BANK OF CANADA
BANQUE DU CANADA

Working Paper/Document de travail
2009-15

Heterogeneous Beliefs and Housing-Market Boom-Bust Cycles in a Small Open Economy

by Hajime Tomura

Bank of Canada Working Paper 2009-15

May 2009

Heterogeneous Beliefs and Housing-Market Boom-Bust Cycles in a Small Open Economy

by

Hajime Tomura

Financial Stability Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
htomura@bankofcanada.ca

ISSN 1701-9397

Acknowledgements

I thank Jason Allen, James Chapman, Jonathan Chiu, Ian Christensen, Allan Crawford, Sharon Kozicki, Césaire Meh, Miguel Molico, Malik Shukayev and Yaz Terajima on earlier versions of the paper. Thomas Carter, David Xiao Chen and Frances Donald provided excellent research assistance and editorial support.

Abstract

This paper introduces heterogeneous beliefs among households in a small open economy model for the Canadian economy. The model suggests that simultaneous boom-bust cycles in house prices, output, investment, consumption and hours worked emerge when credit-constrained mortgage borrowers expect that future house prices will rise and this expectation is neither shared by savers nor realized ex-post. With sticky prices and a standard monetary policy rule, the model shows that the nominal policy interest rate and the CPI inflation rate decline during housing booms and rise as house prices fall. These results replicate the stylized features of housing-market boom-bust cycles in industrialized countries. Policy experiments demonstrate that stronger policy responses to inflation amplify housing-market boom-bust cycles. Also, higher loan-to-value ratios amplify housing-market boom-bust cycles by encouraging speculative housing investments by mortgage borrowers during housing booms and increasing liquidation of housing collateral during housing busts.

JEL classification: E44, E52
Bank classification: Credit and credit aggregates; Financial stability; Inflation targets

Résumé

L’auteur présente un modèle de petite économie ouverte pour le Canada dans lequel les croyances des ménages sont hétérogènes. Selon le modèle, des cycles simultanés d’envolée et d’effondrement des prix de l’immobilier résidentiel, de la production, de l’investissement, de la consommation et du nombre d’heures travaillées pourraient émerger si les emprunteurs hypothécaires ayant un accès limité au crédit s’attendent à une hausse des prix des maisons mais que ces attentes ne sont pas partagées par les épargnants et sont déçues par la suite. Le modèle montre qu’en présence de prix rigides et d’une règle standard de politique monétaire, le taux d’intérêt directeur nominal et le taux d’augmentation de l’indice des prix à la consommation diminuent durant un boom immobilier et augmentent lorsque les prix des maisons tombent. Ces résultats cadrent avec les grands traits des cycles d’essor et de contraction du marché du logement dans les pays industrialisés. D’après les simulations réalisées, une réaction plus vigoureuse de la politique monétaire face à l’inflation amplifie ces cycles. Un rapport prêt-valeur élevé les accentue aussi en incitant les emprunteurs hypothécaires à effectuer des investissements spéculatifs sur le marché du logement pendant le boom, de sorte que, quand elle se produit, la chute des prix des maisons entraîne une hausse des liquidations de garanties immobilières.

Classification JEL : E44, E52
Classification de la Banque : Crédit et agrégats du crédit; Stabilité financière; Cibles en matière d’inflation

1 Introduction

Significant declines in asset prices tend to follow strong booms in asset markets. The conduct of monetary policy during such boom-bust cycles has been a matter of policy debates. In earlier literature, Bernanke and Gertler (1999) argue that anti-inflationary monetary policy stabilizes output and inflation during asset-market boom-bust cycles, using a model in which boom-bust cycles are generated by exogenous deviations of the market price of capital from the 'fundamental' price of capital that would be implied by competitive equilibrium.[1] Also, Basant Roi and Mendes (2007) consider a similar type of exogenous boom-bust cycle in the housing market in a small open economy model for the Canadian economy. But without completely endogenizing the market prices of assets, these models do not fully take into account feedback from the conduct of monetary policy to asset prices. To analyze the effect of monetary policy during housing-market boom-bust cycles, this paper uses an alternative model in which housing-market boom-bust cycles emerge endogenously.

This paper considers a small open economy model for the Canadian economy. The model incorporates two types of households who respectively take and provide mortgage loans (i.e., borrowers and savers) as well as credit constraints such that households can borrow only up to the collateral value of their housing.[2] As the cause of housing-market boom-bust cycles, the model incorporates over-optimistic household expectations caused by noisy public signals of future fundamentals that are not realized ex-post. This approach follows the so-called "news shock" models.[3] While the previous literature assumes that households hold identical interpretations of public signals, this paper relaxes this assumption, allowing households to hold heterogeneous prior beliefs on the accuracy of public signals. This assumption lets the model incorporate the existence of heterogeneity in household expectations, which is well-established in empirical work using household survey data.[4] Also, the assumption of heterogeneous beliefs regarding the accuracy of public signals

[1] Using a similar model, Cecchetti, Genberg and Wadhwani (2003) disagree with Bernanke and Gertler (1999).

