Macroeconomic Policies and Housing Market in Taiwan

Shiou-Yen Chu
Department of Economics,
National Chung Cheng University
Email: ecdsyc@ccu.edu.tw

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Abstract

This paper develops a dynamic stochastic general equilibrium (DSGE) model that analyzes the transmission mechanisms of a real estate transfer tax and other macroeconomic policies on Taiwan's housing market. Our model matches the volatility of Taiwan's housing prices and housing transactions during 2011-2015, when the loan-to-value ratio was reduced and a transfer tax on real estate was collected. The calibration results indicate that imposing a residential property tax or raising interest rates effectively curbs speculative housing transactions and has prolonged effects on taming housing prices over time. Transfer tax imposition or a decrease in the loan-to-value ratio has short-lived effects on moderating housing markets.

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1 Introduction

The global financial crisis that began in 2008 increased policymakers' attention on the housing market. Several countries have adopted macroprudential polices to ensure the sustainability and resilience of their housing markets. Behind these policies lies the theory that housing prices are more sensitive to monetary policy shocks than consumer prices (Iacoviello 2010; Iacoviello and Neri 2010). Hence, the monetary authority (alone or with fiscal authority) can use policy instruments to stabilize housing prices and economic activities.

The Central Bank of the Republic of China (Taiwan) and the Ministry of Finance have collaborated on mitigating the rise in housing prices since 2010. Their policies include reducing limits on maximum loan-to-value (LTV) ratios from 60% to 50% for luxury properties, the third individually owned property, and corporate real estate. Also, "luxury properties" were reclassified with lower threshold values[1], and an excise tax was levied on non-owner-occupied residential properties bought and sold within two years. The latter was legislated in the Specifically Selected Goods and Services Tax Act and went into effect on June 1st, 2011. Under this tax policy, the property sellers are obligated to pay 15% and 10% of the full selling prices of houses sold within a year and two years of purchase, respectively. Hereafter, we will refer to this excise tax as a real estate transfer tax in the context[2].

[1] The threshold values for luxury properties were lowered from NT$80 million to NT$70 million in Taipei City, from NT$80 million to NT$60 million in New Taipei City, and from NT$50 million to NT$40 million in other districts.

[2] This real estate transfer tax policy ended on December 31st, 2015. Beginning on January 1st, 2016, the capital gains from transferring housing and land are consolidated as taxable income and calculated on the basis of market values. In the old tax scheme, they were taxed separately and at assessed values which are usually below their market prices. Furthermore, non-Taiwanese residents are obligated to pay a flat 35% tax rate for selling property

Taiwan's real estate transfer tax is distinctive for two reasons. First, different from a capital gains tax, it considers the full value of the transaction as the tax base. Second, unlike the stamp duties conducted in Hong Kong and Singapore that also aim to curb booming housing markets, sellers instead of buyers are designated as taxpayers. The two tax brackets are cut off by the holding period of the property but not by the transaction value of the property.

Figure 1 presents the number of home ownership transfers during 2005Q1-2016Q2[3] in Taiwan. The number of ownership transfers through transactions experienced two sustained declines during 2008Q2-2009Q1 and 2010Q4-2012Q1. The first drop was the consequence of the U.S. subprime mortgage crisis and the second drop might have been an effect of the announced changes in the real estate transfer tax policy. Meanwhile, transactions involving first registration of building ownership fell below 40,000 in 2008Q2 and have fluctuated within the range of 20,000 to 40,000 since then. Figure 2 plots the housing price indexes for Taipei City, New Taipei City, and Taiwan from 2005Q1 to 2016Q2[4]. Taipei city is Taiwan's capital city and has a large number of luxury properties, while New Taipei city is the most densely populated city in Taiwan. The housing prices in Taipei slightly dropped since the Real Estate Transfer Tax Act went into effect in June 2011. Nevertheless, sustained decreases in

owned for more than one year. For Taiwanese residents, the tax rates for transferring real estate decrease from 35% to 15% as the holding period lengthens from one year to over ten years.

[3] The data were obtained from the Monthly Bulletin of Interior Statistics, August 2016, Ministry of the Interior. (http://sowf.moi.gov.tw/stat/month/list.htm)

[4] The data were obtained from the website of Sinyi Realty Inc. (http://www.sinyi.com.tw). The first quarter in 2001 was chosen as the base year.

housing prices did not appear until 2014Q2. The housing prices for Taipei City, New Taipei City, and Taiwan during 2011Q2 and 2014Q2 generally showed positive trends.

Taiwan's transfer tax imposition gives a natural experiment for observing the effect of a one-time tax policy on housing markets. The insufficient empirical data (only 19 quarters) limits the methodology that can be conducted to evaluate the policy effects. The purpose of this paper is to provide a theoretical framework that analyzes the transmission mechanism of a real estate transfer tax along with other macroeconomic policies for Taiwan's housing market. Our model intends to capture the fact that owning real estate in Taiwan is considered as a token of wealth accumulation. The Taiwanese government aims to increase homeownership by providing regular households fairly and reasonably priced properties. Nevertheless, speculators purchase additional housing not as a principal place of residence but as an investment target for generating income. Excess demand fuels property price escalation and makes housing unaffordable to regular households. Macroeconomic policies are implemented to mitigate speculative activities in the housing market.

We develop an open-economy dynamic stochastic general equilibrium (DSGE) framework. Our model distinguishes two types of agents: borrowers and savers. They are both homeowners. Borrowers (speculators) are less patient and collateral-constrained when they would like to purchase additional housing for investment purposes. The reason for introducing two kinds of households is stated in Iacoviello's (2005) and Iacoviello and Neri's (2010)

studies. Higher asset prices resulting from demand shocks expand debtors' borrowing capacity against collateralized asset. Higher consumer prices reduce the real value of debtors' obligations and promote their net worth. Both effects strengthen collateral-constrained households' spending capacity. Hence, the presence of collateral-constrained agents magnifies the impact of housing prices on overall consumption.

Moreover, our model classifies two kinds of housing: residential housing and investment housing. The former consists of owner-occupied properties that provide services for borrowers and savers. The latter is characterized as speculative housing in three aspects. First, it does not directly provide utility of housing services since speculators do not live in it. Investment housing is not a speculator's primary residence. Second, investment housing is an input in the production of residential housing. Speculators purchase investment housing, namely unfinished housing units, and make renovations. Investment housing is converted into habitable units through production technology and then put on the market for sale. Third, the expected prices of investment housing affect a speculator's borrowing availability. Only borrowers can purchase investment housing and pledge it as collateral for loans. Two kinds of taxes are imposed on the home properties. Both agents pay property taxes for their primary dwellings. Borrowers pay a transfer tax as a percentage of the transaction price when selling investment housing to the producers of residential housing.

The model is evaluated by property tax shocks, transfer tax shocks, interest rate shocks

and loan-to-value shocks. Our results indicate that our model in response to transfer tax shocks and loan-to-value shocks matches the volatility of Taiwan's housing prices and housing transactions during 2011Q2-2015Q4, when the loan-to-value ratio was reduced and a transfer tax was collected. Property tax imposition or an interest rate hike curbs speculative housing transactions and has prolonged effects on taming housing prices. Relatively, transfer tax imposition or loan-to-value reduction instantly depresses investment housing prices, but not investment housing transactions.

Both property tax shocks and interest rate shocks alter the relative prices of current tradable consumption, future tradable consumption, and residential housing. A property tax raises the holding cost for residential housing and decreases speculator's purchase intent for investment housing. With regard to interest rate shocks, the dominating substitution effect resulting from an interest rate hike shifts borrowers' and savers' resources from current tradable consumption to current residential housing and to future tradable consumption. Strengthened current demand for residential housing initially upholds investment housing prices, while increasing borrowing costs and the associated limited funding liquidity discourage borrowers from purchasing investment housing. One caveat of influencing housing markets with monetary policies is that changing interest rates adds variability in households' consumption.

Different from property tax shocks and interest rate shocks, transfer tax imposition and

loan-to-value ratio restrictions primarily affect borrowers' intertemporal allocation of tradable consumption and intra-temporal allocation between tradable consumption and investment housing. Both shocks weaken borrowers' demand for residential housing, leading to declines in residential housing prices and investment housing prices. Loan-to-value shocks produce similar but less substantial responses in consumption, housing prices, housing transactions and output than transfer tax shocks.

Investment housing plays an important role in the transmission mechanism of exogenous shocks in our model. Although all the shocks dampen residential housing prices, they generate different responses in investment housing prices and transactions. The responses of investment housing stock are closely related to the expected demand of residential housing consumption. Transfer tax and loan-to-value shocks do not immediately depress investment housing stock. This is because a transfer tax is imposed on the sale of previous-period investment housing stock, while loan-to-value shocks impact speculators' borrowing availability that is associated with the future price of investment housing. As long as speculators perceive that a transfer tax and a lower loan-to-value ratio are short-term policies and foresee climbing housing prices, they still purchase investment housing and hold down for future residential housing production.

Our study bridges two strands of research. One strand of research[5] empirically documents

[5] Benjamin et al. (1993), Dachis et al. (2012), Best and Kleven (2013), Besley et al. (2014), as well as Kopczuk and Munroe (2015).

the microeconomic effects of a real estate transfer tax on the housing market under the assumption that the government imposes a real estate transfer tax for revenue-generating purposes. The other strand of research[6] incorporates a housing sector in a DSGE model irrespective of fiscal policy shocks in order to discuss macroeconomic phenomena. More recently, the effects of fiscal policy on the housing market have gained more attention. Alpanda and Zubairy (2016) examine the effects of several housing-related tax policies excluding transfer tax policy on macroeconomic variables. Funke and Paetz (2016) analyze the effects of nonlinear loan-to-value ratios and nonlinear property transfer taxes (stamp duties) on Hong Kong's housing prices in a DSGE framework. In line with the abovementioned studies, our theoretical framework suggests that tax policies or monetary policies moderate housing prices but generate different policy effects in terms of duration and magnitude. However, different from Funke and Paetz (2016), our paper is motivated by Taiwan's peculiar experience of real estate tax imposition and emphasizes the role of speculative housing. In addition to being characterized by the level of impatience and the presence or absence of collateral constraint, savers and borrowers in our model face different real estate transfer tax rates. Our model also considers a rich set of macroeconomic policy shocks on dampening housing prices and housing transactions.

