEHOLDS

The economy is composed of a continuum of households in the interval $(0; 1)$. There are two types of households, named patient and impatient, of measure ω and $1 - \omega$ respectively. Each individual household's time endowment is normalized to 1. Economic size of each group is measured by its wage share, which is assumed to be constant. All households derive utility from consumption goods and housing services and disutility from hours in consumption and housing sectors.

4.1.1. Patient Households

A representative patient household maximizes its expected utility, which depends on current consumption c_t^P , lagged aggregate consumption c_{t-1}^P , housing services h_t^P and hours worked – in the consumption sector $n_{c,t}^P$ and in the housing sector $n_{h,t}^P$:

$$\max_{c_t^P, h_t^P, n_{h,t}^P, n_{c,t}^P} E_t \sum_{t=0}^{\infty} (\beta_P G)^t z_t \left[\Gamma_C^P \ln(c_t^P - \varepsilon^P c_{t-1}^P) + j_t \ln h_t^P - \frac{\tau_t}{1+\eta} (n_{h,t}^{1+\xi} + n_{c,t}^{1+\xi})^{\frac{1+\eta}{1+\xi}} \right] \quad (4.1)$$

where the expression in square brackets denotes the period utility. The marginal utilities of consumption $u_{c,t}^P$ and of housing services $u_{h,t}^P$ are given by:

$$u_{c,t}^P = z_t \Gamma_C \left(\frac{1}{c_t^P - \varepsilon^P c_{t-1}^P} - \frac{\beta_P G \varepsilon^P}{c_{t+1}^P - \varepsilon^P c_t^P} \right);$$

$$u_{h,t}^P = \frac{z_t j_t}{h_t^P}.$$

The marginal disutilities of working in the goods $u_{nc,t}^P$ and housing sector $u_{nh,t}^P$ are given by:

$$u_{nc,t}^P = z_t j_t (1 + \eta) n_{c,t}^{\xi} (n_{h,t}^{1+\xi} + n_{c,t}^{1+\xi})^{\frac{\eta-\xi}{1+\xi}};$$

$$u_{nh,t}^P = z_t j_t (1 + \eta) n_{h,t}^{\xi} (n_{h,t}^{1+\xi} + n_{c,t}^{1+\xi})^{\frac{\eta-\xi}{1+\xi}}.$$

where the discount parameter is β_p . The term z_t captures intertemporal shock to preferences and τ_t captures shocks to labor supply. The parameter ε^p measures the degree of habit formation (persistence) in consumption. Inclusion of the habit formation into the medium-scale macroeconomic model provides a hump-shaped response of consumption to expansionary shocks of various variables, in which consumption peaks in general immediately after the shock and then declines to its long-run level. Such a response is hard to replicate in the absence of habit formation (Schmitt-Grohe and Uribe, 2005). The term j_t captures the housing preference shock that is, exogenous shocks to the demand for housing. Regarding the housing preference shock, there are mainly two interpretations: one interpretation is that the shock captures cyclical variations in the availability of resources to purchase housing services relative to consumption goods or that the shock captures shifts social or institutional factors that affect the housing preference. The other interpretation is that fluctuations in j_t can capture supply-side changes in a way that they could proxy for changes in the factor mix (capital, labor and land) required to produce housing services given a housing stock.

Intertemporal, housing demand and labor supply shocks follow stationary autoregressive processes:

$$\ln z_t = p_z \ln z_{t-1} + u_{z,t} ;$$

$$\ln \tau_t = p_\tau \ln \tau_{t-1} + u_{\tau,t} ;$$

$$\ln j_t = p_j \ln j_{t-1} + u_{j,t} ,$$

where $u_{z,t}$, $u_{\tau,t}$ and $u_{j,t}$ are i.i.d. processes with variances σ_z^2 , σ_τ^2 and σ_j^2 . The term G is the gross growth rate of consumption along the balanced growth path. Because the consumption grows at the rate G every quarter along the balanced growth path, the transformed marginal utility, i.e., $\check{u}_{c,t}$, becomes stationary, and equal to $u_{c,t}^P G$, around the steady state. The scaling factor $\Gamma_C^P = (G - \varepsilon^p)/(G - \beta_p \varepsilon^p G)$ is a simple normalization ensuring that the marginal utility of consumption is equal to $1/c^p$ in the nonstochastic steady state. As in Fisher (2007), the model defines the log-specification of preferences for consumption and housing services to reconcile the trend in the housing prices and the stable nominal share of expenditures

in consumption of investment goods. The disutility of labor is specified with $\xi, \eta \geq 0$, which implies that households have a preference for differentiating labor across housing and consumption sectors. This allows for less than perfect labor mobility across the two sectors. In the case of $\xi = 0$, hours worked in the two sectors are perfect substitutes, so that both sectors pay the same wage in equilibrium. In the case of $\xi > 0$, it is allowed for some degree of sector specificity where relative hours worked respond less to wage differentials across two sectors. The term η measures the inverse Frisch elasticity of labor supply and it is assumed that labor is perfectly mobile across two sectors.³

In the modeling economy developed by Iacoviello and Neri (2010), it is assumed that patient households save through accumulating capital, homes and land and provide funds to impatient households. Also, they lease their capital to firms and choose a capital utilization rate and sell remaining non-depreciated capital. In turn, firms pay a rental rate. This assumption provides the same optimality conditions as in the case of firms who accumulate their own capital stock.

Patient households maximize their utility subject to constraint:

$$\begin{aligned}
c_t^P + \frac{k_{c,t}^P}{A_{k,t}} + k_{h,t}^P + k_{b,t}^P + q_t h_t^P + q_{l,t} l_t^P - b_t^P = & \frac{w_{c,t}^P n_{c,t}^P}{X_{wc,t}^P} + \frac{w_{h,t}^P n_{h,t}^P}{X_{wh,t}^P} + (R_{c,t} z_{c,t}^P + \frac{1-\delta_{k,c}}{A_{k,t}}) k_{c,t-1}^P + \\
(R_{h,t} z_{h,t}^P + 1 - \delta_{k,h}) k_{h,t-1}^P + p_{b,t} k_{b,t}^P - \frac{R_{t-1} b_{t-1}^P}{\pi_t} + (p_{l,t} + R_{l,t}) l_{t-1} + q_t (1 - \delta_h) h_{t-1}^P + Div_t^P - \\
\phi_t^P - \frac{a(z_{c,t}^P) k_{c,t-1}^P}{A_{k,t}} - a(z_{h,t}^P) k_{h,t-1}^P.
\end{aligned} \tag{4.2}$$

The constraint (4.2) allows patient households to choose the levels of consumption c_t^P , capital in the consumption goods' sector $k_{c,t}^P$, capital $k_{h,t}^P$ in the housing sector, intermediate inputs $k_{b,t}^P$ (with a price $p_{b,t}$) in the housing sector, housing h_t^P (with a price q_t), land l_t^P (with a price $q_{l,t}$), hours worked in consumption sector $n_{c,t}^P$, in housing sector $n_{h,t}^P$, capital utilization rates $z_{c,t}^P$ and $z_{h,t}^P$, and borrowing b_t^P for maximization of utility. If patient

³ For a discussion of the literature on micro and macro estimates of the Frisch Labor supply elasticity, see Peterman (2014).

households provide loans to borrowers, then loans yield a nominal return (R_t). $A_{k,t}$ defines investment-specific technological shocks that represent the marginal cost (in terms of consumption) of production capital used in the non-housing market.⁴ The terms $w_{c,t}^P$ and $w_{h,t}^P$ denote the real wage, $R_{c,t}$ and $R_{h,t}$ show the real rental rates in return for leasing of the capital stocks and $\delta_{k,c}$ and $\delta_{k,h}$ give the depreciation rates in consumption and housing sectors, respectively. The terms $X_{wc,t}^P$ and $X_{wh,t}^P$ define the markup between the wage paid by the wholesale firm or housing sector and the wage paid to the households, due to monopolistic competition in the labor market. $\pi_t = \frac{p_t}{p_{t-1}}$ is the inflation rate in the consumption sector, Div_t^P are the lump-sum profits from final goods firms and labor unions, ϕ_t^P is the convex adjustment costs for capital. In the model, there is the possibility of adjustment costs where capital installation causes a cost (ϕ_t^P). Also, the degree of capital utilization is used as a choice variable for the patient households such that z is the capital utilization rate that transforms physical capital k into effective capital zk and $a(z_{c,t}^P)$ and $a(z_{h,t}^P)$ are the convex costs of setting the capital utilization rate to z . The functional forms of the convex adjustment cost for capital and the utilization rate for consumption and housing sectors are given in appendix A.

The first order conditions for the patient households:

$$u_{c,t}^P q_t = u_{h,t}^P + \beta_P G E_t \left(u_{c,t+1}^P q_{t+1} (1 - \delta_h) \right) \quad (4.3)$$

$$u_{c,t}^P = \beta_P G E_t \left(u_{c,t+1}^P \frac{R_t}{\pi_{t+1}} \right) \quad (4.4)$$

⁴ Iacoviello and Neri (2010) assume that investment shocks to economy affect only the capital used in the production of consumption goods. Reason is that the investment-specific technological shocks mostly refers to information technology in the non-housing sectors and construction industry is considered as a non- information technology intensive one.

$$u_{c,t}^P \left(\frac{1}{A_{k,t}} + \frac{\partial \phi_{c,t}^P}{\partial k_{c,t}^P} \right) = \beta_P G E_t u_{c,t+1}^P \left(R_{c,t+1} z_{c,t+1}^P - \frac{a(z_{c,t+1}^P)^{1+\delta_{k,c}}}{A_{k,t+1}} - \frac{\partial \phi_{c,t+1}^P}{\partial k_{c,t+1}^P} \right) \quad (4.5)$$

$$u_{c,t}^P \left(1 + \frac{\partial \phi_{h,t}^P}{\partial k_{h,t}^P} \right) = \beta_P G E_t u_{c,t+1}^P \left(R_{h,t+1} z_{h,t+1}^P - a(z_{h,t+1}^P) + 1 - \delta_{k,h} - \frac{\partial \phi_{h,t+1}^P}{\partial k_{h,t+1}^P} \right) \quad (4.6)$$

$$u_{c,t}^P w_{c,t}^P = u_{nc,t}^P X_{wc,t}^P \quad (4.7)$$

$$u_{c,t}^P w_{h,t}^P = u_{nh,t}^P X_{wh,t}^P \quad (4.8)$$

$$u_{c,t}^P (p_{b,t} - 1) = 0 \quad (4.9)$$

$$R_{c,t} A_{k,t} = a'(z_{c,t}^P) \quad (4.10)$$

$$R_{h,t} = a'(z_{h,t}^P) \quad (4.11)$$

$$u_{c,t}^P p_{l,t} = \beta_P G E_t u_{c,t+1}^P (p_{l,t+1} + R_{l,t+1}) \quad (4.12)$$

where $u_{c,t}^P$ denotes the marginal utility of consumption, $u_{h,t}^P$ denotes the marginal utility of housing services. The terms $u_{nc,t}^P$ and $u_{nh,t}^P$ show the marginal disutility of working in the goods and housing sectors, respectively. (4.3) gives the first order condition (FOC) with respect to housing h_t^P , (4.4) gives FOC with respect to lending b_t^P , (4.5) and (4.6) give FOCs with respect to capital stocks $k_{c,t}^P$ and $k_{h,t}^P$, (4.7) and (4.8) give FOCs with respect to disutility from workings $u_{nc,t}^P$ and $u_{nh,t}^P$, (4.9) gives FOC with respect to intermediate inputs $k_{b,t}^P$, where

it provides that price level of the intermediate inputs is equal to 1. (4.10) and (4.11) give FOCs with respect to capital utilization rates $a(z_{c,t}^P)$ and $a(z_{h,t}^P)$ and (4.12) gives FOC with respect to land l_t^P .