[2] Except for heterogeneous beliefs, the features of the model follow Iacoviello (2005).

[3] For example, see Beaudry and Portier (2004), Den Haan and Kaltenbrunner (2006), Jaimovich and Rebelo (2006), Floden (2007), Kobayashi, Nakajima and Inaba (2007), and Christiano, Ilut, Motto, and Rostagno (2007).

[4] For example, Mankiw, Reis and Wolfers (2004) document that disagreement in inflation expectations both among consumers

is a common feature among behavioural-finance models that analyze the joint behaviour of overpricing and trading volume in the stock market.[5] In this regard, this paper adds to the behavioural-finance literature by considering the effects of heterogeneous beliefs on house prices.

The model in this paper shows that if credit-constrained borrowers expect that future house prices will rise and this expectation is not shared by savers or realized ex-post, then the equilibrium dynamics of the model replicate the stylized pattern of housing-market boom-bust cycles in industrialized countries, that is, house prices, output, consumption, investment and hours worked have tended to co-move during housing-market boom-bust cycles, while the nominal policy interest rate and the CPI inflation rate have tended to fall during housing booms and rise as house prices fell. The model explains these features of housing-market boom-bust cycles as follows: When borrowers expect that future house prices will rise, they increase housing investments, which causes a housing boom. Since borrowers are credit-constrained, they work more to finance their housing investments during the boom. At the same time, when savers do not share the optimistic expectations of borrowers, they instead expect the boom to be temporary and increase savings for a future recession. The increases in labour supply and savings reduce real wages and the real interest rate, respectively. Given sticky prices, a resulting fall in the marginal cost of production lowers the inflation rate, and, in response to this, the central bank cuts the policy rate. When the optimistic expectations of borrowers are not realized ex-post, however, a housing bust occurs. In response, savings and labour supply decline. As a consequence, the inflation rate rises, inducing a monetary policy tightening. Policy experiments in the model demonstrate that greater anti-inflationary weight in the monetary policy rule amplifies boom-bust cycles in housing markets, since it enhances the counter-cyclical movements in the nominal policy interest rate during housing-market boom-bust cycles.

The model assumes that credit-constrained borrowers have higher elasticity of labour supply than savers.

---

and professional economists varies through time.

[5] Investors are assumed to hold heterogeneous beliefs on the accuracy of public signals of the future fundamental value of stocks. When a public signal is observed, optimistic investors buy shares from pessimistic investors. Thus, the upward dynamics of asset prices is generated by the beliefs of the optimistic investors, and the overpricing is accompanied by the flow of trade from the pessimistic investors to the optimistic investors. See Hong and Stein (2007) for a recent survey of the literature.

This assumption is motivated by two observations in data: mortgage borrowers tend to be young, while old households own a large fraction of financial assets in the economy; and young households show higher volatility of hours worked than old households.[6] In this regard, heterogeneous expectations between borrowers and savers in the model are related to heterogeneous expectations between different age groups. In fact, given this interpretation, the result of the model that housing booms occur when borrowers become more optimistic than savers is consistent with the observation that the real house price growth rate has been positively correlated with the difference of household expectations of young households from those of old households. Also, the main role played by labour supply in the model is consistent with the pro-cyclicality of total hours worked during housing boom-bust episodes in industrialized countries as well as the observation that the hours worked of young households have been more strongly correlated with real house prices than the hours worked of old households have.

In the related literature, Piazzesi and Schneider (2008) quantify the effect of heterogeneous expectations between different age groups on household portfolio choice and asset prices by imposing household expectation survey data on an overlapping generations model. While the direct use of survey data is one of the strengths of their analysis, they must take household expectations as exogenous in the model. In this paper, household expectations are endogenous to parameters in the model. This feature of the model ensures that policy experiments take into account the responses of household expectations to policy changes.

Also, the model in this paper suggests that higher loan-to-value ratios amplify housing-market boom-bust cycles by encouraging speculative housing investments by credit-constrained borrowers. This result contrasts with preceding dynamic equilibrium models with credit-constrained borrowers considered by Iacoviello (2005) and Kiyotaki, Michaelides and Nikolov (2007), which find that the loan-to-value ratio does not significantly alter aggregate house-price dynamics.