The remainder of this paper is organized as follows. Section 2 provides a brief review of

[6] Aoki et al. (2004), Iacoviello (2010), Iacoviello and Neri (2010), Funke and Paetz (2013), Stark (2015), and Piazzesi and Schneider (2016).

related literature. Section 3 describes our model. Section 4 presents calibration results, and section 5 concludes.

2 A Brief Review of Related Literature

2.1 Real Estate Transfer Tax

Benjamin et. al (1993) utilize real estate data consisting of 352 single-family home sales from February 1987 through June 1989 in Philadelphia to discuss the valuation effects of a transfer tax. Nominally the tax payment is distributed between sellers and buyers. Due to a short-time period dataset and the evidence that used home transactions are relatively larger than new home transactions, they assume that the supply of housing is inelastic. This creates a strict hypothesis that the seller will completely absorb the tax burden along with a decline in the home prices by the full amount of the tax. A rejection of the hypothesis leads to two implications. First, the housing supply is not perfectly inelastic. Second, mortgage markets are not perfect. Households become more down-payment constrained in response to additional taxes, accordingly reducing housing demand and prices. Their second hypothesis lies on the information issue that home prices should decrease on the date of bill passage in order to avoid the tax liability. Their results indicate that home prices fall as expected, but not statistically significantly.

Dachis et. al (2012) employ a data set of 139,266 single-family houses in the greater

Toronto area between January 2006 and August 2008 to estimate the impact of a land transfer tax on the housing market. Their methodology is a hybrid of a regression discontinuity model and differences-in-differences estimation. Their findings show that the new tax policy results in reduced transaction volume and lower home prices. Most importantly, it causes a substantial welfare loss. The authors suggest that the government should consider revenue-equivalent alternatives to the land transfer tax.

Best and Kleven (2013) examine the impact of UK property transaction taxes (also known as the Stamp Duty Land Tax, SDLT) on the housing market from 2004-2012. The statutory taxpayer of the SDLT is the buyer, whose tax liability is calculated as a proportional tax rate times the entire transaction price. The tax rate is constant within each bracket. The presence of the SDLT alters the cost of homeownership. Since it cannot be paid with mortgage loans, it creates excess pressure for liquidity constrained buyers. The authors estimate the elasticity of housing prices with respect to the marginal tax rate by using the notches at the cutoff prices that are discontinuities in the overall tax liability. Their results indicate that housing prices and transaction activities are sharply responsive to tax changes, supporting the implementation of fiscal stimulus on economic recovery from recessions.

Similarly, Besley et. al (2014) estimate the effect of a UK stamp duty holiday on housing prices and transactions during 2008-2009. Their findings show that a stamp duty holiday generates lower property prices and a significant but short-lived increase in transaction

volumes. They also calibrate a simple bargaining model and conclude that buyers' tax liability was reduced by 60% during the holiday window.

Kopczuk and Munroe (2015) examine the consequences of a transfer tax levied on the sales of houses and apartments in New York and New Jersey exceeding $1 million. By law the buyers are responsible for paying the so-called "mansion tax" in New York state and New Jersey. Their paper focuses on the tax incidence, price distortion between asking price and sale price, as well as search frictions in response to policy changes. They conclude that a transfer tax increases inefficiency in the house search process.

2.2 DSGE models with a Housing Sector

Aoki et al. (2004) examine the financial accelerator effect of homeowners' borrowing funds from financial intermediaries to purchase houses. Homeowners rent housing services to tenants and also provide tenants "transfers" for consumption. A composite of homeowners and tenants in the model captures the fact that home equity can be used to finance both consumption and housing investment. As home prices go up and the transfer payments stay the same, homeowner's net worth will increase, leading to lower future borrowing costs. Their results show that monetary policy shocks have substantial impacts on housing investment, housing prices and consumption.

Iacoviello (2010) summarizes several facts about housing markets and the macroeconomy. First, consumption expenditure and housing investment move procyclically with housing

wealth. Second, housing wealth accounts for a larger share of national wealth than GDP. Third, variables in the housing market, such as residential investment and housing price inflation, are more volatile and proceed in advance compared to variables in other markets.

Iacoviello and Neri (2010) propose that nominal rigidity either in prices or wages propagates the transmission of monetary shocks to housing consumption. The presence of collateral-constrained borrowers amplifies the effect of housing prices on aggregate consumption since impatient agents have a greater propensity to consume at the margin than patient agents. Hence, to quantify the housing demand shocks and monetary policy shocks on the economy, nominal rigidity and collateral-constrained households are two essential elements in a DSGE model. In their paper, housing preference shocks, monetary shocks, and technology shocks are analyzed to capture some of the business cycle facts. Three findings are summarized here. First, increasing housing demand, denoted as a shift towards housing preference, will boost housing prices and collateral-constrained households' borrowing capacity. Tightening money supply, denoted as an increase in nominal interest rates, depresses aggregate demand and housing prices. Last, an improved productivity in the goods sector increases housing prices while a positive technology shock in the housing sector decreases housing prices.

Funke and Paetz (2013) construct a two-agent, two-sector, open-economy DSGE model to examine the impact of housing price cycles on Hong Kong's economy. In their model, the

domestic country interacts with the foreign country through two channels. First, residential and non-residential consumption goods are both tradable. Second, domestic savers can trade bonds with foreign households to completely share the country-specific risks. The model is calibrated with households' preference shocks, loan-to-value shocks, sector-specific cost-push shocks, and sector-specific technology shocks. Their findings indicate that Hong Kong's property prices are mainly driven by the intra-temporal marginal rate of substitution between residential and non-residential goods. Shocks on the loan-to-value ratios do not significantly affect housing prices.

Stark (2015) constructs a two-agent, two-sector, and closed-economy DSGE model to study the relationship between home prices and unemployment during the U.S. great recession. He finds that declining housing prices associated with lower home equity creates unemployment, particularly for the collateral-constrained households. A decrease in home prices restricts the impatient households' borrowing availability along with their geographical mobility.

Alpanda and Zubairy (2016) develop a model consisting of two sectors (housing and non-housing goods) and three types of households (patient, impatient, and renter households) to assess the welfare consequences of several housing-related tax policies, such as an increase in the property tax rate, elimination of the mortgage interest deduction, elimination of depreciation allowance for rental income, elimination of the property tax deduction, and

taxation of imputed rental income on macroeconomic variables. Welfare consequences are measured by the output loss, lifetime consumption-equivalent loss, and generated tax revenue. They find that taxation of imputed rental income from owner-occupied households and the elimination of the property tax deduction cause the greatest output losses. The elimination of the mortgage interest deduction can effectively raise the most tax revenue per unit of output loss.

Funke and Paetz (2016) analyze the effects of nonlinear LTV ratios and nonlinear property transfer taxes on Hong Kong's housing prices in a DSGE framework. The central bank is assumed to adjust LTV ratios and tax rates responding to property price inflation over a threshold value. Comparing the nonlinear policies with a linear Taylor-type LTV policy, their results suggest that nonlinear property transfer taxes are more effective than nonlinear or linear LTV policies in taming home prices. The dampening effect of nonlinear LTV policies becomes intensified while that of nonlinear property transfer taxation becomes weakened as the number of time periods for which the policy takes effect increases.

3 Our Model

Our model is a modified version of Iacoviello and Neri's (2010) model. The economy is assumed to consist of borrowers (speculators) and savers (patient households). There is an equal number of borrowers and savers. Both borrowers and savers are homeowners. Borrowers are less patient and collateral-constrained when purchasing additional properties for

investment purposes. Their borrowing capacity is tied to the expected future value of the investment housing. Savers have accumulated sufficient wealth and are not credit-constrained.

Households share the same preferences, consuming a CES composite of domestic tradable goods, foreign tradable goods, and non-traded goods (residential housing). Domestic firms in the tradable goods sector produce intermediate goods with labor in a monopolistically competitive market. Domestic firms in the housing sector produce intermediate goods with labor and investment housing in a monopolistically competitive market. The final goods markets in both sectors are assumed to be perfectly competitive. The presence of imperfect competition creates market distortions and provides a rationale for the central bank to implement monetary policy rules.

3.1 Borrowers

The preference of the representative borrower is defined over a composite consumption of tradable goods C_t^B, non-traded goods D_t^B and disutility of employment in two sectors $N_{C,t}^B$ and $N_{D,t}^B$. The objective of the representative borrower is to maximize the expected present discounted utility (1) subject to the budget constraint (3) and the collateral constraint (4) in real terms.

$$Max \quad E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\ln\left(C_t^B\right) + \eta_t \ln\left(D_t^B\right) - \frac{\left(N_{C,t}^B\right)^{1+\varsigma}}{1+\varsigma} - \frac{\left(N_{D,t}^B\right)^{1+\varsigma}}{1+\varsigma} \right] \right\} \tag{1}$$

$$C_t^B = \left[(1-\alpha_C)^{\frac{1}{\varepsilon}} \left(C_{H,t}^B\right)^{\frac{\varepsilon-1}{\varepsilon}} + (\alpha_C)^{\frac{1}{\varepsilon}} \left(C_{F,t}^B\right)^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{2}$$

st.

$$C_t^B + (1+\tau_{1t}) Q_t \left[D_t^B - (1-\delta) D_{t-1}^B \right] + H_t \left[K_t - (1-\delta)(1-\tau_{2t}) K_{t-1} \right] + \frac{\phi}{2} \frac{\left(K_t - K_{t-1}\right)^2}{K_{t-1}}$$

$$= b_t - \left(1+r_{t-1}^B\right) \frac{b_{t-1}}{\pi_{C,t}} + S_t b_t^* - \left(1+r_{t-1}^{B^*}\right) \frac{S_t}{\pi_{C,t}} b_{t-1}^* + w_{C,t} N_{C,t}^B + w_{D,t} N_{D,t}^B + \frac{T_t^B}{P_t^C} \tag{3}$$

$$\left(1+r_t^B\right) b_t + \left(1+r_t^{B^*}\right) S_t b_t^* = \chi_t (1-\delta) E_t \left\{ K_t H_{t+1} \pi_{C,t+1} \right\}, \tag{4}$$

where β is the borrowers' discount factor, η_t is a housing preference shock and ς is the elasticity of marginal disutility with respect to labor supply. ε is the elasticity of substitution between domestic goods $C_{H,t}^B$ and foreign goods $C_{F,t}^B$. α_C is the steady-state share of foreign goods in tradable goods consumption.