4.1.2. Impatient Households

The representative impatient household maximizes its expected utility function:

$$\max_{c_t^I, h_t^I, n_{h,t}^I, n_{c,t}^I} E_t \sum_{t=0}^{\infty} (\beta_I G)^t z_t \left[\Gamma_C^I \ln(c_t^I - \varepsilon^I c_{t-1}^I) + j_t \ln h_t^I - \frac{\tau_t}{1+\eta^I} (n_{h,t}^{1+\xi^I} + n_{c,t}^{1+\xi^I})^{\frac{1+\eta^I}{1+\xi^I}} \right] \quad (4.13)$$

where the assumption is $\beta_I < \beta_P$.

Unlike the patient households, this group of households does not accumulate capital stock and do not own finished good firms or land. In the modeling economy, it is assumed that there are labor unions (explained later), which are the only source of the dividends for the impatient households. They have revenues from working in goods and housing sectors. In financing their expenditures, they also borrow from the patient household with the amount of b_t^I and have to repay the previous period's loan together with the interest $R_{t-1} b_{t-1}^I$.

The marginal utility of consumption $u_{c,t}^I$ is given by:

$$u_{c,t}^I = z_t \Gamma_C^I \left(\frac{1}{c_t^I - \varepsilon^I c_{t-1}^I} - \frac{\beta_I G \varepsilon^I}{c_{t+1}^I - \varepsilon^I c_t^I} \right).$$

The marginal utility of housing services and the marginal disutilities of working in the goods and housing sectors are also similar to those of the patient households. The scaling factor $\Gamma_C^I = (G - \varepsilon^I)/(G - \beta_I \varepsilon^I G)$ is a simple normalization ensuring that the marginal utility of consumption is equal to $1/c^I$ in the nonstochastic steady state. Features regarding the disutility of labor specified with $\xi^I, \eta^I \geq 0$, are similar to those in the case of patient households.

Impatient households maximize their utility subject to budget constraint:

$$c_t^I + q_t h_t^I - b_t^I = \frac{w_{c,t}^I n_{c,t}^I}{X_{wc,t}^I} + \frac{w_{h,t}^I n_{h,t}^I}{X_{wh,t}^I} - \frac{R_{t-1} b_{t-1}^I}{\pi_t} + q_t (1 - \delta_h) h_{t-1}^I + Div_t^I \quad (4.14)$$

There also exists a borrowing constraint on the impatient households:

$$b_t^I \leq m E_t \left(\frac{q_{t+1} h_{t+1}^I \pi_{t+1}}{R_t} \right) \quad \text{where } 0 \leq m \leq 1 \quad (4.15)$$

which denotes the maximum amount they can borrow from the patient households b_t^I , which is given by the expected present value of their housing stock multiplied by the loan-to-value ratio m . A fixed parameter m , is used rather than providing a time-varying LTV rule that responds to certain indicators i.e., credit expansion.⁵ As stated by Gerali et al. (2010, p.14), policy implication of this rule is that when the economy is exposed to an excessive credit growth, a lower LTV ratio is determined, which results in collateral constraints to become tighter. Another (microeconomic) implication of the rule is that $(1 - m)$ can be defined as the proportional cost of the collateral re-possession for the patient households who own the loans in the case of possible default of impatient households.

The first order conditions for the impatient households:

$$u_{c,t}^I q_t = u_{h,t}^I + \beta_I G E_t \left(u_{c,t+1}^I q_{t+1} (1 - \delta_h) \right) + E_t \left(\lambda_t \frac{m q_{t+1} \pi_{t+1}}{R_t} \right) \quad (4.16)$$

$$u_{c,t}^I = \beta_I G E_t \left(u_{c,t+1}^I \frac{R_t}{\pi_{t+1}} \right) + \lambda_t \quad (4.17)$$

⁵ In Kannan et al. (2012) and Rubio and Carrasco-Gallego (2013), a time-varying LTV rule is implemented as an instrument to moderate credit cycles. In the latter study, a Taylor-type rule for the LTV rule that responds inversely to credit growth, which aims at prevention of episodes of excessive credit growth. Accordingly, once such an episode is observed, lowering the LTV ratio tightens the collateral constraint and hence restricts the amount of borrowings.

$$u_{c,t}^I w_{c,t}^I = u_{nc,t}^I X_{wc,t}^I \quad (4.18)$$

$$u_{c,t}^I w_{h,t}^I = u_{nh,t}^I X_{wh,t}^I \quad (4.19)$$

where λ_t shows the multiplier on the collateral constraint and is greater than zero in a neighborhood of the equilibrium. The impatient households only accumulate housing assets depending on the collateral constraints. Hence along with the equilibrium path, the main mechanism under the (4.15) is that cycles in the housing values affect the borrowing and spending capacity of the impatient agents considering m as the instrument that alters the liquidity of housing wealth. In the case of a larger value of m , the effects of fluctuations are expected to be higher.

4.2. WHOLESALE GOODS FIRMS and TECHNOLOGY

In the modeling economy, there is the assumption of price rigidity in the consumption sector. Accordingly, to introduce price rigidity in this sector, a distinction is made between wholesale firms that produce both consumption goods and houses using two production technologies in a competitive price mechanism and a final good firm that operates in the consumption sector under monopolistic competition.

Wholesale firms solve the following maximization problem:

$$\max \frac{Y_t}{X_t} + q_t I H_t - \left(\sum_{i=c,h} w_{i,t}^P n_{i,t}^P + \sum_{i=c,h} w_{i,t}^I n_{i,t}^I + \sum_{i=c,h} R_{i,t} Z_{i,t}^P k_{i,t}^P + R_{l,t} l_{t-1}^P + p_{b,t} k_{b,t}^P \right) \quad (4.20)$$

which delivers zero profits because of the constant returns to scale assumption and where the markup of final goods over wholesale goods is denoted with X_t . It is assumed that the

wholesale goods have the nominal price P_t^w and are transformed into final goods by final goods firms at a price P_t , where $P_t = X_t P_t^w$.

The two production technologies for wholesale goods and houses:

$$Y_t = \left(A_{c,t} \left(n_{c,t}^P \alpha n_{c,t}^L \right)^{1-\alpha} \right)^{1-\mu_c} (z_{c,t} k_{c,t-1}^P)^{\mu_c} \quad (4.21)$$

$$IH_t = \left(A_{h,t} \left(n_{h,t}^P \alpha n_{h,t}^L \right)^{1-\alpha} \right)^{1-\mu_h-\mu_b-\mu_l} (z_{h,t} k_{h,t-1}^P)^{\mu_h} k_{b,t}^{\mu_b} l_{t-1}^{\mu_l} \quad (4.22)$$

In (4.21), wholesale goods producing firms use capital and labor in order to produce wholesale goods or final output Y_t . In (4.22), these firms use capital, labor, land and intermediate input $k_{b,t}^P$ to produce new housing services IH_t . It should be noted that $k_{b,t}^P$ is produced in the wholesale goods sector. The terms $A_{c,t}$ and $A_{h,t}$ measure the productivity in the wholesale goods and housing sectors, respectively. The both production technologies are expressed in terms of a Cobb-Douglas production function and are modeled as trend-stationary. Along the balanced growth path, when there exists a rise in $A_{c,t}$ relative to $A_{h,t}$, then there will be an increase in the price of housing services compared to one of consumption goods. The parameter α measures the labor income share of patient/unconstrained households.

Optimality conditions for the wholesale goods firms:

$$(1 - \mu_c) \alpha \frac{Y_t}{X_t n_{c,t}^P} = w_{c,t}^P \quad (4.22)$$

$$(1 - \mu_c)(1 - \alpha) \frac{Y_t}{X_t n_{c,t}^L} = w_{c,t}^L \quad (4.23)$$

$$(1 - \mu_h - \mu_b - \mu_l)\alpha \frac{q_t IH_t}{n_{h,t}^P} = w_{h,t}^P \quad (4.24)$$

$$(1 - \mu_h - \mu_b - \mu_l)(1 - \alpha) \frac{q_t IH_t}{n_{h,t}^I} = w_{h,t}^I \quad (4.25)$$

$$\mu_c \frac{Y_t}{x_t k_{c,t-1}^P} = R_{c,t} z_{c,t} \quad (4.26)$$

$$\mu_h \frac{q_t IH_t}{k_{h,t-1}^P} = R_{h,t} z_{h,t} \quad (4.27)$$

$$\mu_l q_t IH_t = R_{l,t} l_{t-1} \quad (4.28)$$

$$\mu_b q_t IH_t = p_{b,t} k_{b,t} \quad (4.29)$$

where (4.22) gives the first order condition (FOC) with respect to $n_{c,t}^P$, (4.23) gives FOC with respect to $n_{c,t}^I$, (4.24) gives FOC with respect to $n_{h,t}^P$, (4.25) gives FOC with respect to $n_{h,t}^I$, (4.26) gives FOC with respect to $k_{c,t-1}^P$, (4.27) gives FOC with respect to $k_{h,t-1}^P$, (4.28) gives FOC with respect to l_t^P and (4.29) gives FOC with respect to $k_{b,t}^P$.

4.3. NOMINAL RIGIDITIES and MONETARY POLICY

4.3.1. Wage Stickiness

It is assumed for wage rigidity to prevail in both consumption and housing sectors. The patient and impatient households supply their (homogenous) labor services to labor unions. There are four monopolistically competitive labor unions, two for both constrained and unconstrained households in consumption sector and two for housing sector. Based on a Calvo-type wage stickiness model, following Schmitt-Grohe and Uribe (2006) and Smets and Wouters (2007)⁶, it is assumed that the labor services of the households are transformed by labor unions into differentiated labor inputs, which are reassembled by some intermediate packers. Wholesale firms hire these labor inputs from these intermediate packers and make them as the homogenous labor composites n_c^P, n_h^P, n_c^I and n_h^I . Probability of labor unions to change nominal wages in each sector is common to both households. Assuming some monopoly power over nominal wages gives explicit wage equations and paves the way for introduction of sticky nominal wage assumption following Calvo (1983). The Calvo-type wage rigidity is based on the assumption that prices that are not re-adjusted are partially indexed to past inflation rates. Accordingly, prices are set in function of current and expected marginal costs, but are also determined by past inflation rates (Smets and Wouters, 2007, p.10). In a similar vein, wages depends on past and expected wages and are partially indexed to past inflation rates.

⁶ Schmitt-Grohe and Uribe (2006) use two ways of modeling Calvo-type wage rigidities. In the first way, each household is the monopolistic supplier of a differentiated labor input whereas in the second, as in the Iacoviello and Neri (2010), monopolistically competitive labor unions transform the homogenous labor input into differentiated labor inputs. Schmitt-Grohe and Uribe (2006) show that up to a log-linear approximation, these two variants of wage stickiness feature identical equilibrium conditions prevailing similar expectations-augmented wage Phillips curves and that both variants fit the data well over medium-scale macroeconomic models.