The rest of the paper is organized as follows. Section 2 summarizes the cross-country evidence on the stylized features of housing-market boom-bust cycles in Canada and other industrialized countries and

[6]See Meh and Terajima (2008) for detailed analysis of wealth distribution among Canadian households. See Section 4 in this paper for more details on the volatility of hours worked.

suggestive evidence for the effect of heterogeneous beliefs on house prices in Canadian and U.S. data. Section 3 describes the model. Section 4 explains the solution method and parameter specification. Section 5 presents the main results. Section 6 conducts policy experiments and sensitivity analysis. Section 7 investigates the effects of public signals of future shocks to monetary policy, the real world interest rate and export demand. Section 8 concludes.

2 Stylized features of housing-market boom-bust cycles

2.1 Cross-country evidence

Ahearne, et al. (2005) document the median dynamics of macroeconomic indicators around the peaks of housing-market boom-bust cycles in industrialized countries from 1973 to 2000. They find that output, consumption and investment have tended to positively co-move with real house prices during boom-bust cycles, while the nominal policy interest rate and the CPI inflation rate have tended to decline during housing booms and rise as house prices fell. Also, Ahearne, et al. find that the stylized relationship between house prices and the nominal policy interest rate is broadly similar between the pre-1985 and the post-1985 sub-sample periods.

Figure 1 reproduces the charts 3.1-3 reported by Ahearne, et al. for the real GDP growth rate, the CPI inflation rate, and the nominal policy interest rate over the entire sample period, 1973-2000, following their data appendix. The panels in the figure are not completely identical with their charts, since for the nominal policy interest rate and the CPI inflation rate, I take the medians of the changes in the variables from 5 years before the peaks of housing booms, while Ahearne, et al. show the medians of the levels of these variables, which are not stationary over time. Also, for the CPI inflation rate, Ahearne, et al. use the rates targeted by central banks if exist, while I use total CPI inflation rates. See data appendix in this paper for more details on the methodology.

Adding to the finding of Ahearne, et al., I conduct a similar exercise for total hours worked in Figure 1. The panel shows the hours worked index constructed from the medians of hours worked growth rates. It indicates that total hours worked have tended to grow strongly during housing booms and decline significantly during housing busts.

Figure 2 extracts the episodes of housing-market boom-bust cycles in Canada from the cross-country data. According to the definition used by Ahearne, et al., Canada has experienced three house-price peaks since the 1970s: in 1976, 1981 and 1989. The last two boom-bust episodes display the features commonly shared among cross-country data. More specifically, in the last two episodes, real house prices co-moved with the output and hours worked. As in the cross-country evidence, the policy rate and the inflation rate showed noticeable increases around the house-price peaks.[7]

Figure 3 shows that the behaviour of the inflation rate during the boom-bust episode around 1989 depends on the inclusion of shelter costs in the CPI. The inflation rate of the total CPI, which includes shelter costs, tended to be stationary during the housing boom. In contrast, the exclusion of shelter costs from the CPI was associated with a decline in the inflation rate during the housing boom. In Section 6.3, I will discuss why the behaviour of the inflation rate depends on the exclusion of shelter costs from the CPI.

2.2 Suggestive evidence for the effects of heterogeneous beliefs on house prices

The model in this paper will indicate that house prices would rise with over-optimism of credit-constrained borrowers compared to savers and that the labour supply of credit-constrained borrowers would be pro-cyclical during housing-market boom-bust cycles. In this section, I discuss suggestive evidence for these results from data on the hours worked and the expectations of young and old households. I focus on different age groups, since credit-constrained borrowers who take mortgage loans tend to be young and savers who provide mortgage loans through financial intermediaries tend to be old. This section describes two empirical findings: the hours worked of young households co-move with house prices more closely than those of old households do; and the real house price growth rate positively responds to the difference of a household

[7] On the other hand, the dynamics around the house-price peak that occurred in 1976 did not clearly show the stylized pattern identified by Ahearne, et al. This might be because the boom-bust cycle that took place in 1976 was immediately followed by another boom-bust cycle. Thus, the dynamics during the bust period after 1976 were also influenced by economic factors behind the housing boom that peaked in 1981.

expectation index for the young from that for the old.