Non-traded goods, D_t, include housing units as principle residences and their incurred housing-related services. Borrowers also purchase housing units, K_t, for investment purposes and use them as collateral for loans. K_t can be interpreted as the unfinished housing units and considered as an input in the production function of residential housing. Hereafter, we will name D_t as residential housing and K_t as investment housing. An increase in K_t increases the supply of residential housing and brings a positive wealth effect to speculators. Q_t is the relative price of residential housing or imputed rent, defined as $P_{D,t}/P_{C,t}$. H_t is the relative price of investment housing, defined as $P_{K,t}/P_{C,t}$. We assume that each unit of investment housing incurs an additional resource cost. ϕ measures the magnitude of adjustment costs for

K_t . A greater ϕ hinders the accumulation of the stock of investment housing. The government intends to impose two kinds of taxes on properties. τ_{1t} is the property tax rate shock, and τ_{2t} is the transfer tax rate shock on the sales of investment housing[7].

Households hold domestic borrowing $b_t \equiv B_t / P_{C,t}$ and foreign borrowing $b_t^* \equiv B_t^* / P_{C,t}$. An asterisk represents the foreign country. r_t^B represents the domestic loan rate. $w_{C,t} = W_{C,t} / P_{C,t}$ and $w_{D,t} = W_{D,t} / P_{C,t}$ represent the real wages in two sectors. S_t represents the price of the foreign currency in units of domestic currency. An increase in S_t represents the depreciation of domestic currency. $\pi_{C,t} \equiv P_{C,t} / P_{C,t-1}$ is the domestic inflation rate of tradable goods. T_t^B is the lump-sum transfer from the government to borrowers. χ_t represents the fraction of housing value that can be used as collateral. Monacelli (2009) and Calza et al. (2013) refer to $1-\chi_t$ as the down-payment rate. We follow Funke and Paetz (2013) in using χ_t as a proxy for the loan-to-value ratio shocks.

Let λ_t and $\lambda_t \gamma_t$ be multipliers for the budget constraint and collateral constraint, respectively. The first order conditions are defined in equations (5)-(11).

$$\frac{\beta^t}{C_t^B} = \lambda_t , \tag{5}$$

$$\left(N_{\mathrm{C},t}^B\right)^{\varsigma} = \frac{1}{C_t^B} \cdot w_{\mathrm{C},t} , \tag{6}$$

$$\left(N_{\mathrm{D},t}^B\right)^{\varsigma} = \frac{1}{C_t^B} \cdot w_{\mathrm{D},t} , \tag{7}$$

[7] We assume that borrowers only hold investment housing for one period and must sell it in the next period. The uncertainty arises in that agents do not know in which particular period policy shocks will occur.

$$\gamma_t\left(1+r_t^B\right)=1-\beta E_t\left\{\frac{C_t^B}{C_{t+1}^B}\cdot\frac{\left(1+r_t^B\right)}{\pi_{C,t+1}}\right\}, \tag{8}$$

$$\gamma_t\left(1+r_t^{B*}\right)=1-\beta E_t\left(\frac{C_t^B}{C_{t+1}^B}\cdot\frac{\left(1+r_t^{B*}\right)}{\pi_{C,t+1}}\cdot\frac{S_{t+1}}{S_t}\right), \tag{9}$$

$$\frac{\eta_t}{D_t^B}+\beta\left(1+\tau_{1t}\right)\left(1-\delta\right)E_t\left(\frac{Q_{t+1}}{C_{t+1}^B}\right)=\left(1+\tau_{1t}\right)\frac{Q_t}{C_t^B}, \tag{10}$$

$$\lambda_t\left[H_t+\phi\frac{\left(K_t-K_{t-1}\right)}{K_{t-1}}\right]$$

$$=\lambda_{t+1}\left[\left(1-\tau_{2t+1}\right)\left(1-\delta\right)H_{t+1}+\frac{\phi\left(K_{t+1}-K_t\right)\left(K_{t+1}+K_t\right)}{K_t^2}\right]+\lambda_t\gamma_t\chi_t\left(1-\delta\right)E_t\left(H_{t+1}\pi_{C,t+1}\right). \tag{11}$$

Equations (6) and (7) show the trade-offs between consumption and labor choice in sectors C_t and D_t, respectively. Equation (8) is an intertemporal Euler equation. Equation (9) derives the uncovered interest parity. Equation (10) states that the marginal benefit of increasing an additional unit of residential housing at time t must equal the marginal utility of tradable goods consumption at time t. The former consists of the marginal utility from housing services and the marginal utility of tradable goods consumption from selling the house at time period $t+1$. Equation (11) states that the marginal cost and the marginal benefit of increasing an additional unit of investment housing must be equalized. The latter includes the increases in utility of more wealth associated with higher future housing prices and in utility associated with greater borrowing capacity against home equity.

3.2 Savers

Savers are assumed to be more patient than borrowers and are not collateral-constrained. Their optimization problem is defined as follows.

$$Max \quad E_0\left\{\sum_{t=0}^{\infty}\tilde{\beta}^t\left[\ln\left(C_t^S\right)+\eta_t\ln\left(D_t^S\right)-\frac{\left(N_{C,t}^S\right)^{1+\varsigma}}{1+\varsigma}-\frac{\left(N_{D,t}^S\right)^{1+\varsigma}}{1+\varsigma}\right]\right\} \tag{12}$$

$$C_t^S=\left[\left(1-\alpha_C\right)^{\frac{1}{\varepsilon}}\left(C_{H,t}^S\right)^{\frac{\varepsilon-1}{\varepsilon}}+\left(\alpha_C\right)^{\frac{1}{\varepsilon}}\left(C_{F,t}^S\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

st.

$$C_t^S+\left(1+\tau_{1t}\right)Q_t\left[D_t^S-\left(1-\delta\right)D_{t-1}^S\right]+\tilde{b}_t+S_t\tilde{b}_t^*$$

$$=\left(1+r_{t-1}^S\right)\frac{\tilde{b}_{t-1}}{\pi_{C,t}}+\left(1+r_{t-1}^{S*}\right)\frac{S_t}{\pi_{C,t}}\tilde{b}_{t-1}^*+w_{C,t}N_{C,t}^S+w_{D,t}N_{D,t}^S+\frac{T_t^S}{P_t^C}, \tag{13}$$

where $\tilde{b}_t\equiv\tilde{B}_t/P_t^C$ and $\tilde{b}_t^*\equiv\tilde{B}_t^*/P_t^C$ are loans provided by domestic households and foreign households with rates of return r_t^S and r_t^{S*}, respectively. T_t^S is the lump-sum transfer from the government to savers. Equation (13) represents savers' budget constraint. The main difference between (13) and (3) is that savers purchase housing mainly as principle residences, not for investment purposes. K_t is hence omitted here. The first order conditions for savers are defined in equations (14)-(18). $\tilde{\beta}$ is the savers' discount factor. r_t^S defines the rate of return for deposits.

$$\left(N_{C,t}^S\right)^{\varsigma}=\frac{1}{C_t^S}\cdot w_{C,t} \tag{14}$$

$$\left(N_{D,t}^S\right)^{\varsigma}=\frac{1}{C_t^S}\cdot w_{D,t} \tag{15}$$

$$\tilde{\beta}\left(1+r_t^S\right)\cdot\frac{1}{\pi_{C,t+1}}=E_t\left(\frac{C_{t+1}^S}{C_t^S}\right) \tag{16}$$

$$\frac{1+r_t^S}{1+r_t^{S*}} = E_t\left(\frac{S_{t+1}}{S_t}\right) \tag{17}$$

$$\frac{\eta_t}{D_t^S} + \beta\left(1+\tau_{1t}\right)\left(1-\delta\right)E_t\left(\frac{Q_{t+1}}{C_{t+1}^S}\right) = \left(1+\tau_{1t}\right)\frac{Q_t}{C_t^S} \tag{18}$$

3.3 Retailers and Intermediate Goods Producers

Retailers combine intermediate goods with no additional inputs and sell final goods to consumers in a perfectly competitive market. Retailer production is a constant-elasticity-of-substitution aggregate of a continuum of intermediate producers. The production functions for domestic retailers in the tradable goods sector and housing sector are defined as

$$Y_{l,t} = \left[\int_0^1 \left(Y_{l,t}(j)\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}, \quad l = C, D \tag{19}$$

where θ refers to the elasticity of substitution between any two differentiated goods and is assumed to be the same in both sectors.