Thus, the pricing rules set by the labor unions imply four wage Phillips curves:

$$\ln \omega_{c,t}^P - \iota_{w,c} \ln \pi_{t-1} = \beta G(E_t \ln \omega_{c,t+1}^P - \iota_{w,c} \ln \pi_t) - \varepsilon_{w,c} \ln(X_{wc,t}^P / X_{w,c}^P) \quad (4.30)$$

$$\ln \omega_{h,t}^P - \iota_{w,h} \ln \pi_{t-1} = \beta G(E_t \ln \omega_{h,t+1}^P - \iota_{w,h} \ln \pi_t) - \varepsilon_{w,h} \ln(X_{wh,t}^P / X_{w,h}^P) \quad (4.31)$$

$$\ln \omega_{c,t}^I - \iota_{w,c} \ln \pi_{t-1} = \beta_I G(E_t \ln \omega_{c,t+1}^I - \iota_{w,c} \ln \pi_t) - \varepsilon_{w,c}^I \ln(X_{wc,t}^I / X_{w,c}^I) \quad (4.32)$$

$$\ln \omega_{h,t}^I - \iota_{w,h} \ln \pi_{t-1} = \beta_I G(E_t \ln \omega_{h,t+1}^I - \iota_{w,h} \ln \pi_t) - \varepsilon_{w,h}^I \ln(X_{wh,t}^I / X_{w,h}^I) \quad (4.33)$$

where $\omega_{c,t}^i$ and $\omega_{h,t}^i$ are the nominal wage inflation in consumption and housing sector, respectively, that is, $\omega_t^i = w_t^i - w_{t-1}^i + \pi_t$ or $\omega_t^i = \frac{w_t^i \pi_t}{w_{t-1}^i}$. (4.30) and (4.31) denote the wage Phillips curves for patient households in the consumption and housing sector and (4.32) and (4.33) denote the ones for impatient households. Under Calvo-type pricing mechanism with a partial indexation to previous inflation level, index wages respond to the previous period inflation rate with elasticity $\iota_{w,c}$ and $\iota_{w,h}$. The parameters $\varepsilon_{w,c}^i$ and $\varepsilon_{w,h}^i$ define the slope of wage equations and $\theta_{w,c}$ and $\theta_{w,h}$ denote the wage-stickiness in goods and housing sectors such that

$$\varepsilon_{w,c} = (1 - \theta_{w,c})(1 - \beta G \theta_{w,c}) / \theta_{w,c},$$

$$\varepsilon_{w,h} = (1 - \theta_{w,c})(1 - \beta G \theta_{w,c}) / \theta_{w,c},$$

$$\varepsilon_{w,c}^I = (1 - \theta_{w,c})(1 - \beta_I G \theta_{w,c}) / \theta_{w,c},$$

$$\varepsilon_{w,h}^I = (1 - \theta_{w,h})(1 - \beta_I G \theta_{w,h}) / \theta_{w,h}.$$

4.3.2. Price Stickiness

In the modeling economy, Calvo-type nominal price stickiness is defined in the consumption-business investment sector whereas flexible price mechanism is assumed to hold for housing sector.⁷ Price stickiness is introduced by assuming monopolistic competition at the retail level, so that retailers purchase Y_t from the wholesale firms at the nominal price P_t^w in a competitive market and transformed into final goods s at a price P_t , and sell at a markup $X_t = P_t/P_t^w$ over the marginal cost. Households buy those final goods by converting the CES aggregates into consumption and business investment goods. A fraction $1 - \theta_\pi$ of final goods firms or retailers set prices optimally, whereas a fraction θ_π cannot set optimal prices and index their nominal prices to the previous period inflation rate.

The resulting inflation equation is the new Keynesian Phillips curve:

$$\ln \pi_t - \iota_\pi \ln \pi_{t-1} = \beta G (E_t \ln \pi_{t+1} - \iota_\pi \ln \pi_t) - \varepsilon_\pi \ln \left(\frac{X_t}{X} \right) + u_{p,t} \quad (4.34)$$

⁷ Regarding assumption of flexibly priced newly constructed housing, Barsky et al. (2003, p.2) state that neoclassical sticky price models that are augmented with durable goods with flexible prices, match the main features of the data, so that production of housing services falls sharply following a monetary contraction, while the production of non-durables falls very little. They point out that the purchases of the latter are subject to consumption smoothing logic of the permanent income hypothesis, whereas the intertemporal elasticity of substitution for purchases of housing assets is nearly infinite, which results in real effects of monetary disturbances.

where ι_π denotes the elasticity of indexation to previous period inflation rate, $\varepsilon_\pi = (1 - \theta_\pi)(1 - \beta G \theta_\pi) / \theta_{w,\pi}$ is the slope of the inflation equation and $u_{p,t}$ denotes the cost-push shocks that affect inflation independently from changes in markup, which is assumed to be i.i.d. process with variance σ_p^2 .

Based on the Barsky et al. (2003), Iacoviello and Neri (2010) feature several reasons on why housing assets might have flexible prices. First, housing assets are relatively expensive on a per-unit basis relative to consumption goods, so that if the explicit and implicit costs of negotiation-i.e. menu costs- have an important fixed component, then there will be a large incentive to negotiate on the price of a housing asset. Second, most houses are priced for the first time when they are sold. Third, the price of the housing assets fall more in response to monetary contractions relative to that of non-housing goods.

4.3.3. Monetary Policy

The modeling economy is assumed to follow an inflation-targeting policy regime in which the central bank sets the policy rate R_t that responds to inflation and output gap.

The policy rule is described by the traditional Taylor rule:

$$R_t = R_{t-1}^{rr} \pi_t^{(1-r_r)r_\pi} \left(\frac{GDP_t}{GXGDP_{t-1}} \right)^{(1-r_r)r_Y} \bar{rr}^{1-r_r} \frac{u_{R,t}}{s_t} \quad (4.35)$$

where $\bar{rr}$ is the steady state level of real interest rate and is assumed to be equal to patient households' discount rate $1/\beta$. The term GDP_t is the sum of the two sectors. It sums the growth rates of consumption, business investment and residential investment by their nominal shares at steady state. That is, $GDP_t = C_t + IK_t + \bar{q}IH_t$, where $\bar{q}$ is the real price of the housing assets along the balanced growth path. Iacoviello and Neri (2010) use a definition of GDP with steady state house prices, so that short-run changes in the real house prices do not

have an impact on GDP growth. The implication of this standard Taylor rule is that the central bank changes the nominal interest rate in response to the deviations in inflation from its steady state level and the deviations in total output from the natural level. Besides, central bank takes previous value of nominal interest rates into consideration in determining the current nominal interest rate. As Çebi (2011) argues that the high value for the degree of interest rate smoothing reduces the contemporary responsiveness of the nominal interest rates to inflation and output gap.

The term $u_{R,t}$ denotes a monetary policy shocks that is assumed to be i.i.d. process with variance σ_R^2 and s_t denotes a stochastic process introduced to implicitly model long-lasting deviations of inflation from its targeted level which may arise due to shifts in the monetary authority's inflation target. That is:

$$\ln s_t = p_s \ln s_{t-1} + u_{s,t},$$

where $u_{s,t}$ is assumed to follow i.i.d. process with variance σ_s^2 and $p_s > 0$.

4.4. MARKET CLEARING CONDITIONS

$$C_t + \frac{IK_{c,t}}{A_{k,t}} + IK_{h,t} + k_{b,t} = Y_t - \phi_t^P \quad (4.36)$$

where the goods market produces consumption C_t , business investment $\frac{IK_{c,t}}{A_{k,t}}$, residential investment goods $IK_{h,t}$ and intermediate inputs $k_{b,t}$ for housing sector, adjusted with the convex adjustment cost of capital ϕ_t^P , which is zero at the steady state. The term $C_t = c_t^P + c_t^I$ denotes the aggregate consumption, $H_t = h_t^P + h_t^I$ denotes the aggregate stock of housing assets, $IK_{c,t} = k_{c,t}^P - (1 - \delta_{k,c})k_{c,t-1}^P$ denotes aggregate business investment and $IK_{h,t} = k_{h,t}^P - (1 - \delta_{k,h})k_{h,t-1}^P$ denote the total intermediate input in the housing sector. Also, the supply of land l_t is assumed to be fixed and normalized to 1.

$$H_t - (1 - \delta_h)H_{t-1} = IH_t \quad (4.37)$$

where the housing market produces new houses IH_t .

$$b_t^P + b_t^I = 0 \quad (4.38)$$

where in the loan market, constrained and unconstrained agents trade one-period nominal loans.

4.5. TRENDS and BALANCED GROWTH

It is assumed that there are linear deterministic trends in the technologies A_c , A_h and A_k in the consumption, residential and business investment sectors, respectively and that corresponding net growth rates of technology in each sector are γ_c , γ_h and γ_k . These trends in the productivities follow the processes:

$$\ln A_{c,t} = t \ln(1 + \gamma_c) + \ln Z_{c,t}, \quad \text{and} \quad \ln Z_{c,t} = p_{a,c} \ln Z_{c,t-1} + u_{c,t};$$

$$\ln A_{h,t} = t \ln(1 + \gamma_h) + \ln Z_{h,t}, \quad \text{and} \quad \ln Z_{h,t} = p_{a,h} \ln Z_{h,t-1} + u_{h,t};$$

$$\ln A_{k,t} = t \ln(1 + \gamma_k) + \ln Z_{k,t}, \quad \text{and} \quad \ln Z_{k,t} = p_{a,k} \ln Z_{k,t-1} + u_{k,t}.$$

where innovations $u_{c,t}$, $u_{h,t}$ and $u_{k,t}$ are assumed to be i.i.d. processes with standard deviations $\sigma_{A,c}$, $\sigma_{A,h}$ and $\sigma_{A,k}$. Provided by these trends, the variables $Y, c^P, c^I, \frac{k_c}{A_k}, k_h, k_b, q$, all grow at a common rate along the balanced growth path. It is because of the assumption on constant returns to scale in the production functions, so that there exist common expenditure shares.

As stated before, the preferences and production functions have the Cobb-Douglas form where a balanced growth path exists, along which the growth rates of the real variables are:

$$G = 1 + \gamma_C + \frac{\mu_c}{1-\mu_c} \gamma_K \quad (4.39)$$

$$G_{IK,c} = 1 + \gamma_C + \frac{1}{1-\mu_c} \gamma_K \quad (4.40)$$

$$G_{IH} = 1 + (\mu_h + \mu_b) \gamma_C + \frac{\mu_c(\mu_h + \mu_b)}{1-\mu_c} \gamma_K + (1 - \mu_h - \mu_b - \mu_l) \gamma_H \quad (4.41)$$

$$G_q = 1 + (1 - \mu_h - \mu_b) \gamma_C + \frac{\mu_c(1-\mu_h-\mu_b)}{1-\mu_c} \gamma_K - (1 - \mu_h - \mu_b - \mu_l) \gamma_H \quad (4.42)$$

Accordingly, G is the trend growth rate of real consumption. Also, when $\gamma_K > 0$, then business investment grows faster than consumption along the balanced growth path. Last, the trend growth rate in real house prices along the balanced growth path G_q offsets differences in the productivity growth between the consumption and the housing sector. These differences arise because the rates of technological progresses are defined to be different in the two sectors and because of the presence of land in the production function of housing assets.

The variables are detrended by their balanced growth trends where each variable is scaled by its growth rate once the variables are expressed within the transformed model.

5. ESTIMATION

In this section we introduce the dataset used, structural parameters and the estimation methodology utilized in estimating the set of equations, which enable us to analyze the dynamics of the model economy and answer some questions with alternative policy rules regarding the exploration of the nexus defined above.