2.2.1 Positive correlations between house prices and hours worked of young households

Figure 4 compares the real house price index and the hours worked of young and old households in Canada. It shows that the average hours worked of young households (less than 45 years old) rose and fell with housing booms and busts, respectively, around 1980 and 1990, while the average hours worked of old households (45-65 years old, and 45 years old and over) did not show such a clear correlation with house prices in those periods. Note that the average hours worked in the figure are hours worked per population per week for each age group, which include both intensive and extensive margins. Correlations between house prices and hours worked reported in Table 1 confirm the implications of Figure 4. In Table 1, since the U-shape development of the hours worked of old households may reflect long-term demographic and institutional changes, I consider different ways of time de-trending, including no de-trending, for hours worked. The table shows that the average hours worked of young households are more positively correlated with linearly de-trended real house prices than those of old households are, regardless of the type of de-trending for hours worked.

2.2.2 Positive response of the real house price growth rate to over-optimism of young households compared to old households

Next, I examine the responses of house prices to the differences in expectations between young and old households. For a proxy to household expectations, I construct an index of household expectations of future economic conditions from a subset of the survey data from the Conference Board of Canada that are used for constructing the Index of Consumer Confidence. More specifically, there are two questions about future economic conditions among the four overall survey questions:

- considering everything, do you think that your family will be better off, the same or worse off financially six months from now?
- how do you feel the job situation and overall employment will be in this community six months from now?

Following the methodology for constructing the Index of Consumer Confidence, I derive an index of household expectations by adding the percentage of positive responses and subtracting the percentage of negative responses for each question. Thus, higher values of the index indicate more optimistic views of households. I measure the over-optimism of young households compared to old households by the difference of the index for young households (less than 45 years old) from the index for old households (45 years old and over), and regress the real house price growth rate on this difference as well as lagged dependent variables, the average index of household expectations for all ages, the real GDP growth rate and the real interest rate. I estimate the coefficients by OLS, assuming that unobserved house price shocks are orthogonal to the difference in the index of household expectations. Due to availability of the survey data for age groups, the sample period is for 1990:4-2007:1.

Table 2 shows the regression results. There are three regressions with different sets of regressors. In each regression, the lag-2 difference of the index of household expectations for the young from the old shows a statistically significant positive effect on the real house price growth rate. Even though the contemporaneous difference in the index has negative coefficients in Regressions 1 and 2, the coefficient becomes insignificant when I consider the full set of regressors, adding the average index of household expectations for all ages.

Note that the household expectation survey data for age groups in Canada are available only for the recent period, so that the sample period for the regressions has to be short. Also the horizon of the questions is 6 month, which is short, too. These properties of the regressions may affect the regression results. To circumvent these problems, I look at U.S. data in addition. In U.S., the University of Michigan Surveys of Consumers provide the Index of Consumer Expectations for age groups for a longer sample period from 1978. The horizons of the questions that the Index is based on are 1 and 5 years, depending on each question. Figure 5 compares the real house price growth rate and the difference of the Index of Consumer Expectations for young households (less than 45 years old) from that for old households (45 years old or more) in U.S. The figure shows that the two series have co-moved very closely, especially before the mid 1990s. Tomura (2009) reports that in fact the contemporaneous difference in the Index of Consumer Expectations between the young and the old has robustly significant positive effects on the real house price growth rate in regressions similar to those considered in Table 2.

3 Model

This paper explains the stylized macroeconomic dynamics around house-price peaks documented above, using a small open economy model featuring Canada. The model includes two types of households who take and provide mortgage loans, as well as collateral constraints on residential mortgages as in Iacoviello (2005). I introduce public signals of future economic conditions, allowing the two types of households to disagree on the accuracy of public signals, which generates heterogeneous expectations. The model also incorporates monopolistic firms producing intermediate inputs, a representative firm producing final goods, and a monetary authority.

3.1 Production

Final good production. There is a representative firm that acts in a perfectly competitive market and uses composite domestic and imported inputs to produce final goods, y_t, according to the following CES technology:

$$y_t = \left\{(1-\omega)^{\frac{1}{\theta}} (y_{D,t})^{\frac{\theta-1}{\theta}} + \omega^{\frac{1}{\theta}} (y_{M,t})^{\frac{\theta-1}{\theta}}\right\}^{\frac{\theta}{\theta-1}}, \tag{1}$$

where

$$y_{i,t} = \left[\int_0^1 y_{i,t}(j)^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}} \qquad \text{for } i = D, M. \tag{2}$$

Domestic inputs are denoted by D, and imported inputs are denoted by M. The parameter $\omega > 0$ denotes the share for imported inputs in the production of final goods, and $\theta > 0$ is the elasticity of substitution between different intermediate inputs.