Intermediate goods firms use different kinds of technology while producing tradable goods and residential housing in monopolistically competitive markets. The production functions for individual firms in sectors C and D are defined by equations (20)-(21). $Z_{C,t}$ and $Z_{D,t}$ are the productivity shocks and are assumed to be identical for each firm. α_H is the steady-state share of investment housing used in residential housing production.

$$Y_{C,t}(j) = Z_{C,t}N_{C,t}(j) \tag{20}$$

$$Y_{D,t}(j) = Z_{D,t}\left(N_{D,t}(j)\right)^{1-\alpha_H}\left(K_{t-1}(j)\right)^{\alpha_H} \tag{21}$$

Each firm charges a price mark-up over its nominal marginal cost. Each period only a fraction $1-\varpi$ of all firms can adjust their prices. ϖ is a measure of the degree of nominal rigidity. Each firm faces a constant elasticity demand curve given by equation (22). Equations (23)-(24) represent the real marginal costs in two sectors. We assume that the nominal wages in the two sectors are deflated by the aggregate consumer price index. This setting implies that exchange rate changes will affect the real marginal costs in two sectors, since the aggregate consumer price is composed of the prices of domestic tradable goods and foreign tradable goods.

$$Y_{l,t}(j) = \left(\frac{P_{l,t}(j)}{P_{l,t}}\right)^{-\theta} Y_{l,t}, \quad l = C, D \tag{22}$$

$$MC_{C,t} = \frac{W_{C,t}/P_{C,t}}{Z_{C,t}} \tag{23}$$

$$MC_{D,t} = \frac{1}{Z_{D,t}}\left[\left(1-\alpha_H\right)\frac{W_{D,t}/P_{D,t}}{Q_t} + \alpha_H H_t\right] \tag{24}$$

3.4 The Banking Sector

The banking sector operates in a standard Dixit-Stiglitz monopolistically competitive market. We assume that banks can transform the mortgage loans into securities with a constant-return technology. These mortgage-based securities will be sold to domestic savers and foreign savers for banks' additional funding sources. Individual banks face a deposit

demand function (25) and a loan demand function (26).

$$\left[\tilde{b}_{j,t}+S_t\tilde{b}^*_{j,t}\right]=\left(\frac{r^S_{j,t}}{r^S_t}\right)^{\mu}\left[\tilde{b}_t+S_t\tilde{b}^*_t\right]. \tag{25}$$

$$\left[b_{j,t}+S_t b^*_{j,t}\right]=\left(\frac{r^B_{j,t}}{r^B_t}\right)^{-\mu}\left[b_t+S_t b^*_t\right], \tag{26}$$

where $r^S_{j,t}$ and $r^B_{j,t}$ are the interest rates offered by bank j to saving and borrowing, respectively. $\tilde{b}_{j,t}+S_t\tilde{b}^*_{j,t}$ is the total deposit (domestic and foreign) collected by each bank j; while $b_{j,t}+S_t b^*_{j,t}$ is the total borrowing (domestic and foreign) issued by each bank j. μ represents the interest rate elasticity of demand for deposits and loans.

Each bank is assumed to maximize its expected present value of profit flows (27) subject to deposit and loan demand functions. The last term in (27) represents the adjustment cost incurred when the loan rate at $t+1$ differs from that at t. The parameter k_B measures the degree of interest rate adjustment cost. The banking sector has the same discount factor as savers since we assume savers own banks. Equation (28) represents the banks' balance sheet constraint, indicating that loans issued to borrowers equal the level of savers' deposits.

$$E_0\sum\nolimits_{i=0}^{\infty}\tilde{\beta}\left(\frac{C^S_t}{C^S_{t+i}}\right)\left[r^B_{j,t+i}(b_{j,t+i}+S_t b^*_{j,t+i})-r^S_{j,t+i}\left(\tilde{b}_{j,t+i}+S_{t+i}\tilde{b}^*_{j,t+i}\right)-\frac{k_B}{2}\left(\frac{r^B_{j,t+i}}{r^B_{t+i-1}}-1\right)^2 r^B_{t+i}\left(b_{t+i}+S_{t+i}b^*_{t+i}\right)\right]. \tag{27}$$

$$\left(b_{j,t}+S_t b^*_{j,t}\right)=\left(\tilde{b}_{j,t}+S_t\tilde{b}^*_{j,t}\right). \tag{28}$$

We assume all banks make the same decisions. After substituting the bank's balance sheet into the profit function and imposing the symmetric conditions, we obtain

$$\left(\mu\ -1+k_B\right)r_t^B = k_B r_{t\text{-}1}^B + \mu\ r_t^S \tag{29}$$

3.5 Fiscal and Monetary Authorities

The real government budget constraint is defined as equation (30). The fiscal authority owns the initial stock of investment housing, financing government purchases and transfer payments with tax revenue from residential properties and proceeds from the sales of investment housing[8]. The sales conducted by the government are assumed to be exempted from the transfer taxes. The monetary authority operates the interest rate by responding to a lagged policy rate, output gap and aggregate inflation. Let a lower case variable with a hat denote the percentage deviation of a variable around its steady state. In terms of the deviation from zero inflation, the interest rate rule can be expressed as equation (31). ρ_R is the weight imposed on lagged policy rates. ρ_Y is the weight imposed on the inflation rate and output gap. κ_π and κ_Y are the coefficients of inflation and output gap, respectively, in the Taylor rule. Equations (32) and (33) are the inflation adjustment equations for sectors C and D.

$$\tau_{1t}Q_t\left[D_t^B-\left(1-\delta\right)D_{t-1}^B+D_t^S-\left(1-\delta\right)D_{t-1}^S\right]+\tau_{2t}H_t\left(1-\delta\right)K_{t-1}+H_t\left[K_t-\left(1-\delta\right)K_{t-1}\right]=\frac{T_t^B}{P_t^C}+\frac{T_t^S}{P_t^C}+G_t \tag{30}$$

$$\hat{r}_t^S=\rho_R\cdot\hat{r}_{t-1}^S+(1-\rho_R)\cdot\left[\kappa_\pi\left[\left(1-\alpha\right)\hat{\pi}_{C,t}+\alpha\hat{\pi}_{D,t}\right]+\kappa_Y\hat{y}_t\ \right]+u_t\,. \tag{31}$$

[8] The fiscal authority has incentives to sell unfinished houses (investment housing) since residential property taxes and transfer taxes are the only sources for generating government revenue.

$$\hat{\pi}_{C,t} = \beta E_t \hat{\pi}_{C,t+1} + (1-\varpi)\cdot(1-\beta\varpi)\cdot(\hat{w}_t - \hat{z}_{C,t})/\varpi \,. \tag{32}$$

$$\hat{\pi}_{D,t} = \beta E_t \hat{\pi}_{D,t+1} + (1-\varpi)\cdot(1-\beta\varpi)\cdot\left[(1-\alpha_H)(\hat{w}_t - \hat{q}_t) + \alpha_H \hat{h}_t - \hat{z}_{D,t}\right]/\varpi \,. \tag{33}$$

3.6 Equilibrium

Equations (34)-(38) represent the equilibrium equations in the model. In equation (34), domestic production Y_t equals the sum of the following: domestic consumption of tradable goods and residential housing services, resource costs of investment housing, government purchases and exports of domestically produced goods. The foreign demand for domestically produced goods is proportional to the foreign country's aggregate income Y_t^*. Equation (35) defines the terms of trade condition. With complete exchange rate pass–through, the imported price of foreign goods equals the foreign currency price denominated in the domestic currency, that is, $P_{F,t} = S_t P_{H,t}^*$. We assume the foreign country is relatively larger than the home country, so its consumer price inflation and producer price inflation are the same. Hence, $P_{F,t} = S_t P_{C,t}^*$. Equations (36)-(38) imply that the labor market and bond market are in equilibrium. Finally, foreign households are assumed to have the same preferences as domestic households. The individual intermediate goods producer's production function in the foreign country takes the same form as that in the domestic country.

$$Y_t = (1-\alpha_C)\left[C_t^B + C_t^S\right] + D_t^B - (1-\delta)D_{t-1}^B + D_t^S - (1-\delta)D_{t-1}^S + \frac{\phi}{2}\frac{(K_t - K_{t-1})^2}{K_{t-1}} + G_t + \alpha_C \mathrm{O}_t Y_t^* \tag{34}$$

$$\mathrm{O}_t = \frac{P_{F,t}}{P_{H,t}} = \frac{S_t P^*_{H,t}}{P_{H,t}} = \frac{S_t P^*_{C,t}}{P_{H,t}} \tag{35}$$

$$N_{C,t} = N^B_{C,t} + N^S_{C,t}, \tag{36}$$

$$N_{D,t} = N^B_{D,t} + N^S_{D,t}, \tag{37}$$

$$\left(b_t + S_t b^*_t\right) + \left(\tilde{b}_t + S_t \tilde{b}^*_t\right) = 0. \tag{38}$$

3.7 Exogenous Shocks

Productivity shocks in two sectors, housing preference shocks, tax rate shocks, monetary policy shocks, loan-to-value shocks, foreign productivity shocks and exchange rate shocks are assumed to be exogenous and follow an exogenous $AR(1)$ process in equations (39)-(47). m_{1t}, m_{2t}, m_{3t}, m_{4t}, m_{5t}, m_{6t}, m_{7t}, m_{8t} and m_{9t} are assumed to be a serially uncorrelated process with mean zero. ρ is assumed to be less than 1.

$$\ln Z_{C,t} = \rho \ln Z_{C,t-1} + m_{1t} \tag{39}$$

$$\ln Z_{D,t} = \rho \ln Z_{D,t-1} + m_{2t} \tag{40}$$

$$\ln \eta_t = \rho \ln \eta_{t-1} + m_{3t} \tag{41}$$

$$\ln \tau_{1t} = \rho \ln \tau_{1t-1} + m_{4t} \tag{42}$$

$$\ln \tau_{2t} = \rho \ln \tau_{2t-1} + m_{5t} \tag{43}$$

$$\ln u_t = \rho \ln u_{t-1} + m_{6t} \tag{44}$$

$$\ln \chi_t = \rho \ln \chi_{t-1} + m_{7t} \tag{45}$$

$$\ln Z^*_t = \rho \ln Z^*_{t-1} + m_{8t} \tag{46}$$

$$\ln S_t = \rho \ln S_{t-1} + m_{9t} \tag{47}$$

4 Calibration Results

4.1 Parameters and steady-state values

Following previous literatures (Teo 2009; Huang and Ho 2012) that apply a DSGE framework to Taiwan's economy, the depreciation rate of housing δ is set to be 0.025. The elasticity of substitution between any two differentiated goods θ is set to be 6, implying that a price markup over marginal cost is 20%. The degree of nominal rigidity ϖ is set equal to 0.75, implying that the expected time between price adjustments is one year.