5.1. DESCRIPTION OF THE DATA

The model is estimated using quarterly data from the first quarter of 2010 to the last quarter of 2014 where the observable variables are real consumption (C_t), real residential investment (IH_t), real non-residential investment (IK_t), real house prices (q_t), inflation (π_t) nominal interest rate (R_t) worked hours and wage inflation in housing (NH_t , WH_t) and in consumption-wholesale sector (NC_t , WC_t). The variables in smoothed form are given in Figure D.21. Due to the limited availability of data for price index in housing sector for Turkey, a relatively short length of sample period for estimation is determined. However, while this sample period is obviously shorter than a desired one, observing the studies with similar sample length⁸, the aforementioned sample period is accounted as elucidative in estimation of the parameters. Following the literature, some standard transformations are defined to make the data series consistent with the corresponding model variables. In Appendix C, a summary of the data and sources is given. Consumption, investments in business and housing sectors and total hours are expressed in per capita terms. With the calibration of depreciation parameters, the capital shares in the production functions, mark-up ratios and the weights in the utility functions given in Table D.1, it is assumed that the steady state share of consumption in output is 0.67, while the shares of steady state housing and business investments in total output are 0.06 and 0.27, respectively, which enables the model dynamics to roughly match with the data for sample period, as shown in Table D.2. Besides,

⁸ See e.g. Alp and Elekdag (2011), who analyze the monetary policy framework in Turkish economy along with a relationship with global financial crisis in a relatively short length of sample period.

calibration of the discount factors at the rates as shown below leads to a steady state annual real interest rate at 3 percent. It should be noted that the four estimated parameters that denotes the trend growth rates $-\gamma_C, \gamma_K, \gamma_H$ – and income share of unconstrained households – α – do not so much change the steady state ratios of consumption, business and residential investment to total output. Also, we remove the mean from inflation and the nominal interest rate in the sample period.

Before the estimation of the model parameters, a transformation of the data is made to provide the consistency with the assumption of balanced growth path. In Appendix B, the measurement equations are given following the benchmark model. As stated above, in the transformed model the variables are detrended by their trend growth where each variable is scaled by its growth rate. Once variables are scaled by their trend growth, the model is linearized around the steady state. It is assumed that there are linear deterministic trends in the technologies A_c , A_h and A_k in the consumption, residential and business investment sectors, respectively. Due to the multi-sector structure with housing and non-housing goods, different technologies are defined in the model. In a similar vein, in An and Schorfheide (2007), with the assumption of one-sector structure of the model, since the non-stationary technological process induces a stochastic trend in output and consumption they express the model in terms of de-trended variables. Accordingly, their model economy has a unique steady state in terms of the de-trended variables, which is attained if the innovations are zero.

The transformed variables in our model are expressed as follows:

$$C_t = \frac{c_t}{G_t}, IH_t = \frac{IH_t}{G_{IH,t}}, IK_t = \frac{IK_t}{G_{IK,t}}, q_t = \frac{q_t}{G_{q,t}},$$

where it is assumed that along the balance growth path the consumption grows at the rate G and likewise for other transformed variables. In equilibrium these transformed variables remain stationary.

As Given in Appendix B, the transformation of the data is made by taking the logarithm - subtracted from the first observation 2010:Q1- of data for real consumption, real business and residential investment and the real house prices.

5.2. CALIBRATED PARAMETERS

Current model is richly parameterized where some of the parameters are calibrated, some are determined in accordance with their steady state values and the remaining is estimated. Calibrated parameters are given in Table D.1 and steady state values are given in Table D.2. In order to determine the structural parameters that describe preferences of the agents and technology the literature is significantly followed. Accordingly, the discount factors β_p, β_I , the weight on housing in the utility function j_t , technology parameters $\mu_c, \mu_h, \mu_b, \mu_l$, depreciation parameters $\delta_{k,h}, \delta_{k,c}, \delta_h$, the macro-prudential policy rule m , the steady state level of gross price and wage mark-up ratios $X, X_{W,c}, X_{W,h}$ are calibrated.

The choice of preference parameters is almost standard in the DSGE literature. Accordingly, the parameters of discount factors belonging to patient and impatient households, respectively are $\beta_p = 0.9928$ and $\beta_I = 0.97$ (Iacoviello, 2005 and Alp and Elekdağ, 2011). Discount factor of patient household is determined at this rate, so that a steady state annualized real interest rate of 3% is obtained. Inclusion of a different value for the discount factor of the impatient household does not create important effects on the dynamics of the model economy, but it does generate a binding borrowing constraint in equilibrium for impatient household sector by guaranteeing a large enough impatience motive for these agents (Iacoviello, 2005). The preference parameter for the weight on housing in the utility function j is set at 0.1.

Following Alp and Elekdağ (2011), the steady state share of capital in the production function is set at 0.4 of which the capital share in the goods production function μ_c is set at 0.30 and capital share in the housing production function μ_h is set at 0.10. Besides, following Davis and Heathcote (2005), a land share in the housing production function μ_l is determined at 0.10.⁹ Also, the intermediate inputs produced by goods market and used to produce

⁹ Since the share of newly-available land in home production is not available in the literature for Turkey, it is determined at the rate in the benchmark model (rather than ignoring the raw land in home production) to capture the dynamics of housing market more realistically. In addressing the dynamics of residential investment and housing boom-busts, Davis and Heathcote (2005) use a multi-sector model where a more land-intensive and more construction-intensive technologies are defined for home production compared to those technologies in production of other durables. Accordingly, the share of the raw land in new houses is set to 0.106. Also, they state that increasing land's share in house production raises the model correction with the data, which is achieved when the land's share exceeds 0.17.

wholesale goods and new houses are defined in the model, so that steady state share of the intermediate goods μ_b is set at 0.10. The main aim for defining the material cost μ_b is to capture the dynamics behind sticky-price intermediate inputs that are used in production functions.

Depreciation rate in the housing sector δ , is taken as 0.0125 so that 5% is the annual depreciation rate of the housing stock. This parameter along with the weight on housing in the utility function j , gives a ratio of the residential investment to total output at around 6%.¹⁰ Similarly, the depreciation rate in the capital in the consumption sector $\delta_{k,c}$ and capital in the housing sector $\delta_{k,h}$ are set equal to 0.035 and 0.03, respectively (Iacoviello and Neri, 2010 and Yüksel, 2013). That the construction machinery has slightly longer life time (which demonstrates an annual depreciation on capital at 12 percent) than the non-residential equipment (which gives an annual depreciation rate of 14 percent) is also supported by Yeldan and Kolsuz (2014).

The parameters for the steady state rate of mark-up in the price and wage settings are calibrated since these parameters are difficult to estimate. Accordingly, following Alp and Elekdağ (2011), we fix X at 1.15 implying that the steady state mark-up is set at 15% in the consumption-good sector. In a similar vein, $X_{w,c} = X_{w,h} = 1.15$, which denote the steady state mark-ups (because of monopolistic competition in the labor market) between the wage paid by the wholesale good firms and wage paid to households (in consumption and housing sectors, respectively).¹¹ As stated before, in the model economy, a stochastic process s_t is defined to capture the deviations of inflation from its steady state level due to e.g. shifts in the monetary authority's inflation target. Accordingly, the parameter p_s denotes the correlation-persistence of the inflation objective shock, which is fixed at 0.95. A high value for p_s demonstrates low-frequency movements well in inflation. Still, a slightly lower parameter p_s compared to the one in benchmark model is determined given the historical phases of inflation in Turkish economy.

¹⁰ This ratio is close to share of housing in total output in data for Turkey. According to Turkish Statistical Institute (TURKSTAT), it has gradually increased to 6 % in the post-crisis period although it had fallen to below of 4% in 2009.

¹¹ In the literature, the steady state price and wage mark-ups mostly lie in a range between 10-20 percent e.g. in Kannan et al. (2012) these parameters are set at 1.1 whereas in Brzoza-Brzezina et al. (2013), the steady state markups in the labor and product markets are set at 2.

Considering the parameter related to macro-prudential policy tool, the LTV ratio on (mortgage loans) m is set at 0.75, determined by Banking Regulation and Supervision Agency (BRSA) in Turkey in 2010. This parameter is used to measure the LTV rule for homebuyers who may be among credit constrained ones, so that the maximum amount they can borrow from the impatient households is given by the expected present value of their housing stock multiplied by the loan-to-value ratio m . A fixed parameter m is used rather than providing a time-varying LTV rule observing the implementation of the rule. Besides, to draw some policy implications, different values for LTV rule is also calibrated.

5.3. ESTIMATION METHODOLOGY

In estimation of the parameters of model Bayesian estimation techniques are applied.¹² We do so since Bayesian estimation techniques allow for incorporation of a *priori* information on the parameters of the model. Also, pure maximum likelihood tends to produce fragile results, particularly in situations in which some parameters are weakly identified (Iacoviello and Neri, 2010).¹³ An and Schorfheide (2007, p.123) state that pure maximum likelihood estimation of DSGE models has not turned into the estimation method of choice due to the dilemma of absurd parameter estimates and that estimates of structural parameters generated with maximum likelihood procedures based on a set of observations are often at odds with additional information that the research may have i.e., the micro level evidence. Also, given a relatively shorter sample period for this study, it is thought that the Bayesian methods can deal with the identification problems better.

In Schorfheide (2011), Bayesian inference is described as follows: In the Bayesian framework the likelihood function is reweighted by a prior density. With an assumption that θ denotes the collection of parameters of DSGE model, Bayesian inference starts from a *priori*

¹² For description of the estimation methodology in this study, An and Schorfheide (2007) and Schorfheide (2011) are strictly followed.

¹³ Canova and Sala (2009) provide detailed explanations about identification issues in DSGE models. Defining the identification as the ability to draw inference about the parameters of a theoretical model from an observed sample they state that Bayesian approach can deal with identification problems compared to the likelihood function of DSGE models once reliable information is provided.

distribution represented by a *prior* density is denoted by $P(\theta)$. Also, with the assumption that sample observations are collected in the matrix Y , the *prior* is combined with the conditional density of the data Y given the parameters, denoted by $P(Y, \theta)$. It is the joint probability distribution of the data Y and the parameters θ . According to Bayes Theorem, the *posterior* distribution – the conditional distribution of parameters given data – is given by

$$P(\theta|Y) = P(Y|\theta)P(\theta)/P(Y), \quad P(Y) = \int P(Y|\theta)P(\theta)d\theta,$$

where $P(Y)$ denotes the marginal likelihood or data density. Hence, the information contained in the *prior* distribution is regenerated with the likelihood, that is $P(Y|\theta)$, of the sample observations to deliver the *posterior* distributions of the parameters $P(\theta|Y)$. Then the *posterior* density provides statistical inference on the functions of parameters.

In applications of DSGE model, it is generally not possible to obtain moments and distributions of the posterior analytically. Rather, Bayesian inference is implemented by providing some numerical methods such as MCMC simulation. MCMC algorithms deliver serially correlated sequences of draws from the density $P(\theta|Y)$. Grounded on these draws, we can approximate the posterior density, its moments and distributions. With the Monte Carlo simulation algorithm, one can generate a vector of draws from an unknown distribution using a known distribution (Iacoviello and Neri, 2010). Also, the convergence towards a true unknown distribution is provided as the length of the simulation rises where Metropolis algorithm is commonly used. Hence, the estimation procedure consists of various steps: the transformation of the sample observations into a form suitable for the computation of the likelihood function using the state-space representation of the model; the choice of appropriate prior distributions for the parameters; the estimation of the posterior distribution with Monte Carlo methods (ibid).

In this study we use the Metropolis algorithm. We linearize the equations of the model economy to describe the equilibrium conditions around the balanced growth path. Given the parameter values, the solution of the set of equations is defined in the form of a state-space model, so that the likelihood function is obtained. The model is solved numerically using the toolbox Dynare over MATLAB.

6. RESULTS

6.1. PRIOR and POSTERIOR DISTRIBUTIONS

6.1.1. Prior Distributions

In determination of the prior distributions, their means and standard deviations, the literature is closely followed, so that gamma distribution is assumed for positive parameters; the beta distribution is assumed for the parameters which vary between 0 and 1; inverse gamma distribution is assumed for the standard errors of shocks and normal distribution is chosen for the remaining.