The resulting demand function for the intermediate inputs is

$$y_{i,t}(j) = \left(\frac{P_{i,t}(j)}{P_{i,t}}\right)^{-\theta} y_{i,t} \tag{3}$$

for $i = D, M$. Cost minimization for the final-good firm entails the following demand curves for $y_{D,t}$ and

$y_{M,t}$:

$$y_{D,t} = \left(\frac{P_{D,t}}{P_t}\right)^{-\theta} (1-\omega) y_t \tag{4}$$

$$y_{M,t} = \left(\frac{P_{M,t}}{P_t}\right)^{-\theta} \omega y_t, \tag{5}$$

where the price indices for domestic and imported intermediate inputs are defined by

$$P_{i,t} = \left(\int_0^1 P_{i,t}(j)^{1-\theta} dj\right)^{\frac{1}{1-\theta}}$$

for $i = D, M$. The domestic aggregate price level, P_t, is defined by

$$P_t = \left[(1-\omega) P_{D,t}^{1-\theta} + \omega P_{M,t}^{1-\theta} dj\right]^{\frac{1}{1-\theta}}. \tag{6}$$

Final goods can be consumed, invested into capital stock or exported abroad.

Intermediate inputs. There is a continuum of firms indexed by $j \in [0,1]$ that monopolistically produce $y_{D,t}(j)$ units of each domestic intermediate input according to a standard Cobb-Douglas function:

$$y_{D,t}(j) = (k_t(j))^{\alpha} (A_t l_t(j))^{1-\alpha}, \tag{7}$$

where $k_t(j)$ is the amount of capital stock, $l_t(j)$ is units of labour and $\alpha \in (0,1)$ is the constant share of capital in production. A_t denotes labour augmenting technology. The monopolistic firms can only infrequently adjust the prices of their products with probability $1-\chi$ every period. When adjusting the price, each firm maximizes the present discounted value of profits while the price remains fixed:

$$\max_{P_{D,t}(j)} E_t' \left[\sum_{s=t}^{\infty} \chi_{s-t} \Lambda_{t,s} \left(\frac{\Pi_{D,s}(j)}{P_s}\right)\right], \tag{8}$$

subject to the demand function (3). E_t' and $\Lambda_{t,s}$ are the subjective conditional expectation operator for firms and the firms' discount factor between periods t and s, respectively. The expectation operator and the discount factor are identical to those of the share holders of firms that will be described below. Firms' profits in real terms are given by

$$\frac{\Pi_{D,s}(j)}{P_s} = \left[\frac{P_{D,s}(j)}{P_s} - f_s\right] y_{D,s}(j), \tag{9}$$

where

$$f_s \equiv \left(\frac{r_{K,s}}{\alpha}\right)^{\alpha} \left[\frac{w_s}{(1-\alpha)A_s}\right]^{1-\alpha}, \tag{10}$$

which is the marginal cost of production for domestic inputs implied by competitive factor markets and the production function (7).

Each variety of imported inputs is supplied to the domestic market by a monopolistic importing firm. Importers buy homogeneous foreign goods at a unit cost of $e_t P_t^*$ for a given nominal exchange rate, e_t, and foreign price level, P_t^*. Thus the real exchange rate, s_t, becomes the real acquisition price of imported goods. Importers produce each variety of imported intermediate inputs, $y_{M,t}(j)$, from homogeneous foreign goods via one-to-one transformation. Each monopolistic importer sets the price $P_{M,t}(j)$ of each variety of imported inputs. As in the domestic intermediate inputs sector, each importer faces a constant probability $1-\chi$ of being allowed to change her price, solving a similar problem to (8):

$$\max_{P_{M,t}(j)} E_t' \left[\sum_{s=t}^{\infty} \chi_{s-t} \Lambda_{t,s} \left(\frac{P_{M,s}(j)}{P_s} - s_s\right) y_{M,s}(j)\right], \tag{11}$$

subject to the demand function (3).

3.2 Households

I consider two types of households that differ in terms of the subjective discount factor: one type of household has a higher time-discount rate than the other. Following Iacoviello (2005), I characterize the former type as ‘patient’, and the latter type as ‘impatient’. The two types of households are of mass $\mu \in (0,1)$ and $1-\mu$, respectively. As described below, the heterogeneity in time discount rates implies that patient households provide mortgage loans to impatient households in the neighbourhood of the deterministic steady state. I also assume collateral constraints on residential mortgages. As home-buyers who take mortgage loans tend to be young and savers who provide mortgage loans tend to be old, patient and impatient households can be interpreted as reduced-form representations of young and old households, respectively. See Meh and Terajima (2008) for detailed analysis of wealth distribution among Canadian households. Given this interpretation, I allow the elasticity of labour supply of impatient households to differ from that of patient households.

This assumption is consistent with the empirical observation that the volatility of labour supply is higher for younger households. Overall, the model incorporates two types of households who are heterogeneous in three dimensions: borrowing and lending behaviour, the elasticity of labour supply, and expectations.