Based on Taiwan's real data during 2000-2013, the discount factor $\tilde{\beta}$ for savers is pinned down to 0.9945, which implies an annualized deposit rate of 2.23%. The discount factor β for borrowers is 0.9467, which implies an annualized lending rate of 4.27%[9]. The steady-state share of housing-related expenditure in total consumption α is 0.23, and the steady-state share of foreign goods in tradable goods consumption α_C is 0.56[10]. The non-labor share of housing production α_H is set to be 0.30[11]. $\bar{K}/\bar{Y}$ is set to be 0.02 based on the average ratio of real residential investment to Taiwan's real GDP during 2000-2013. $\bar{D}/\bar{Y}$ is set to be 0.17 based on the average ratio of real housing-related consumption plus the

[9] In the steady state, $\beta + \bar{\gamma} = 1/(1+\bar{r}^B)$, $\tilde{\beta} = 1/(1+\bar{r}^S)$.

[10] Housing-related expenditure includes the spending on residential services, water, electricity, gas, and other fuels, as well as furnishings, household equipment, and routine household maintenance. The average share of housing-related consumption over total household consumption during 2000-2013 in Taiwan was about 0.23. Due to data availability, we use the import-to-GDP ratio as a proxy for the share of foreign goods consumption in tradable goods consumption. The average ratio of imports of goods and services over GDP during 2000-2013 in Taiwan was about 0.56.

[11] The average ratio of employees' compensation in the sectors of furniture, manufacturing, real estate and ownership of dwellings during 2000-2013 was about 0.7.

gross capital formation for construction as well as real estate and ownership of dwellings to Taiwan's real GDP during 2000-2013. $\bar{Y}_D/\bar{Y}$ is set to be 0.12 based on the average share of Taiwan's real GDP in the sectors of furniture, manufacturing, real estate and ownership of dwellings during 2000-2013. $\bar{C}/\bar{Y}$ is set to be 0.61 based on the average ratio of Taiwan's private consumption over its real GDP during 2000-2013. $\bar{G}/\bar{Y}$ is set to be 0.0005 in order to satisfy the steady-state real government budget constraint.

The central bank in Taiwan uses the discount rate as a monetary policy target. Hence, we apply an ordinary least squares method on equation (31) with Taiwan's discount rate, changes of consumer price index, and output gap from 2000Q1 to 2013Q4 to determine the coefficients in the Taylor rule. The output gap is defined as the deviation of seasonally adjusted real GDP from its HP-filtered trend. The results show that all the coefficients $\rho_R = 0.95$, $\kappa_\pi = 0.77$, and $\kappa_Y = 1.13$ are statistically significant.

The elasticity of substitution between domestic goods and foreign goods ε is assumed to be 1. The magnitude of adjustment costs for investment housing ϕ is set to be 2. The elasticity of marginal disutility with respect to labor supply ς is pinned down to 0.65. The interest rate elasticity of demand for loans μ is pinned down to 10. Steady-state money demand preference $\bar{\eta}$ is pinned down to be 0.023. The magnitude of interest rate adjustment cost k_B is set to be 1. The persistence of policy shocks ρ is assumed to be 0.97. Two steady-state tax rates $\bar{\tau}_1$ and $\bar{\tau}_2$ are assumed to be zero. The steady-state loan-to-value ratio

$\bar{\chi}$ is set to be 0.6. All steady-state prices, $\bar{P}^C$, $\bar{P}^D$, $\bar{Q}$, $\bar{H}$, $\bar{O}$, and $\bar{S}$, are set to be 1. The work hours $\bar{N}^B$ and $\bar{N}^S$ are parameterized to 0.33. Table 1 summarizes the baseline parameters and table 2 presents the steady-state values of the variables.

Table 3 presents our model's relative standard deviations of housing prices and housing transactions to output in response to transfer tax shocks and LTV shocks, which are compared with those in the real data during 2011Q1-2015Q4. With respect to real data, housing transactions of ownership transfer are calculated by the percentage change from the previous period. Housing prices are measured by the percentage change from the base year's (2011) price. The results show that our model in response to transfer tax shocks and LTV shocks matches the volatility of housing prices and housing transactions during the period when LTV reduction was launched and a transfer tax was collected. One poor dimension is that our model predicts a strongly negative correlation while real data indicates a mildly negative correlation between housing prices and housing transactions. This may be because housing price is not the only determinant for Taiwanese households to buy or sell residential properties. There are other motives for engaging in housing activities, such as precautionary savings and intergenerational transfers. Our model does not consider these factors and thus overstates the negative correlation between housing prices and housing transactions.

4.2 Impulse Reponses

Figures 3 and 4 depict the dynamics of major variables in response to

20-percent-standard-deviation shocks of the residential property tax and the transfer tax. The results indicate that an increase in the property tax rate or transfer tax rate reduces borrowers' residential housing consumption (d_t^B), savers' residential housing consumption (d_t^S) and residential housing prices (q_t). Transfer tax shocks have a more substantially adverse impact on residential housing prices than property tax shocks. A transfer tax depresses investment housing price (h_t), but not investment housing transaction (k_t). This is because a transfer tax is imposed on the sale of previous-period investment housing stock. The purchase of additional investment housing in the current period greatly depends on speculators' prospects toward the future. If speculators foresee climbing housing prices and higher demand for residential housing, they will purchase investment housing and hold down for residential housing production. A property tax, relatively, increases the cost of holding properties so as to discourage savers' and borrowers' residential housing consumption and speculator's purchase intent for investment housing. Meanwhile, greater demand for tradable consumption incites tradable inflation, non-traded inflation and the price of investment housing.

Figure 5 indicates that an increase in the policy rate reduces investment housing stock (k_t) and borrowing availability (b_t). The substitution effects caused by an increase in the interest rate dominate the income effects, reducing both savers' and borrowers' current tradable consumption. To sustain higher future tradable consumption, savers and borrowers increase their work hours, resulting in greater total production. An interest rate hike allocates

households' resources from tradable consumption to housing consumption. The strengthened current demand for residential housing initially upholds the investment housing price (h_t). However, an increase in the policy rate raises borrowing costs and discourages speculators from purchasing investment housing (k_t). Residential housing prices and investment housing prices gradually fall. As figure 6 shows, a lower LTV ratio reduces residential housing prices and investment housing prices. LTV shocks directly impact speculators' borrowing capacity so as to decrease their current residential housing consumption. Savers, by contrast, experience increases both in tradable consumption and residential housing consumption. Higher future demand for residential housing sustains current investment housing stock and future investment housing prices. For most variables, LTV shocks generate similar dynamics with transfer tax shocks.

In summary, all the policies dampen residential housing prices, but have different impact on investment housing prices and transactions. Property tax imposition or interest rate hikes reduces the stock of investment housing and extends the decline of investment housing prices. Investment housing prices do not bounce back until after 40 quarters. Transfer tax imposition or LTV ratio reduction curbs investment housing prices, but not investment housing transactions.

Among the shocks, the borrowing availability increases rather than decreases in response to property tax shocks. The borrowing availability is tied to the value of the multiplier of

collateral constraint. In equation (8), a property tax raises the ratio of current tradable consumption over next-period tradable consumption multiplied by the ratio of the lending rate over tradable inflation. The value of the multiplier of collateral constraint accordingly falls, resulting in a loosened collateral constraint (more borrowing capacity). Yet, rising holding cost of property weakens residential housing demand and gradually reduces investment housing prices and speculators' funding availability.

We compare the relative standard deviations under four macroeconomic policy shocks. Table 4 indicates that interest rate shocks cause the greatest volatility of savers' and borrowers' tradable and housing consumption. Borrowing availability and investment housing prices fluctuate most widely in response to LTV shocks since changes in LTV ratios affect borrowers' funding liquidity and willingness to invest in speculative properties. Interest rate shocks and LTV shocks generate roughly the same volatility in residential housing prices.

4.3 Sensitivity Analysis

We conduct three sensitivity analyses for the benchmark model. The first sensitivity analysis discusses the effects of raising interest rate elasticity of demand for loans, μ. A greater μ increases the substitutability among banks, resulting in a more competitive financial market. Figure 7 presents the impulse responses of major variables against contractionary monetary policy shocks when μ increases from 10 to 20. After shocks occur, lending rates (r_t^B) increase but do not show significant variation in a more competitive banking

environment. Given the same lending rate across banks, greater bank competition fosters more funding sources for borrowers, which mitigates the initial and sequential negative responses of borrowing (b_t) and the value of collateral constraint multiplier (γ_t). The investment housing stock (k_t) does not change significantly, however, more funding sources fuel the investment housing price (h_t). In a more competitive banking environment, a higher policy rate tampers residential and investment housing prices gradually and to a lesser extent.

The second and third sensitivity analyses explore the impact of increasing the proportion of investment housing in the residential housing production, α_H, from 0.30 to 0.70. As shown in figure 8, when residential housing production relies more heavily on investment housing than on labor, raising policy rates magnifies the decline in residential housing prices (q_t). Investment housing prices fall but bounce back earlier compared to the benchmark case. This is because an interest rate hike advances the intra-temporal allocation between current tradable goods and residential housing when the proportion of investment housing in the residential housing production increases. Stronger demand for residential housing weakens the effectiveness of a contractionary policy on dampening speculative housing prices and transactions. Figure 9 shows that compared to the benchmark model, residential housing prices decrease more and households shift consumption from residential housing to tradable goods more substantially in response to transfer tax shocks. When the proportion of investment housing in the residential housing production increases, speculators have greater incentives to

hold down unfinished housing units for future residential housing production, so the positive initial responses of investment housing stock are stronger.

5 Conclusions

This paper evaluates the effects of several macroeconomic policies on Taiwan's housing market. Our results indicate that the responses of investment housing prices are closely linked with residential housing consumption for savers and borrowers. Higher expected demand for residential housing tends to increase speculator's purchase intent for investment housing so as to boost future investment housing prices. Property tax imposition and interest rate hikes increase the holding costs of property vacancy and borrowing costs, respectively, resulting in decreases in speculative housing transactions. They also have prolonged effects on mitigating speculative housing prices. Transfer tax imposition and LTV ratio deduction instantly hamper investment housing prices but not investment housing transactions. A transfer tax is imposed on the sale of previous-period investment housing stock while a LTV shock restricts speculators' funding availability associated with future investment housing prices. Speculators can potentially defer their purchase and sale decisions of speculative housing. Hence, the impact of a transfer tax and a downward LTV ratio on moderating housing market is effective for a limited time.