The values regarding the choice of prior and posterior distributions, the means, standard deviations and degrees of freedom of the estimated parameters, being consistent with previous studies are given in Table D.3. Accordingly, the prior mean of the habit persistence in consumption for both patient and impatient agents is set at 0.5, implying a relatively lower consumption smoothing patterns of agents. Regarding the monetary policy rules, the interest rate smoothing coefficient is set at 0.7 and the priors on responsiveness of the standard Taylor rule to inflation, output gap are determined at 1.4 and 0.25, respectively, following Alp and Elekdag (2011) and Yüksel (2013). Since the central bank's main policy objective is the provision of price stability, a higher value for the response to inflation is determined relative to that for output gap. The capital adjustment costs for capital and housing are both set at 0.10. Given the functional form of convex adjustment costs of capital in Appendix A, it is implied that the elasticity of investment to its shadow value is $1/\phi\delta$ and as in the benchmark model of Iacoviello and Neri (2010) the prior distribution of the parameters gives an elasticity of less than 3.

As stated in Appendix A, the curvature of the capacity utilization function is specified as ς which is bounded between 0 and 1. The prior mean of this parameter is set at 0.5 as a plausible rate along with the observation that this utilization parameter can be set at zero if capacity utilization can be varied at no cost and is set at one if capacity utilization never changes. Determining the disutility of working at 1.5, the prior mean for η and η^l which denotes the inverse Frisch elasticity of labor supply is set at 0.66. These ratios give reasonable

wage elasticity for the labor supply. Also, to allow for less than perfect labor mobility across housing and consumption sectors, the priors for ξ and ξ^l , which are the inverse elasticity of substitution across hours in the two sectors, are set at 1. As stated above, in the case of $\xi = 0$, hours worked in the two sectors are perfect substitutes, so that both sectors pay the same wage in equilibrium. However, when $\xi > 0$, it is allowed for some degree of sector specificity where relative hours worked respond less to wage differentials across two sectors. The prior means of both the Calvo-type price and wage parameters are set at 0.5 which are close to the estimates of Alp and Elekdağ (2011) and Çebi (2011) with a standard deviation of 0.10. Also, following Smets and Wouters (2007), the prior means for the indexation parameters are set at 0.5. The prior mean for the labor income share of the unconstrained households is set at 0.65. Lastly, the prior means for the technological progress in business investment, consumption goods and housing sectors are taken as 0.005 with normal distribution so that parameters $100\gamma_{AK}, 100\gamma_{AC}, 100\gamma_{AH}$ provide us to draw certain conclusions on trend movements of these technologies.

In Table D.4, following the benchmark model and the previous studies, the values for choice of prior distributions for the persistence parameters and standard deviations belonging to the stochastic processes are determined. Accordingly, the shock persistence parameters are set with a mean of 0.80 and a standard deviation of 0.10. Also, being close to the previous studies and observation sample, the prior means for the standard deviations of shock processes are given.

6.1.2. Posterior Distributions

In Table D.3 and D.4 the posterior means and their confidence intervals for both structural parameters and shock processes are given along with the mean and standard deviation of the prior distributions. These tables report the posterior means of the estimated parameters where draws from the posterior distributions are obtained with the Metropolis-Hastings sampling algorithm based on a total sample of 500,000 draws. Figures D.1 to D.5 denote the posterior kernel density estimates for shock processes and estimated parameters

along with the prior densities. In general terms, from these estimates, it is seen that the sample period is quite informative in estimation of the parameters though it is obviously shorted than desired one. However, as stated by Alp and Elekdağ (2011), it should be noted that although the parameter estimates are in line with those in other studies regarding the exploration handled in this thesis, it should be recognized that the comparison of the parameter estimates with previous studies can be less elucidative than desired due to certain reasons. One is that the structural features of the economies studied may differ. Also, sample period and choice of time series may differ across studies. Another reason is the modeling differences in these studies i.e., use of a different monetary policy rule (Alp and Elekdağ, 2011, p.40).

The posterior estimate of the habit persistence in consumption for both patient and impatient agents is found around 0.5, implying a moderate degree of consumption smoothing patterns of both agents. The degree of habits in consumption is lower than the estimates of some other studies, e.g., Alp and Elekdağ (2011) who find a higher degree of habit formation in consumption patterns of households in their study for the case of Turkey.

The posterior estimates of the parameters on the monetary policy rules coincide with the previous evidence. First, it is found that estimate of the interest rate smoothing parameter in Taylor-type policy rule is slightly below of 0.70. Second, the estimate of the inflation weight parameter in Taylor rule is around 1.55. Third, the estimate of the output gap parameter is around 0.25. These coefficients regarding the responsiveness of the policy rates coincide with the findings in Smets and Wouters (2007) and Alp and Elekdağ (2011). Thus, given that the primary goal of the Central Bank of Turkey is the price stability within an inflation-targeting policy framework, the estimates of a higher response to inflation gap relative to output gap are in line with the empirical evidence. Also, a relatively high estimate of interest rate smoothing parameter implies that the Central Bank take the past values of the nominal interest rates into consideration in determining the current level of nominal interest rate. As stated by Çebi (2011), the high value for the degree of interest rate smoothing reduces the contemporary responsiveness of the nominal interest rates to inflation and output gap. However, it is also needed to state that the comparison of the estimates on the monetary policy rules with the findings in other studies may be difficult due to the fact that different specifications in the modeling of the policy rate is defined in the literature. For instance, in

Yüksel (2013) in which there exists a different specification of the policy rule including real exchange rate depreciation in rule, the coefficient of the responsiveness to output gap output gap is captured at too low.

Regarding the labor income share of credit-constrained agents, the posterior estimate is 0.65, being quite close to prior mean. This value of the estimated parameter together with the some others determines how large the elasticity of consumption to house prices becomes when a housing preference shock is taken into account. Since impatient households have lower discount factor, they have a higher marginal propensity to consume but a low average propensity to consume due to their high steady state debt payments (Iacoviello and Neri, 2010). Thus, their wage share affects the amount of consumption of housing assets in total.

The posterior estimate for the elasticity of work effort in terms of the real wage for the patient households η is around 0.65 and for impatient households η^I is around 0.67, being close to previous studies. Thus, the inverse Frisch elasticity of labor supply gives reasonable wage elasticity for the labor supply, implying a disutility of working around 1.5. Besides, the estimated parameter for the inverse elasticity of substitution across hours in the two sectors for patient and impatient agents is found around 1 in which the former is slightly higher. As stated above, when this parameter ξ is higher than zero, then it is allowed for some degree of sector specificity where the relative hours worked respond less to wage differentials across two sectors. Also together with η and η^I , they imply less than perfect labor mobility across housing and consumption sectors.

In consideration of the nominal rigidities - the Calvo-type parameters in price and wage settings, it is found that the estimate of the Calvo parameter for price settings θ_π is around 0.60, which implies that the prices are adjusted for every 2.5 quarter on the average. Thus, in terms of the price rigidity, it is relatively low. This result is in line with the estimates of Alp and Elekdağ (2011). Besides, it coincides with the empirical study of Özmen and Sevinç (2011) who explore the price rigidity in Turkey using a micro-level data. Their results suggest that in terms of price stickiness, it is low in Turkey. Additionally, they argued that there exists a mixed pricing strategy which is a combination of state and time dependent pricing and there is great heterogeneity across groups in Turkey, Thus, a reliable comparison of the results for this parameter with the other studies in literature is difficult. Also, the

estimates of the Calvo-type parameter in wage settings in consumption goods sector and housing sector are 0.56 and 0.35, respectively, implying that the wages in consumption goods sector are adjusted for every 2 quarters and the wages in housing sector are adjusted for every 1.5 quarters on the average. Thus, for the wages, it is found that the stickiness in the housing sector is less than the consumption sector. It is also found that the elasticity of indexation to previous period's inflation is more than 0.5. The parameters regarding the degree of indexation of wages to previous period in goods and housing sectors are around 0.4 and 0.50, respectively, which implies a higher degree of indexation in housing sector. This set of parameters implies that the - both wage and new Keynesian – Phillips curves have backward looking components at a significant rate. Regarding the history of high inflation periods in Turkey, the backward looking behavior of wage and price inflation is meaningful (Yüksel, 2013). Also, these results are in line with the findings in Alp and Elekdağ (2011).

In consideration of the technological progress for different sectors, it is found from posteriors that there is a high rate of technological progress in the production of business investment goods, followed by the technological progress in housing goods, which is slightly higher than those in consumption goods, which together determine the long-run features of the economy.

In Table D.4, the posterior means for the persistence parameters and standard deviations of shock processes are given. It is seen from the estimated parameters that all shocks are quite persistent that lie within a range of 0.82 for the shock to labor supply and 0.94 for the shocks to technological progress in goods sector. Observing the estimates of the standard deviations of the shocks it is seen that the volatility of the shocks are quite small in general except for the case of the housing demand shock and for the case of the innovations in stochastic processes in inflation targeting regime. The latter estimate is actually in line with the empirical evidence for Turkey given the frequent changes in the inflation target of the Central Bank for the observation period of 2010-2014. In discussion of the housing sector dynamics, the persistence parameter for the shock to housing preference is 0.90 together with a quite high standard deviation of 0.07. Also, shocks to technological progress in housing sector are also persistent but less volatile. Lastly, it is estimated that the standard deviation of

the measurement error for the hours and wage inflation in the housing sector is high for the case of labor supply and low for the case of wage income.

Lastly, regarding the posterior estimates of the technological progress in business investment, consumption goods and housing sectors $100\gamma_K, 100\gamma_C, 100\gamma_H$, a faster rate of technological progress in business investment, followed by residential investment and consumption is found 34, 16, 15, respectively, which imply a long-run growth rates of technologies of these sectors. Accordingly, there is a slow rate of productivity increase in consumption and housing sectors compared to business investment sector. Also, together with the calibrated parameters - $\mu_l, \mu_c, \mu_h, \mu_b$ – these values estimate a growth of real house prices for the sample period of around 2%. Besides, in the model economy, the land is assumed as a fixed factor in the production of new houses, which is expected to contribute to the increase in real housing prices. Accordingly, together with a posterior estimate of technological progress in residential investment, γ_H , at 0.16% the share of land in the production of new houses, μ_l , at 10%, affects the real house prices adversely as given in equation (4.42).

6.2. IMPULSE RESPONSES AND SECOND MOMENTS

In this section, main dynamics of the model are discussed through the impulse response functions and the second moments. Regarding the exploration of the nexus between the housing cycles and monetary and macro-prudential policy rules, a three-fold analysis over the impulse response functions is primarily carried out. First, to examine the response of some macroeconomic fundamentals and housing variables to the changes in monetary policy rules, an inverse policy shock raising the nominal interest rates is given to economy. Second, a housing preference shock is given to the economy, which may enable us to see how it creates an (housing collateral) effects on the business cycles. Third, some technology shocks on different sectors are given to see how they can explain the business cycles and housing variables. Beside to these shocks, some other shocks are also considered: the cost shocks, inflation target shocks, labor supply shocks and intertemporal preference shocks. In the baseline model, the macro-prudential policy rule of loan-to-value ratio is set at 0.75. These

figures denote the responses of real consumption (data_CC), real business investment (data_IK), real residential investment (data_IH), real GDP (zata_GDP)¹⁴, real house prices (data_QQ) and the nominal interest rate (data_RR) to aforementioned shocks.

Figure D.6 denotes an adverse i.i.d. shock to monetary policy rule where the y-axis measures the percent deviation from the steady state values and the solid line is the mean impulse response whereas the thinner lines are the 10% and 90% posterior intervals – as for the other figures. It is seen from Figure D.6 that the real house prices do not much drop and remain below its baseline for about 4 quarters as a result of an adverse monetary policy shock.