Patient Households. Each patient household, denoted by ($'$), derives utility from consumption, c'_t, and housing services provided by the housing stock, h'_t, and disutility from supplying labour, l'_t. This is specified by the following utility function:

$$E'_t \left\{ \sum_{s=t}^{\infty} \beta'^{s-t} \left[\ln(c'_s) + \gamma \ln(h'_s) - \frac{\eta (l'_s)^{1+\xi'}}{1+\xi'} \right] \right\}, \tag{12}$$

where E'_t is the subjective conditional expectation operator for patient households, β' is the time-discount rate, and γ, η, $\xi' > 0$. The patient household's budget constraint is given by

$$c'_t + q_t \Delta h'_t + s_t \left(b'_{F,t} - r_{F,t-1} b'_{F,t-1} \right) + \frac{\zeta_B}{2} (b'_{F,t})^2 + \tilde{\zeta}_K(i'_t, k'_{t-1}) + b'_{D,t} = w_t l'_t + r_{k,t} k'_{t-1} + \frac{b'_{D,t-1} R_{t-1}}{E'_{t-1} \pi_t} + \Gamma_t, \tag{13}$$

where i'_t is investment in capital stock, k'_t is the end-of-period value of capital stock, $\Delta h'_t = h'_t - h'_{t-1}$ is the change in housing stock, $b'_{F,t}$ is foreign bonds denominated in foreign currency, $b'_{D,t}$ is the supply of mortgage loans to impatient households, q_t is the real price of housing stock, s_t is the real exchange rate, $r_{F,t}$ is the gross real world interest rate, w_t is the real wage, $r_{k,t}$ is the real rental price of capital stock, R_t is the gross nominal interest rate, π_t is the gross domestic inflation rate of final goods, that is, P_t/P_{t-1}, and Γ_t is the sum of the profits from the monopolistic domestic-input producers and importers.[8] On the left-hand side of (13), I consider an adjustment cost on foreign bond holdings, $(\zeta_B/2)(b'_{F,t})^2$, where $\zeta_B > 0$, which ensures that dynamics around the steady state are stationary in the equilibrium analysis presented below.[9] I also assume an adjustment cost on the installation of capital of the following form:

$$\tilde{\zeta}_K(i'_t, k'_{t-1}) = \frac{\zeta_K}{2} \left(\frac{i'_t}{k'_{t-1}} \right)^2 k'_{t-1}, \tag{14}$$

where $\zeta_K > 0$. In the equilibrium analysis below, the existence of the capital adjustment cost will explain co-movement between consumption and investment. On the right-hand side of (13), the nominal interest

[8] Note that money balance does not appear either in the utility function or in the budget constraint. This is equivalent to considering a 'cashless' economy where real money balance enters the utility function in an additive term every period but the real and nominal money balances are so infinitesimal that they do not affect the budget constraint.

[9] See, e.g., Schmitt-Grohé and Uribe (2003) for further details.

rate is divided by the expected inflation rate in the previous period. I assume that domestic bonds are indexed and guarantee the repayment in real terms. I consider indexed loans, rather than nominal loans, to focus on a minimal set of nominal rigidities.

Patient households control the domestic-input firms and the importers as share holders. Hence I assume $\Lambda_{t,s} = (\beta'^{s-t} c'_t / c'_s)$, and that the domestic-input firms, the importers and patient households share the identical subjective conditional expectation operator, E'_t. These assumptions ensure that the domestic-input firms and the importers behave as if they maximize the utility function of patient households.

Impatient Households. Impatient households, denoted by ($''$), maximize the utility function

$$E''_t \left\{ \sum_{s=t}^{\infty} \beta''^{s-t} \left[\ln(c''_s) + \gamma \ln(h''_s) - \frac{\eta (l''_s)^{1+\xi''}}{1+\xi''} \right] \right\}, \tag{15}$$

subject to the following budget and collateral constraints:[10]

$$c''_t + q_t(h''_t - h''_{t-1}) + b''_{D,t} = w_t l''_t + \frac{R_{t-1} b''_{D,t-1}}{E'_{t-1}\pi_t} \tag{16}$$

$$\frac{R_t b''_{D,t}}{E'_t \pi_{t+1}} \geq -m E'_t \left[q_{t+1} h''_t \right]. \tag{17}$$

As in Iacoviello (2005), the collateral constraint (17) implies that impatient households can only borrow up to the collateral value of their housing stock.[11] Since impatient households value current consumption more than patient households, it is possible to show that impatient households borrow up to the limit in the neighborhood of the deterministic steady state.[12] The collateral value of housing is determined by expectations of lenders, who are patient households in the neighbourhood of the deterministic steady state, and the parameter m, representing the maximum loan-to-value ratio for residential mortgages.