Our research has some limitations. First, the supply of investment housing is exogenously determined. Changes in investment housing prices and stock are mainly driven by the demand

for residential housing. Future research can lay out a production function for investment housing. By including land in the production function, the effects of consolidating capital gains from transferring housing and land as taxable income can be analyzed. Second, our research does not address the welfare comparison between different policies but focuses on the policy impact on the housing prices and transactions. Third, we assume that all shocks occur independently. Interrelated shocks could lead to mixed policy effects. Nevertheless, this research builds on the channels that different macroeconomic policies draw upon the housing market and expects to provide meaningful policy implications for the government.

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Table 1 Baseline Parameters

Baseline Parameters	Values	Description
β	0.9467	Borrowers' discount factor
$\tilde{\beta}$	0.9945	Savers' discount factor
δ	0.025	Depreciation rate of non-tradable goods
α	0.23	The share of non-tradable goods in total consumption
α_C	0.56	The share of foreign goods in tradable goods consumption
α_H	0.30	The steady-state share of investment housing used in residential housing production
ϕ	2	The magnitude of adjustment cost for investment housing
ς	0.65	The elasticity of marginal disutility with respect to labor supply
ε	1	The elasticity of substitution between domestic goods and foreign goods
ϖ	0.75	The degree of nominal rigidity
ρ	0.97	The persistence of policy shocks
ρ_R	0.95	The weight imposed on the lagged policy rate
κ_π	0.77	Coefficient of inflation in the Taylor rule
κ_Y	1.13	Coefficient of the output gap in the Taylor rule
μ	10	The interest rate elasticities of demand for deposits or loans
k_B	1	The magnitude of interest-rate adjustment cost

Table 2 Calibrated Steady-State Values

Variables	Steady-State Values	Variables	Steady-State Values
$\bar{\gamma}$	0.0427	$\bar{D}^B = \bar{D}^S$	0.2160
$\bar{N}_C^B = \bar{N}_D^B$	0.33	$\bar{D}/\bar{Y}$	0.17
$\bar{N}_C^S = \bar{N}_D^S$	0.33	$\bar{K}/\bar{Y}$	0.02
$\bar{w}_C/\bar{Y}$	0.46572	$\bar{b}$	0.0148
$\bar{w}_D/\bar{Y}$	0.46572	$\bar{Y}^D/\bar{Y}$	0.12
$\bar{Z}_C$	3.3879	$\bar{Y}^C/\bar{Y}$	0.88
$\bar{Z}_D$	1	$\bar{G}/\bar{Y}$	0.0005
$\bar{\eta}$	0.023	$\bar{Y}$	2.54096
$\bar{\chi}$	0.60	$\bar{Y}^*$	3.29816
$\bar{r}^B = \bar{r}^{B*}$	0.0107	$\bar{\tau}_1$	0
$\bar{r}^S = \bar{r}^{S*}$	0.0056	$\bar{\tau}_2$	0
$\bar{C}/\bar{Y}$	0.61	$\bar{T}^B$	0
$\bar{C}^B = \bar{C}^S$	0.7750	$\bar{T}^S$	0

Table 3 Model Performance

	Our Model in response to transfer tax shocks and LTV shocks		Real data (2011Q2-2015Q4)	
	Relative Standard deviation	Correlation	Relative Standard deviation	Correlation
Home ownership transfers through transaction (D_t)	5.87	-0.92	5.86	-0.25
Housing price (Q_t)	4.11		3.76	

Note: We impose a 20-percent-standard-deviation transfer tax shock and a 20-percent-standard-deviation LTV shock on the model. The correlation between transfer tax and LTV shocks is assumed to be 0.5. Relative standard deviation is the standard deviation of each variable divided by that of real GDP. The real data for housing price and housing transaction are obtained from the Monthly Bulletin of Interior Statistics, Ministry of the Interior in Taiwan, and the Sinyi Realty Inc, respectively. All the real data are taken log-transformation.

Table 4 Relative Standard Deviations in the Benchmark Model

Variables	Property tax shock	Transfer tax shock	Interest rate shock	Loan-to-value ratio shock
Borrowers' tradable consumption C_t^B	1.47	1.66	6.80*	2.64
Savers' tradable consumption C_t^S	1.34	1.45	6.23*	1.05
Borrowers' residential housing D_t^B	4.24	6.13	13.34*	12.05
Savers' residential housing D_t^S	4.22	5.47	12.77*	8.32
Residential housing price Q_t	1.67	4.04	7.15	8.49*
Investment housing price H_t	2.66	11.37	11.56	21.90*
Investment housing stock K_t	0.88	1.01	4.10*	0.38
Borrowing B_t	2.42	10.19	9.17	89.56*

Note: The numbers above show the standard deviation of each variable relative to the standard deviation of output in response to 20-percent-standard-deviation shocks. "*" represents the largest value among all the shocks.

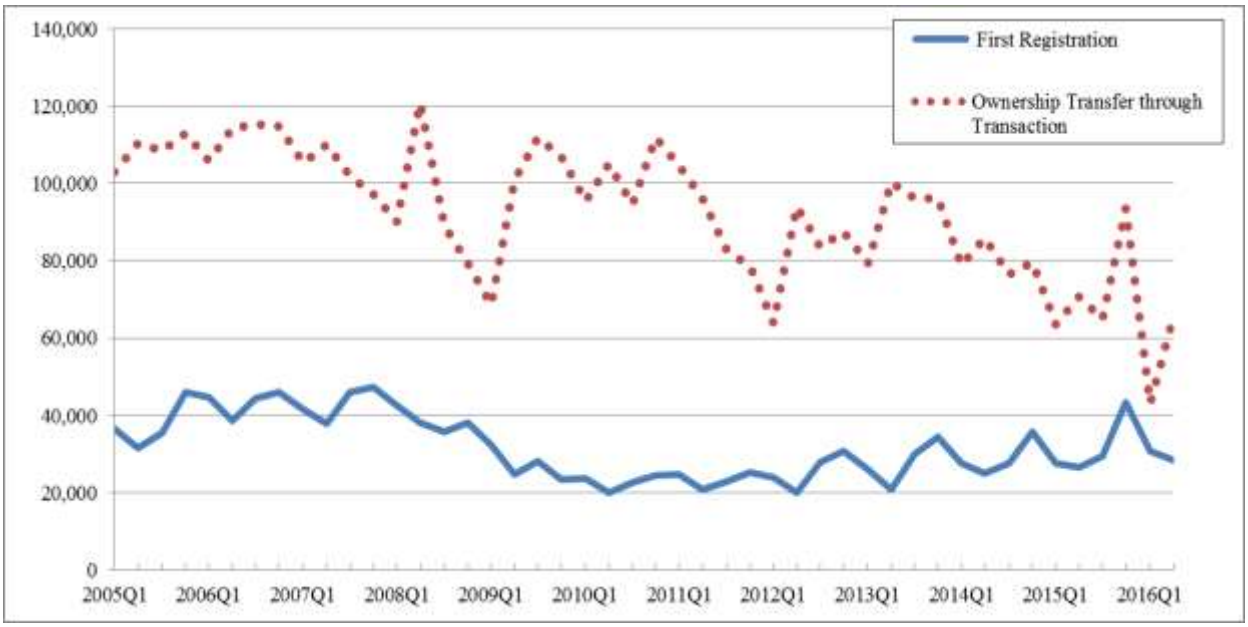

Figure 1 Number of Home Ownership Transfers during 2005Q1-2016Q2

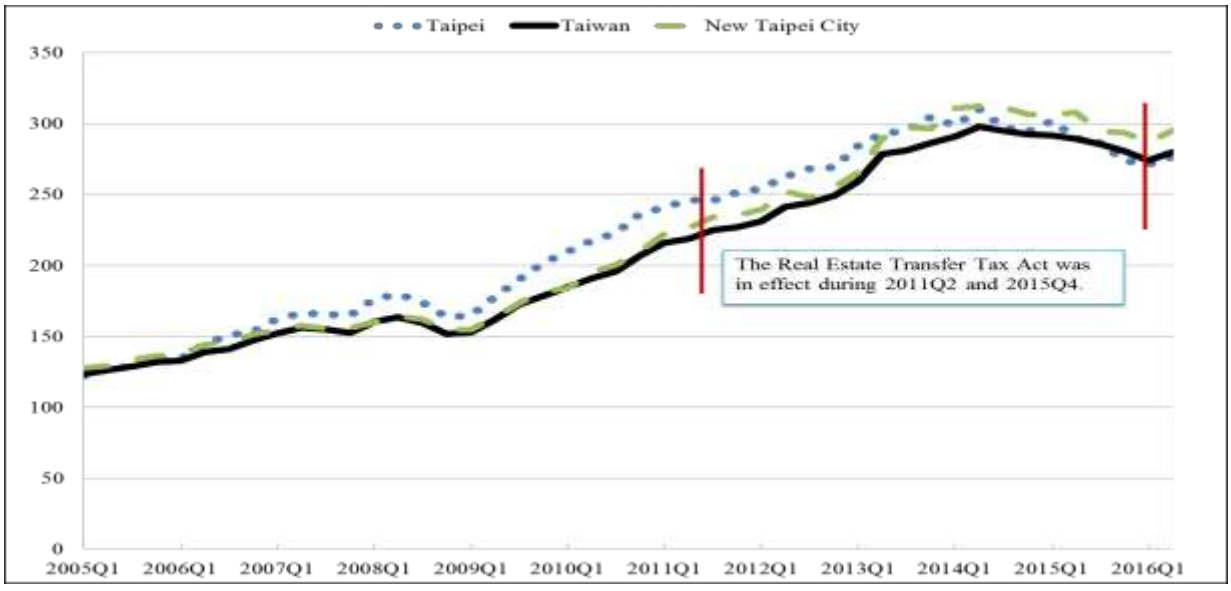

Figure 2 Sinyi Housing Price Index in Taipei City, New Taipei City and Taiwan during 2005Q1-2016Q2