The Figure reveals that all components in the aggregate demand side are adversely affected by the shock where the consumption substantially responds to the shock followed by the real business and residential investments. The former drops around 9 percent and remains below its baseline level for about 6 quarters whereas the responses of real business and residential investments are less persistent. The reason for the aforementioned high response of consumption to the monetary policy shocks can be attributed to the existence of nominal rigidities and collateral effects on constrained households that are generated through the financial frictions - relatively tighter loan-to-value ratio. Besides, since the model does not take the collateral constraints and financial frictions into account on the side of the firms, there exists a marginal response of both the real business and residential investments to the adverse monetary shocks that prompt the nominal rate of interest. As stated by Iacoviello and Neri (2010), the collateral effects slightly reduce the sensitivity of investment to these monetary shocks, because unconstrained households shift loanable funds from the constrained households towards firms – as unconstrained agents - in order to smooth their consumption. Additionally, since it is found from the posterior estimates that the wage rigidity in the housing sector is lower than non-residential sector, it can be expected to have less interest rate sensitivity of the residential investment compared to real business investment.

Eventually, from the impulse response analysis over the monetary policy shocks, it is seen that presumptions for a monetary policy regime that produces aggregate price stability will, as a byproduct, tend to promote stability of housing markets and the financial system

¹⁴ The variable of real GDP (zata_GDP) denotes domestic demand excluding government purchases and it is not among the observable variables and determined as a function of the components of the aggregate demand i.e., consumption, business and residential investments.

e.g., Bordo et al. (2000) and Taylor (2007), don't fully hold in our estimation. Given the inflation targeting policy framework aiming at the price stability as in the case of Turkey, it can be argued that the tighter monetary policy along with the some prudential policy instruments may not result in prevention of a housing "bubble".

Figure D.7 denotes the effects of a positive housing demand shock. As seen from the Figure, by creating new demands towards housing, a positive preference shock substantially raises the real house prices which remain above its baseline level for long periods. The estimated autocorrelation of 0.90 for the housing preference parameter contributes this long-lasting increase in house prices. As a result of an increase in the demand for the new houses, the returns from the investments in the housing sector rise as well, which in turn causes residential investment to increase. Since a macro-prudential policy rule, LTV ratio, is introduced in the credit or collateral constraint, fluctuations in the prices in housing market affect the borrowing capacity of households. Accordingly, a positive housing preference shock increases the value of the housing assets as the collateral of the constrained agents, which increase the borrowing capacity of those agents. As observed from the Figure, this increase borrowing and consumption of the agents in total. Besides, the modeling constrained agents as having high propensity to consume contributes the consumption to rise further.

In consideration of the response of real business and residential investments, it is observed that though the housing demand shock results in an increase in real house prices of more than 10 percent, the real residential investments rise at a much lower rate. As stated before, in the model economy, it is assumed that there are flexible prices in the housing sector and that wage rigidity in the housing sector is low, which in together can be the explanatory instruments for response of the construction of new homes being less sensitive the housing demand shock. Considering the response of the real business investment, it is seen that there exists a sharp drop around 9 percent and remains below its baseline level for about 5 quarters. This can be attributed to transition of the capital in the production of the business investment goods towards to the other two sectors; the consumption goods and housing sectors. Overall, there exist significant effects on the real output where the housing preference shock contributes a significant and long-lasting increase in real GDP.

In Figures D.8 to D.10, technology shocks in housing, consumption goods and business investment sectors are given, respectively. Figure D.8 plots the responses to positive technology shocks in the housing sector which result in a rise in the real residential investments. Housing technology shock also leads the real house prices to drop and remain below its baseline persistently, which can be attributed to the fall in the unit cost of production of construction services. Besides, as a response to positive technology shock, the hours worked in the construction industry rise and the hours in the goods market do not shift – not given in the Figure. Figure D.9 plots the responses to a productivity shock in the consumption goods sector, which results in an increase in the real house prices. As expected, all components of the aggregate demand rise as well. As a response to technology shock in consumption goods sector, hours in consumption goods sector fall whereas hours in the housing sector rise – not given in the Figure. The drop in the hours in goods market can be attributed to the sticky price assumption in the consumption goods where since firms cannot adjust their prices quickly as a response to a positive technology shock, they reduce their labor demand in the goods sector, which contribute to rise in the labor demand in construction industry. Figure D.10 plots the responses to a positive productivity shock in non-residential sector. The responses of the components of aggregate demand are similar to those in the residential sector. There exists a transition of the capital in the production of the residential goods towards to the other two sectors; the consumption goods and business investment goods.

The impulse response functions for other shocks – shocks to inflation target, cost shocks, labor supply shocks and intertemporal shocks - are plotted in Figure D.11 to D.14. Given the recent history of explicit inflation-targeting regime of CBT, it is worthwhile to consider the responses of housing variables to a shock in the central bank's inflation target.

In the monetary policy rule, a stochastic process introduced to implicitly model deviations of inflation from its targeted level which may arise due to shifts in the monetary authority's inflation target. Accordingly, with a shock to the central bank's inflation target that increase the inflation objective, that is u_s , results in a persistent rise in the nominal interest rate and inflation – not given in the Figure D.11. Also, all components of aggregate demand – real consumption, real residential and business investments – increase. However,

those effects vanish after around 5 quarters once the nominal rigidities are compensated. Regarding the effects of the positive inflation objective shocks on the real house prices, it is seen that deviations of inflation from its targeted level when the central bank shift its inflation target cause the housing prices to rise and remain above its baseline level for around one year.

An adverse cost shock u_p results in an increase in the nominal interest rates and inflation and drop in the components of the aggregate demand. Also, it leads to real house prices to drop. With a negative labor supply shock u_r , the macroeconomic indicators give expectable responses such that the real consumption, real residential and business investments and real house prices drop substantially and remain below their baseline for long periods. Lastly, a shock to intertemporal preferences, that is, the discount rate u_z results in an increase in consumption on the one side and a fall in the business and residential investments on the other. Besides, real house prices fall, which can be attributed to transition of the preferences from the durable goods to non-durables that in turn reduces the housing demand.

Table D.5 and D.6 define the cyclical properties of the model, which are obtained based on 200,000 draws from the posterior distribution. In consideration of the extent to which the one-sided Kalman filter estimates of the observed variables of the model are close to those in the data, it is found that the model based moments are capable of closely replicating business cycle features of the data. However, the model mildly underestimates the volatilities of nominal interest rate and inflation – not given in the Figure. Considering the business cycle facts regarding the behavior of housing variables, it is seen that the volatilities of real residential investments and real house prices are quite high for the aforementioned sample period. Overall, the estimates of the observed variables match well the second moments of the data. Besides, the correlations matrix in Table D.6 reveals that the model catches well the joint behavior - comovement of the components of aggregate demand and housing variables. Accordingly, regarding the comovement between housing and non-housing variables, it is seen that both the extent and direction of the correlation between real residential investments and other components of aggregate demands, where the former is positively correlated with the real GDP and business investment (0.48 and 0.30 respectively), adversely correlated with the nominal interest rate and inflation (-0.22 and -0.18 respectively). Besides, regarding the comovement between the real house prices and other variables, an

adverse relationship between real house prices and real residential investment (-0.76) occurs and it is found that there exist no significant relationship between the former and other components of aggregate demand – real consumption, real business investment - and real GDP.

6.3. VARIANCE-SHOCK DECOMPOSITIONS AND SENSITIVITY ANALYSIS

To consider the dynamic features of the model further, variance, shock decomposition and sensitivity analyses are made. Accordingly, the asymptotic variances of housing and non-housing variables at the business cycles frequencies are computed which enable us to see the role of each shock, in particular to the housing preference, housing investment and monetary policy rules in producing fluctuations in abovementioned variables. In Table D.7, the variance decomposition analysis is given considering a relatively *tighter* macro-prudential policy rule where the parameter for LTV ratio is set at 0.75 whereas in Table D.8, the variance composition analysis is made for a relatively *loose* macro-prudential policy rule i.e., the LTV ratio is set at 0.90. Besides, in Figures D.15 to D.17, the shock decompositions of real house prices, policy rate and real residential investment are given - where a tight macro-prudential policy rule is considered observing the implementation of this rule in practice by financial regulators (BRSA) in Turkey. From both Tables D.7 and D.8 some important results are reached such that under both tight and loose macro-prudential policy rules, variance of the real house prices are determined by (productivity) shocks in housing sector to a considerable extent and productivity shocks in consumption sector affects the real house prices. Besides, housing preference shocks and shocks to intertemporal preferences are important for the boom-bust cycles of the real house prices. However, a worthy result is that monetary policy shock and shocks in central bank's inflation target do not explain the volatility of real house prices. They appear to explain around 2 percent of the variance of real house prices. Also, use of a different weight for parameter of the macro-prudential policy rule, i.e., LTV ratio is raised from 0.75 to 0.90, does not change the volatility of the real house prices. Therefore, we can conclude that demand shocks represented

by housing preference and supply shocks represented by the changes in housing technology and in consumption technology in the housing market determine the boom-bust cycles of the real housing prices. In a similar vein, it is found from the Tables D.7 and D.8 that variance of the real residential investment is considerably determined by housing (productivity) shocks and by intertemporal preference shocks to some extent. Also, shocks to monetary policy rules do not explain the volatility of the housing investments. In consideration of determinants of the volatility of nominal interest rate, it is found that the shocks in central bank's inflation target account for about one half of variance of interest rate. Also, intertemporal preference shocks are important for volatility of nominal interest rate. Lastly, as expected, the changes in central bank's inflation target significantly affect the variance of inflation whereas cost-push shocks affect the variance of inflation but at a lower rate than expected.

Figures D.15 to D.17 depict the historical shock decompositions of real house prices, policy rate and real residential investment during the estimated period of 2010-2014. Figure D.15 depicts the historical shock decomposition of real house prices. As shown in Figure D.15, consumption productivity shocks have mattered for the volatility of real house prices for the sample period by positively affecting the latter. In addition to this, until the mid of 2011 – shown between 0 and 6 in the Figure - cost-push shocks had played an important role in generating the variance of the real house prices with an adverse effect whereas in the subsequent periods, these type of shocks positively affect the variance of real house prices. Also, as given in the variance decomposition analysis, the housing technology shocks have significant effects on real house prices, which can be interpreted such that positive housing technology shocks result in cost of producing housing services in the construction industry to decrease, which is in turn expected to pull down the real house prices.

Figure D.15 reveals that intertemporal preference shocks appear to generate effects on cycles of real house prices. These shocks have contributed to variance of real house prices by adversely affecting the latter particularly with the early periods of 2011. An interpretation is that the intertemporal preference shocks, e.g. discount shock, result in an increase in consumption on the one side and a fall in the business and residential investments on the other. Accordingly, as shown in the Figure, real house prices was affected adversely, which

can be attributed to transition of the preferences from the durable goods to non-durables that in turn reduces the housing demand.

Figure D.16 depicts the historical shock decomposition of nominal interest rate during the estimated period. As stated in the variance decomposition analysis, shock decomposition analysis reveals that shocks to intertemporal preferences and inflation target shocks had played an important role in generating the variance of policy rate. Besides, deviations of inflation from its targeted level due to shifts in the monetary authority's inflation target (ϵ_{π}) have positively contributed to volatility of nominal interest rate with the early periods of 2014 though there had been an opposite relation between these two in the previous periods. Additionally, as expected, positive monetary policy shocks contributed the variance of the nominal interest rate for all the sample period.

In consideration of the shock decomposition of real residential investments shown in Figure D.17, it is observed that housing (productivity) shocks was the leading source for the volatility of real residential investments for all the sample period. Besides, intertemporal preference shocks generated adverse effects on cycles of housing investments. As Stated before that the intertemporal preference shocks as of a discount shock result in an increase in consumption and a fall in the business and residential investments which can make a transition of the preferences from the durable goods to non-durables that in turn reduces the housing demand and thus housing investment. From the Figure it is understood that the shocks to monetary policy rules had minor effects on the cycles of housing investment during the estimated period.