[10]The budget constraint (16) implies that impatient households do not invest in capital. This assumption lets me abstract me from considering the allocation of capital stock between the two types of households, given the convex investment cost.

[11]See Kiyotaki and Moore (1997) for the bargaining environment behind the collateral constraint. I assume that borrowers can renegotiate debt contracts only before the realization of aggregate shocks in the next period, so that lenders can seize borrowers' labour income in period $t+1$ if their debts exceed the value of the collateral after the realization of shocks.

[12]See Iacoviello (2005) for the details.

3.3 Monetary policy

I assume that the central bank follows a simple interest-rate rule in the form:

$$\widehat{R}_t = \phi_R \widehat{R}_{t-1} + (1-\phi_R)\phi_\pi \widehat{dCPI}_t + (1-\phi_R)\phi_Y \widehat{GDP}_t + \psi_t, \tag{18}$$

where ϕ_R is a smoothing-term parameter, ϕ_π and ϕ_Y determine the responses of the nominal policy interest rate to CPI inflation and real GDP, respectively, and ψ_t is an i.i.d. monetary policy shock. The variables denoted by the hat symbol "$\widehat{\ }$" are the log deviations from the steady state values. Here I assume that the monetary policy rule does not include the expected value of the future inflation rate or future output. This type of monetary policy rule is standard in the literature, and also lets the model abstract from specifying the formation of subjective expectations of the central bank.

On the right-hand side, GDP_t denotes real GDP and $dCPI_t$ denotes the CPI inflation rate. Real GDP is the value of domestic production, which equals $P_{D,t}y_{D,t}/P_t$. The CPI inflation rate is defined as

$$\begin{aligned} dCPI_t =& \frac{(1-\lambda)\frac{P_t}{P_{SS}} + \lambda \frac{P_t r_{h,t}}{P_{SS} r_{h,SS}}}{(1-\lambda)\frac{P_{t-1}}{P_{SS}} + \lambda \frac{P_{t-1} r_{h,t-1}}{P_{SS} r_{h,SS}}} \\ =& \pi_t \cdot \frac{(1-\lambda) + \lambda \frac{r_{h,t}}{r_{h,SS}}}{(1-\lambda) + \lambda \frac{r_{h,t-1}}{r_{h,SS}}}, \end{aligned} \tag{19}$$

where P_t is the nominal price of final goods, λ is the fixed weight on the housing-rent components of the CPI, and $r_{h,t}$ is the real value of the housing-rent components of the CPI. The subscript SS denotes steady state values. I use the steady-state values for the base-year values of the price indices for housing rent and final goods.

The housing-rent components of the CPI, $r_{h,t}$, move only slowly in the data possibly due to rent-ceiling regulations and the fact that the mortgage interest cost in the CPI is affected by long-term mortgage contracts. Figure 6 shows that despite the steady appreciations in house prices in the 2000s, the inflation rate of the housing-rent components of the CPI has been persistently lower than the rate of growth of the nominal house price index. I take this into account by considering two alternative reduced-form specifications:

$$\widehat{r}_{h,t} = \kappa \widehat{q}_t \tag{20}$$

or

$$\widehat{r}_{h,t} = \kappa \widehat{u}_t, \tag{21}$$

where

$$u_t \equiv q_t - \frac{E'_t\left[\pi_{t+1} q_{t+1}\right]}{R_t}. \tag{22}$$

In both specifications (20) and (21), κ is an exogenous parameter that controls for the elasticity of the housing-rent components of the CPI. This parameter will be calibrated to Canadian data as described below. In the specification (20), it is assumed that the housing-rent components of the CPI co-move with house prices. In the specification (21), I consider the user cost of housing for patient households as a proxy to the housing-rent components of the CPI.[13] The strength of the specification (21) is that u_t is closer to the concept of rent than q_t. The weakness is that it is difficult to estimate household expectations in order to construct the user cost of housing and calibrate the value of κ. In this regard, the specification (20) is more straight-forward and convenient. In the equilibrium analysis below, I find that the main results of the model do not depend on the housing-rent specification adopted in the analysis.