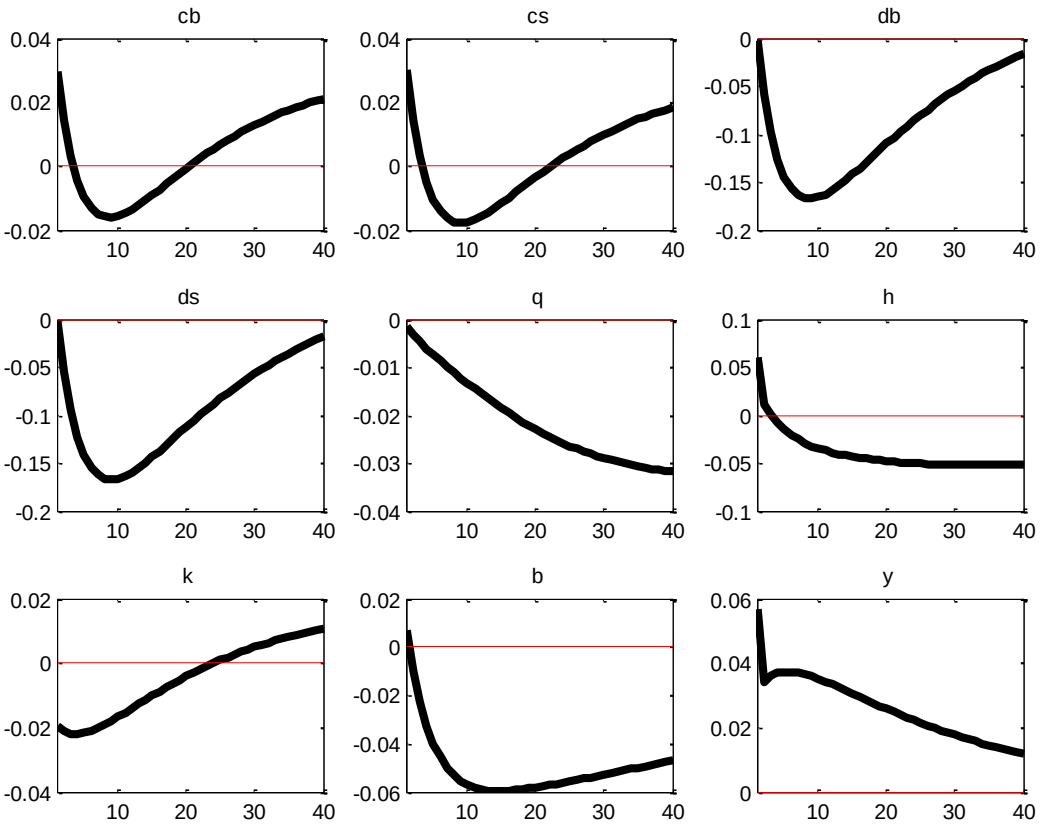

Figure 3 Impulse responses to 20-percent-standard-deviation property tax shocks

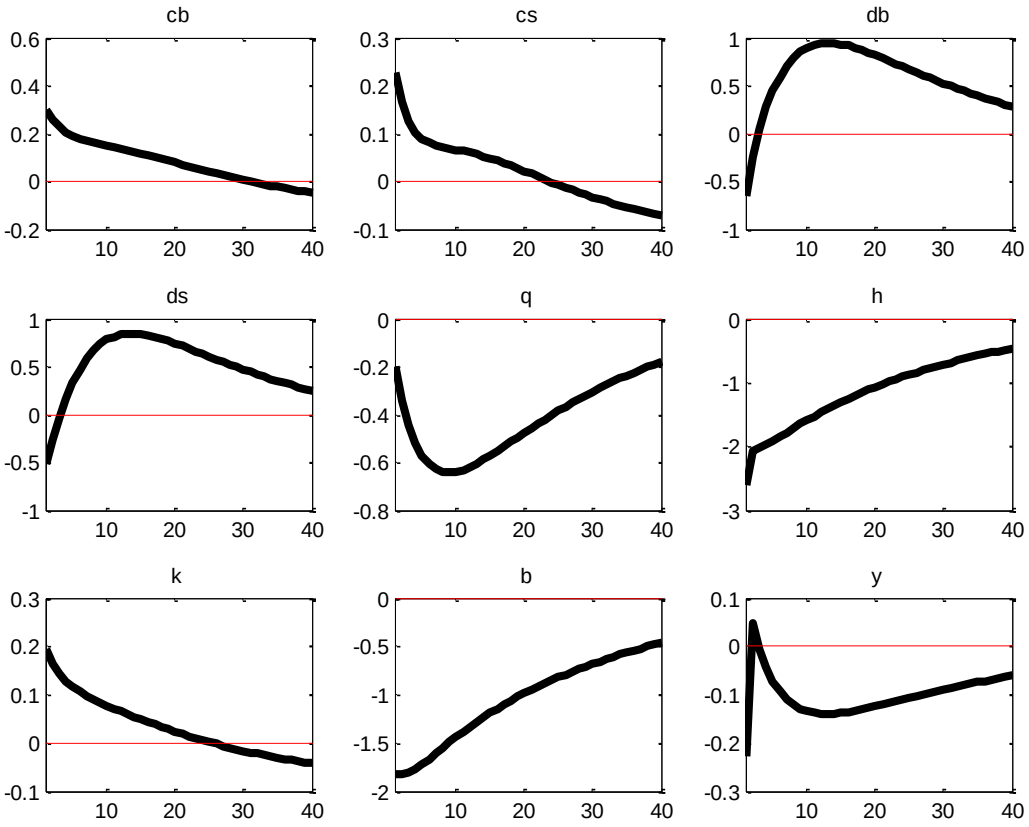

Figure 4 Impulse responses to 20-percent-standard-deviation transfer tax shocks

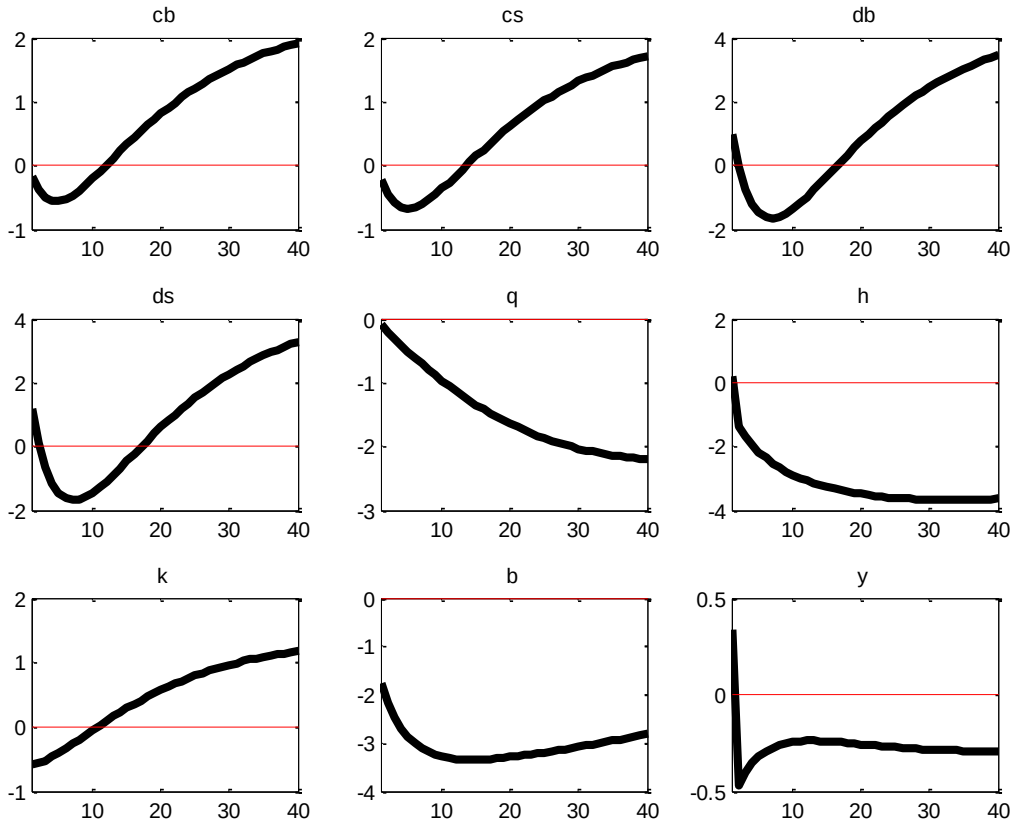

Figure 5 Impulse responses to 20-percent-standard-deviation interest rate shocks

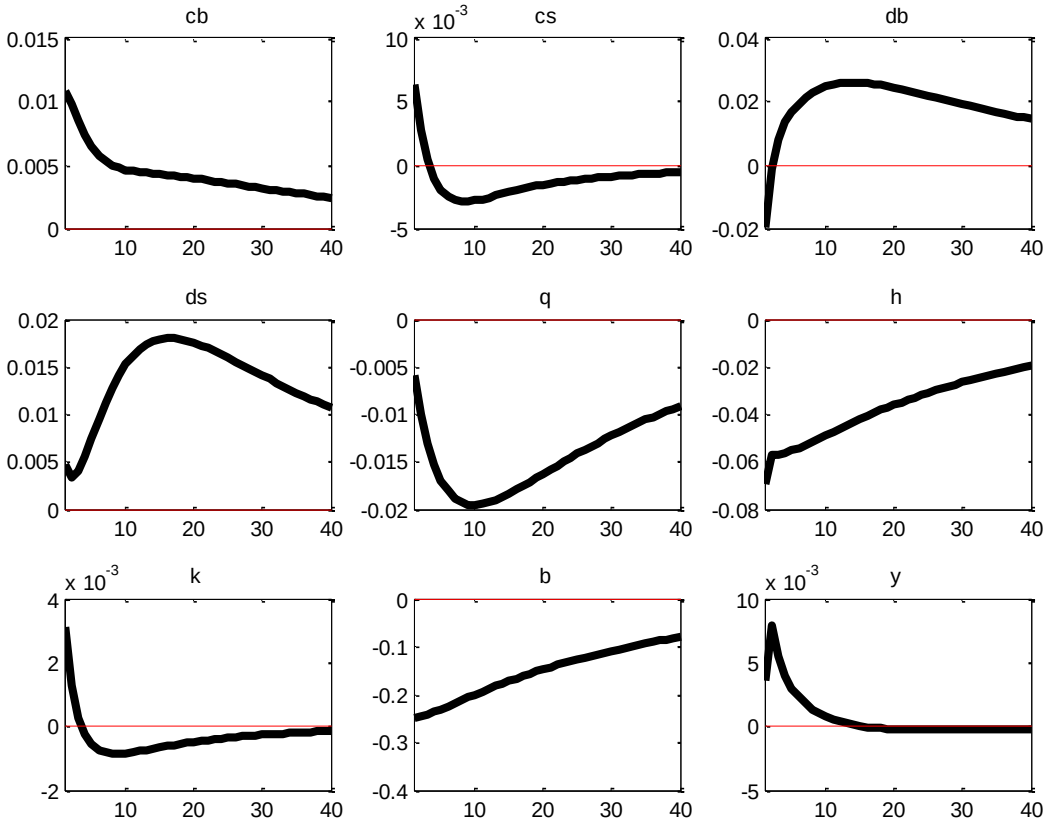

Figure 6 Impulse responses to 20-percent-standard-deviation loan-to-value shocks

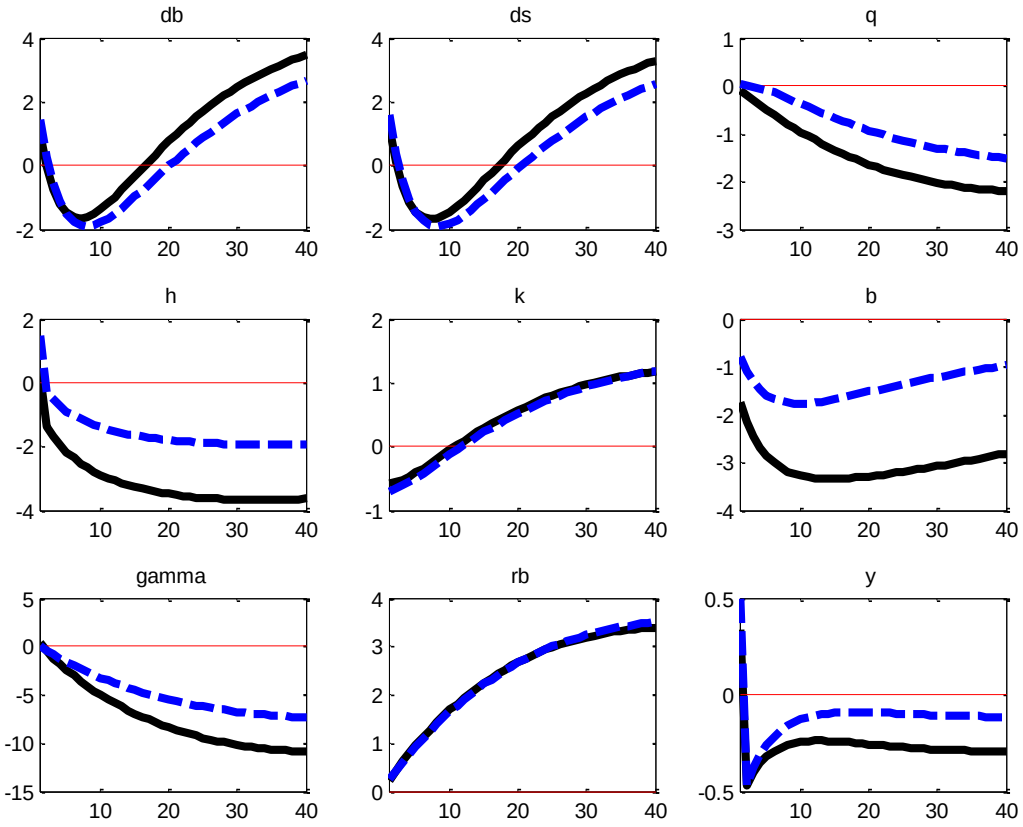

Figure 7 An increase in the interest rate elasticity of demand for loan against 20-percent-standard-deviation interest rate shocks. The dashed line represents the case when $\mu = 20$ and the solid line represents the case when $\mu = 10$ (the benchmark model).