In order to understand how important the macro-prudential policy rules together with the monetary policy are in determining the boom-bust cycles of the housing variables, a sensitivity analysis is made through Figures D.18 – D.20. Figure D.18 depicts impulse response functions to a monetary policy shock with two specifications of the macro-prudential policy rule: one is the tight policy rule where LTV ratio is calibrated to value 0.75 and the other is the loose policy rule where the LTV ratio is set at 0.90.

Main argument is that loan-to-value rules can create financial frictions in the credit and housing markets due to possibility of liquidity constraints for potential borrowers and

thus of potential trade-offs between financial stability benefits and economic activity (BoE, 2011). Accordingly, a LTV rule can reduce the volatility of the house prices but in return for deterioration of the economic activity. In Figure D.18, it is examined whether a decrease in the LTV ratio (from a value of 0.90 to 0.75) reduce the volatility of house prices and increase the economic activity. As shown in Figure D.18, the response of the model variables for different values of LTV ratio is qualitatively the same but there is some difference in magnitude of these responses, particularly for those of consumption and residential investment. However, considering a monetary policy shock, it is clear that two specifications of the LTV ratio do not have a substantial effect on the real house prices. Similarly, in Figures D.19 and D.20, impulse response functions to a housing demand shock and inflation target shock are defined with two specifications of the macro-prudential policy rule, which give similar results with the case of a monetary policy shock. Accordingly, considering the housing preference and inflation target shocks, two specifications of the LTV ratio do not have an important effect on the real house prices but give smoother responses for consumption - with a tighter LTV ratio.

7. CONCLUSION

The pro-cyclical behavior of the financial sector on real economy was well-demonstrated by the global financial crisis of 2008-2009 revealing the severe macroeconomic consequences of the financial imbalances-instabilities which denoted itself through a combination of the excessive credit growth and boom episodes in housing variables on the one hand and the loose monetary and weak regulatory policies on the other. Given such a pro-cyclicity of housing markets on macroeconomic fundamentals, still there is not enough empirical evidence regarding the exploration of the nexus between cycles of housing variables and monetary and prudential policy responsibilities, which is also valid for the case of Turkish economy. Accordingly, it is important to analyze how effective the monetary policy tools are in prevention of these cycles of housing variables and how much the effectiveness of those tools differs when some macro-prudential policies are accessorially considered.

Observing the developments in housing market in Turkey, that is, the simultaneous increase in both house prices and residential investments in the last decade and recognizing that the shocks to the economy may result in unsustainable boom-bust cycles in house prices and residential investments that in turn can create unfavorable effects on Turkish economy through e.g., deteriorations in consumption and credit mechanisms, the nexus between housing market and macroeconomy deserves a further investigation. Accordingly, this paper examines the abovementioned existence of the nexus between cycles of housing variables and monetary and prudential policy responsibilities. Besides, in this paper, the main dynamics and driving forces of the housing variables as well as of some macroeconomic indicators are examined.

A Bayesian estimation of a medium-scale closed economy DSGE model with housing sector is made for the Turkish economy for period 2010-2014. The model economy developed by Iacoviello and Neri (2010) is used to make estimation analysis. In general terms, it is seen that the sample period is quite informative in estimation of the parameters and that business cycle features of the model show a good data fit though it is obviously shorted than desired one. Under the conceptualization of a *lean-against-the-bubble* strategy with a more moderate policy action where CBT uses monetary policy to target the inflation and

output, not asset markets instead of an *aggressive-bubble-popping* one with a more activist policy framework where central banks raises policy rates proactively to eliminate potential bubbles in asset prices, the results show that under a moderate *lean-against-the-bubble* strategy, presumption that aggregate price stability will, as a byproduct, tend to promote stability of housing markets don't fully hold in our estimation. Given the inflation targeting policy framework aiming at the price stability, it can be argued that the tighter monetary policy along with the some prudential policy instruments may not result in prevention of a housing "bubbles". Also, the variance decomposition analysis reveals that demand and supply shocks dramatically determine the cycles of the real housing prices and residential investment whereas the monetary policy shocks and shocks in central bank's inflation target do not explain the volatility of real house prices too much. From historical shock decomposition analysis, it is seen that demand and inflation target shocks had played an important role in generating the variance of policy rate and shifts in the monetary authority's inflation target have positively contributed to volatility of nominal interest rate with the early periods of 2014 though there had been an opposite relation between these two in the previous periods. Besides, sensitivity analysis reveals that tighter macro-prudential policy rules with lower loan-to-value ratio do not significantly change the volatility of the housing variables.

For the future research, it would be interesting to consider the capital flows within an open-economy framework in the model economy, so that dynamics of the financial markets and nexus between housing sector and monetary policy rules can be better understood. Besides, some alternative macro-prudential policy instruments can be examined.

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APPENDIX A: the Functional Form of Adjustment Costs of Capital

The functional form for the convex adjustment cost of capital is

$$\phi_t^P = \frac{\phi_{k,c}}{2G_{IK,c}} \left(\frac{k_{c,t}^P}{k_{c,t-1}^P} - G_{IK,c} \right)^2 \frac{k_{c,t-1}^P}{\Gamma_{AK}^t} + \frac{\phi_{k,h}}{2G_{IK,h}} \left(\frac{k_{h,t}^P}{k_{h,t-1}^P} - G_{IK,h} \right)^2 k_{h,t-1}^P$$

where Γ_{AK}^t is the gross growth rate of the investment specific technology progress in the goods sector, $G_{IK,c}$ and $G_{IK,h}$ are the gross growth rate of capital in the goods and housing sectors, respectively along the balanced growth path, $\phi_{k,c}$ and $\phi_{k,h}$ are the growth rate of adjustment costs of capital along the balanced growth path.

The functional form for the utilization rate for consumption and housing sectors:

$$a(z_{c,t}^P) = R_c \left(\frac{\varpi z_{c,t}^2}{2} + (1 - \varpi) z_{c,t} + \left(\frac{\varpi}{2} - 1 \right) \right)$$

$$a(z_{h,t}^P) = R_h \left(\frac{\varpi z_{h,t}^2}{2} + (1 - \varpi) z_{h,t} + \left(\frac{\varpi}{2} - 1 \right) \right)$$

where R_c and R_h denote the steady state levels of the rental rate of capital in the consumption goods and the housing goods, respectively. In the model, the curvature of the capacity utilization function is specified as $\varsigma = \frac{\varpi}{1+\varpi}$ and ϖ is positive, so that ς is bounded between 0 and 1.

APPENDIX B: the Measurement Equations

$$\log C_t^d - \log C_{2010:1}^d = \hat{C}_t + (G - 1)t$$

$$\log IK_t^d - \log IK_{2010:1}^d = \widehat{IK}_t + (G_{IK} - 1)t$$

$$\log IH_t^d - \log IH_{2010:1}^d = \widehat{IH}_t + (G_{IH} - 1)t$$

$$\log q_t^d - \log q_{2010:1}^d = \hat{q}_t + (G_q - 1)t$$

$$\log N_{c,t}^d = \alpha \hat{n}_{c,t}^P + (1 - \alpha) \hat{n}_{c,t}^I$$

$$\log N_{h,t}^d = \alpha \hat{n}_{h,t}^P + (1 - \alpha) \hat{n}_{h,t}^I$$

$$\pi_t^d = \hat{\pi}_t$$

$$R_t^d = \hat{R}_t$$

$$\omega_{c,t}^d = \frac{w_{c,t}^P}{w_{c,t}^P + w_{c,t}^I} \hat{\omega}_{c,t}^P + \frac{w_{c,t}^I}{w_{c,t}^P + w_{c,t}^I} \hat{\omega}_{c,t}^I$$

$$\omega_{h,t}^d = \frac{w_{h,t}^P}{w_{h,t}^P + w_{h,t}^I} \hat{\omega}_{h,t}^P + \frac{w_{h,t}^I}{w_{h,t}^P + w_{h,t}^I} \hat{\omega}_{h,t}^I$$

where the sans-serif font denotes the detrended variables, which denote the variables scaled by their deterministic trend and a hat over the variables denotes the percentage deviation of these variables from their steady states.

Accordingly,

$$C_t = \frac{c_t}{G_t}, \quad IH_t = \frac{IH_t}{G_{IH,t}}, \quad IK_t = \frac{IK_t}{G_{IK,t}}, \quad q_t = \frac{q_t}{G_{q,t}}.$$

APPENDIX C: Data and Sources

- Consumption: Final consumption expenditure of households, seasonally and calendar adjusted, divided by population, at 1998 prices, deflated with Consumer Price Index. Source: Turkish Statistical Institute (TurkStat).
- Residential investment: construction production, seasonally and calendar adjusted, divided by population, at 1998 prices, deflated with Consumer Price Index. Source: TurkStat
- Business fixed investment: Gross fixed capital formation as the sum of manufacturing, other machinery and equipment, transportation and storage, mining, electricity, gas, steam and air conditioning supply etc. seasonally and calendar adjusted, divided by population, at 1998 prices, deflated with Consumer Price Index. Source: TurkStat
- Inflation: Quarter on quarter change of Consumer Price Index, (2003 = 100), demeaned. Source: TurkStat
- Nominal short-term interest rate: one-week repo rate, expressed in quarterly units, demeaned. Source: Central Bank of Turkey (CBT).
- Real house prices: New housing price index for Turkey (2010 = 100) deflated with Consumer Price Index. Source: CBT.
- Hours in housing sector: Total Employment, hours worked in construction sector, thousand hours, seasonally adjusted, divided by Labor force 15+ ages, demeaned. Source: TurkStat
- Hours in consumption goods sector: Total Employment, hours worked in all sectors excluding construction, thousand hours, seasonally adjusted from source divided by Labor force 15+ ages, demeaned. Source: TurkStat

- Wage inflation in housing sector: Quarterly changes of gross wages-salaries index in construction sector, (2010 = 100) seasonally and calendar adjusted index, demeaned. Source: TurkStat
- Wage inflation in consumption sector: Quarterly changes of gross wages-salaries index in total industry, (2010 = 100) seasonally and calendar adjusted index, demeaned. Source: TurkStat

APPENDIX D: Estimation Results

Table D. 1: Calibrated Parameter

Parameters		Values
discount factor of patient households	β_P	0.9928
discount factor of impatient households	β_I	0.97
parameter for the weight on housing in the utility function	j	0.1
capital share in the goods production function	μ_c	0.30
capital share in the housing production function	μ_h	0.10
land share in the housing production function	μ_l	0.10
steady state share of the intermediate goods	μ_b	0.10
the depreciation rate in the capital in the housing sector	$\delta_{k,h}$	0.03
the depreciation rate in the capital in the consumption sector	$\delta_{k,c}$	0.035
Depreciation rate in the housing sector	δ_h	0.0125
LTV ratio	m	0.75
steady state price mark-up in the consumption-good sector	X	1.15
steady state wage mark-up in the consumption-good sector	$X_{W,c}$	1.15
steady state wage mark-up in the consumption-good sector	$X_{W,h}$	1.15
persistence of the inflation objective shock	p_s	0.95

Table D. 2: Steady State Ratios

Description	Variables	Values
consumption share in total output	C/GDP	67%
housing investment share in total output	$q \times IH/GDP$	6%
business investment share in total output	IK/GDP	27%
annual real interest rate	$4 \times R - 1$	3%