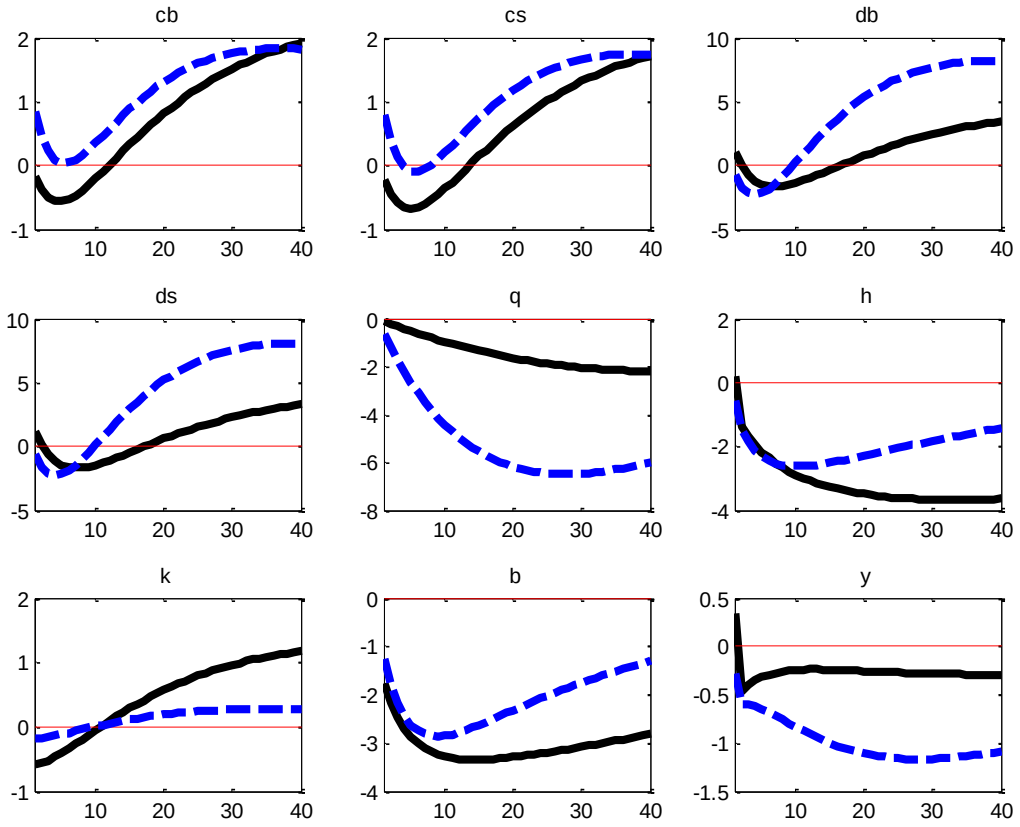

Figure 8 An increase in the portion of investment housing used in residential housing production against 20-percent-standard-deviation interest rate shocks. The dashed line represents the case when $\alpha_H = 0.70$ and the solid line represents the case when $\alpha_H = 0.30$ (the benchmark model).

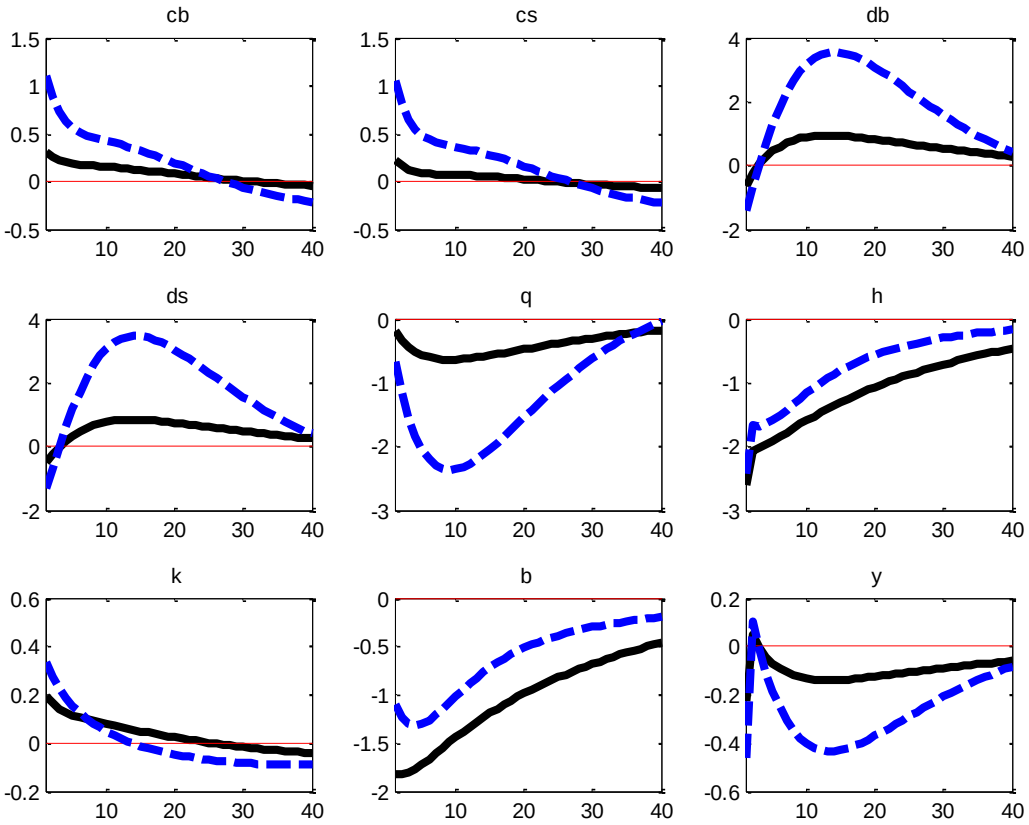

Figure 9 An increase in the portion of investment housing used in residential housing production against 20-percent-standard-deviation transfer tax shocks. The dashed line represents the case when $\alpha_H = 0.70$ and the solid line represents the case when $\alpha_H = 0.30$ (the benchmark model).