Table D. 3: Prior and Posterior Distribution of the Structural Parameters

Parameters	Distributions	Prior Distr.		posterior Distr.		
		mean	std.dev	mean	2.5%	97.5%
Habit persistence parameter in consumption of patient Households-HH	ε^p Beta	0.5	0.01	0.4959	0.4744	0.5134
Habit persistence parameter in consumption of impatient HH	ε^l Beta	0.5	0.01	0.5003	0.4852	0.5111
Interest rate smoothing parameter in Taylor rule	r_r Beta	0.7	0.10	0.6869	0.6072	0.7528
Inflation weight parameter in Taylor rule	r_π Normal	1.4	0.10	1.5683	1.4427	1.7026
Output gap parameter in Taylor rule	r_y Normal	0.25	0.10	0.2719	0.1732	0.3806
Adjustment cost parameter for capital investment	$\phi_{k,c}$ Gamma	10	2.5	13.4517	8.6893	17.3277
Adjustment cost parameter for housing investment	$\phi_{k,h}$ Gamma	10	2.5	9.4472	6.5207	12.8397
the curvature of the capacity utilization function	ζ Beta	0.5	0.20	0.7900	0.6598	0.9525
Disutility of labor supply for patient households	η Gamma	0.66	0.10	0.6576	0.5100	0.8065
Disutility of labor supply for impatient households	η^l Gamma	0.66	0.10	0.6775	0.5363	0.8566
the inverse elasticity of substitution across hours for patient households	ξ Normal	1	0.10	1.0130	0.8700	1.1391
the inverse elasticity of substitution across hours for impatient households	ξ^l Normal	1	0.10	1.0017	0.8471	1.1312
Calvo-type parameter in price settings	θ_π Beta	0.5	0.10	0.6116	0.4779	0.7090
Calvo-type parameter in wage settings in consumption goods sector	$\theta_{w,c}$ Beta	0.5	0.10	0.5688	0.4892	0.6477
Calvo-type parameter in wage settings in housing sector	$\theta_{w,h}$ Beta	0.5	0.10	0.3504	0.2275	0.4803
the elasticity of indexation to previous period inflation rate	ι_π Beta	0.5	0.20	0.5385	0.2542	0.8590
the elasticity of indexation of wage to previous inflation rate in goods sector	$\iota_{w,c}$ Beta	0.5	0.20	0.4168	0.1147	0.7114
the elasticity of indexation of wage to previous inflation rate in housing sector	$\iota_{w,h}$ Beta	0.5	0.20	0.4730	0.1951	0.7705
Technological progress in consumption goods	γ_C Normal	0.005	0.01	0.0015	-0.0005	0.0034
Technological progress in housing investment goods	γ_H Normal	0.005	0.01	0.0016	-0.0008	0.0044
Technological progress in business investment goods	γ_K Normal	0.005	0.01	0.0034	0.0009	0.0060
Labor income share of constrained households	α Beta	0.65	0.10	0.6537	0.5380	0.8099

Table D. 4: Prior and Posterior Distribution of the Shock Processes

Parameters	Distributions	Prior Distr.		posterior Distr.		
		mean	std.dev	mean	2.5%	97.5%
persistence parameter in shocks to intertemporal preferences	p_z Beta	0.80	0.10	0.8869	0.7748	0.9558
persistence parameter in shocks to labor supply	p_τ Beta	0.80	0.10	0.8278	0.7339	0.9273
persistence parameter in shocks to housing preference	p_j Beta	0.80	0.10	0.9036	0.8487	0.9808
persistence parameter in shocks to technological process in goods sector	$p_{a,C}$ Beta	0.80	0.10	0.9333	0.8902	0.9671
persistence parameter in shocks to technological process in housing sector	$p_{a,H}$ Beta	0.80	0.10	0.8478	0.7214	0.9905
persistence parameter in shocks to technology in non-residential sector	$p_{a,K}$ Beta	0.80	0.10	0.8442	0.7290	0.9749
Standard deviation of the innovations in consumption goods sector	$\sigma_{A,C}$ Inverse gamma	0.01	0.01	0.0117	0.0082	0.0149
Standard deviation of the innovations in housing sector	$\sigma_{A,H}$ Inverse gamma	0.03	0.01	0.0184	0.0142	0.0225
Standard deviation of the innovations in non-residential sector	$\sigma_{A,K}$ Inverse gamma	0.01	0.01	0.0086	0.0036	0.0130
Standard deviation of the innovations in intertemporal preferences	σ_z Inverse gamma	0.03	0.01	0.0244	0.0184	0.0304
Standard deviation of the innovations in labor supply	σ_τ Inverse gamma	0.01	0.01	0.0159	0.0112	0.0213
Standard deviation of the innovations in housing demand	σ_j Inverse gamma	0.01	0.01	0.0787	0.0258	0.1183
Standard deviation of the innovations in monetary policy rule	σ_R Inverse gamma	0.001	0.01	0.0011	0.0008	0.0014
Standard deviation of the innovation in the cost shocks in consumption sector Phillips curve	σ_p Inverse gamma	0.01	0.01	0.0064	0.0043	0.0085
Standard deviation of the innovations in stochastic processes in inflation targeting regime	σ_s Inverse gamma	0.10	0.01	0.0367	0.0255	0.0492
Standard deviation of the innovations in stochastic processes in labor supply	$\sigma_{n,h}$ Inverse gamma	0.10	0.01	0.1206	0.1053	0.1435
Standard deviation of the innovations in stochastic processes in wage income	$\sigma_{w,h}$ Inverse gamma	0.03	0.01	0.0235	0.0186	0.0286

Table D. 5: Business Cycle Properties of the Model – standard deviation

Variables	Model	Data
Real consumption	0.0300	0.0382
Real business investment	0.1069	0.0654
Real residential investment	0.2223	0.2823
Real GDP	0.0427	0.0778
Real house prices	0.1827	0.1710
Nominal interest rate	0.0122	0.0542

Table D. 6: Business Cycle Properties of the Model – matrix of correlations

Variables	consumption	business investment	residential investment	house prices	GDP	interest rate
consumption	1.0000					
business investment	0.1795	1.0000				
residential investment	-0.0379	0.3020	1.0000			
house prices	0.0673	0.2618	-0.7655	1.0000		
GDP	0.5826	0.8560	0.4813	-0.0137	1.0000	
interest rate	-0.0722	-0.6150	-0.2233	-0.1948	-0.5195	1.0000

Table D. 7: Variance Decomposition (in percent) - a tight prudential policy rule

Variables	eps_c	eps_e	eps_h	eps_j	eps_k	eps_p	eps_s	eps_t	eps_z
consumption	61.24	0.22	0.02	0.00	5.75	0.68	0.49	0.43	31.16
business investment	10.69	0.17	0.04	0.00	14.51	0.48	0.27	0.08	73.75
residential investment	0.15	0.05	88.29	0.54	0.01	0.02	0.06	0.03	10.85
house prices	11.26	0.11	61.62	20.41	0.11	0.04	0.02	0.00	6.41
GDP	35.65	0.30	7.73	0.05	11.27	0.77	0.51	0.30	43.42
interest rate	2.58	0.46	0.03	0.01	0.71	1.12	46.14	0.02	48.92
inflation	3.70	0.85	0.06	0.01	0.29	4.89	59.99	0.02	30.19

Table D. 8: Variance Decomposition (in percent) - a loose prudential policy rule

Variables	eps_c	eps_e	eps_h	eps_j	eps_k	eps_p	eps_s	eps_t	eps_z
consumption	61.54	0.41	0.25	0.04	5.72	0.88	0.87	0.43	29.86
business investment	10.60	0.13	0.09	0.02	14.66	0.42	0.18	0.08	73.82
residential investment	0.10	0.02	88.74	0.47	0.01	0.00	0.02	0.03	10.60
house prices	11.25	0.10	61.63	20.40	0.11	0.03	0.02	0.00	6.45
GDP	35.47	0.31	8.09	0.06	11.21	0.77	0.52	0.30	43.27
interest rate	2.35	0.32	0.17	0.08	0.75	0.91	47.13	0.02	48.28
inflation	2.92	1.24	0.46	0.09	0.31	4.41	61.33	0.02	29.24

Figure D. 1: Prior Posterior Distributions (Standard Deviations of Shocks)

where the grey and black lines denote the prior and posterior distributions, respectively. Accordingly prior and posterior distributions of technology in consumption goods sector (SE_eps_c), monetary policy shock (SE_eps_e), technology in housing sector (SE_eps_h), housing demand shock (SE_eps_j), technology in business investment sector (SE_eps_k), cost shock (SE_eps_p), inflation target shock (SE_eps_s), labor supply shock (SE_eps_t), shocks to intertemporal preferences (SE_eps_z) are given in the Figure.

Figure D. 2: Prior Posterior Distributions (Parameters)

where the grey and black lines denote the prior and posterior distributions, respectively. Accordingly prior and posterior distributions of standard error of innovations in stochastic processes in labor supply (SE_EOBS_data_NH), Standard error of innovations in stochastic processes in wage income (SE_EOBS_data_WH), labor income share of unconstrained agents (ALPHA), habit persistence of patient households (EC), habit persistence of patient households (EC1), disutility from labor supply of patient households (ETA), disutility from labor supply of patient households (ETA1), adjustment cost for capital investment (FIKC), adjustment cost for housing investment (FIKH) are given in the Figure.

Figure D. 3: Prior Posterior Distributions (Parameters)

where the grey and black lines denote the prior and posterior distributions, respectively. Accordingly, prior and posterior distributions of degree of indexation to previous inflation (LAGP), degree of indexation of wages in goods market (LAGWC), degree of indexation of wages in housing market (LAGWH), inverse elasticity of substitution in hours for patient households (NU), inverse elasticity of substitution in hours for patient households (NU1), persistence of technological shocks in goods market (RHO_AC), persistence of technological shocks in housing market (RHO_AH), persistence of shocks to housing preference (RHO_AJ), persistence of technological shocks in business investment market (RHO_AK) are given in the Figure.

Figure D. 4: Prior Posterior Distributions (Parameters)

where the grey and black lines denote the prior and posterior distributions, respectively. Accordingly, prior and posterior distributions of persistence of shocks to labor supply (RHO_AT), persistence of shocks to intertemporal preferences (RHO_AZ), response to inflation gap (TAYLOR_P), interest rate smoothing (TAYLOR_R), response to output gap (TAYLOR_Y), Calvo parameter in price setting (TETA), Calvo parameter in wage settings of goods market (TETAWC), Calvo parameter in wage settings of housing market (TETAWH), technological progress in consumption goods (TREND_AC) are given in the Figure.

Figure D. 5: Prior Posterior Distributions (Parameters)

where the grey and black lines denote the prior and posterior distributions, respectively. Accordingly, prior and posterior distributions of technological progress in housing goods (TREND_AH), technological progress in business investment goods (TREND_AK), curvature of capital utilization (ZETAKC) are given in the Figure.

Figure D. 6: Impulse Responses: an i.i.d. monetary policy shock

Figure D. 7: Impulse Responses: a housing preference shock

Figure D. 8: Impulse Responses: a housing technology shock

Figure D. 9: Impulse Responses: shocks to technology in consumption goods sector

Figure D. 10: Impulse Responses: a business investment technology shock

Figure D. 11: Impulse Responses: a shock in central bank's inflation target

Figure D. 12: Impulse Responses: an i.i.d cost shock

Figure D. 13: Impulse Responses: a labor supply shock

Figure D. 14: Impulse Responses: a shock to intertemporal preferences

Figure D. 15: shock decomposition of real house prices

Figure D. 16: shock decomposition of policy rate

Figure D. 17: shock decomposition of real residential investment

Figure D. 18: Impulse responses to a monetary policy shock: sensitivity analysis

Note: the black line denotes tight macro-prudential policy rule and dotted blue line denotes the loose policy rule.

Figure D. 19: Impulse responses to a housing demand shock: sensitivity analysis

Note: the black line denotes tight macro-prudential policy rule and dotted blue line denotes the loose policy rule.

Figure D. 20: Impulse responses to an inflation-target shock: sensitivity analysis

Note: the black line denotes tight macro-prudential policy rule and dotted blue line denotes the loose policy rule.

Figure D. 21: Smoothed Variables

Figure D. 22: Smoothed Shocks