3.4 Market-clearing conditions

In each period, the following market clearing conditions are satisfied for labour, capital stock, housing stock and mortgage loans, respectively:

$$\mu l'_t + (1-\mu) l''_t = \int_0^1 l_t(j)dj \tag{23}$$

$$\mu k'_{t-1} = \int_0^1 k_t(j)dj \tag{24}$$

$$\mu h'_t + (1-\mu) h''_t = 1 \tag{25}$$

$$\mu b'_t + (1-\mu) b''_t = 0, \tag{26}$$

[13] If I consider the user cost of housing for impatient households, then u_t declines in the peak of the housing boom due to strong expectations of house-price appreciations by impatient households. I avoid this by considering the user cost of housing for patient households.

I assume a fixed supply of housing stock (i.e. land) normalized to 1. Note that $l_t(j)$ and $k_t(j)$ are the labour and the capital demand, respectively, by the domestic-input firm of the variety j. The second equation implies that the capital stock available for production in the current period must be formed in the previous period. Factor demand, $\{k_t(j), l_t(j)\}_{j\in[0,1]}$, is determined by the first-order conditions implied by cost minimization of the domestic-input firms:

$$k_t(j) = \frac{\alpha f_t\, y_t(j)}{r_{K,t}} \tag{27}$$

$$l_t(j) = \frac{(1-\alpha) f_t\, y_t(j)}{w_t}. \tag{28}$$

3.5 Balance of payment

The trade balance must equal the economy-wide net saving, so that

$$y_{X,t} - s_t y_{M,t} = \mu s_t \left(b'_{F,t} - r_{F,t-1} b'_{F,t-1}\right). \tag{29}$$

In order to close the model, the export demand must be specified. I assume the following simple reduced-form function:

$$y_{X,t} = (s_t)^{\tau} Y_{F,t}, \tag{30}$$

where $\tau > 0$ is the elasticity of the home country's aggregate exports and $Y_{F,t}$ is an export demand shock that summarizes business conditions in the rest of the world. As a rise in s_t implies depreciation, the positive value of τ ensures that export demand rises as the home currency depreciates.

3.6 Shock processes, public signals and heterogeneous expectations

I assume that labour augmenting technology, A_t, the world interest rate, $r_{F,t}$, the export demand shock, $Y_{F,t}$, and the monetary policy shock, ψ_t, follow AR(1) processes. I denote the deterministic steady-state values of $r_{F,t}$ and $Y_{F,t}$ by $\overline{r_F}$ and $\overline{Y_F}$, respectively. Each shock process for $x_t \in \{\ln(A_t),\ \ln(r_{F,t}/\overline{r_F}),\ \ln(Y_{F,t}/\overline{Y_F}),\ \psi_t\}$ is defined by

$$x_t = \rho_x x_{t-1} + \varepsilon_{x,t}, \quad \varepsilon_{x,t} \backsim \text{ i.i.d. } N(0, \sigma^2_{\varepsilon_x}),\ 0 < \rho_x < 1, \tag{31}$$

where ρ_x is an autoregressive coefficient vector and $\varepsilon_{x,t}$ is an uncorrelated and normally distributed innovation with zero mean and standard deviation σ_{ε_x}.

Households receive a public signal $s_{x,t}$ of a future shock $\varepsilon_{x,t+n}$ for each x_t. The signal of each shock is generated by the following process:

$$s_{x,t} = \varepsilon_{x,t+n} + \omega_{x,t}, \tag{32}$$

where $\omega_{x,t}$ is an uncorrelated and normally distributed innovation with zero mean and standard deviation ν_x^2.

I assume that each type of household holds a time-invariant belief on the value of ν_x, regardless of the realization of shocks, $\varepsilon_{x,t}$. I denote the beliefs of patient and impatient households by $\nu_x^{'}$ and ν_x'', respectively.[14] I can show that the subjective conditional expectations of future shocks are given by

$$E'[\varepsilon_{x,t+n}|s_{x,t}] = \frac{\sigma_{\varepsilon_x}^2 s_{x,t}}{\sigma_{\varepsilon_x}^2 + (\nu_x')^2}, \tag{33}$$

$$E''[\varepsilon_{x,t+n}|s_{x,t}] = \frac{\sigma_{\varepsilon_x}^2 s_{x,t}}{\sigma_{\varepsilon_x}^2 + (\nu_x'')^2}. \tag{34}$$

Thus, public signals generate heterogeneous expectations of future economic conditions between households. This assumption of time-invariant heterogeneous beliefs is motivated by a vast strand of the behavioural finance literature that analyzes the joint behaviour of stock prices and trading volume in the stock market. See Hong and Stein (2007) for a survey.

3.7 Equilibrium conditions

Equilibrium conditions are defined as follows. Every period t, $\{c_s', h_s', l_s', b_s', i_s'\}_{s=t}^{\infty}$ solves the maximization problem for patient households, $\{c_s'', h_s'', l_s'', b_s''\}_{s=t}^{\infty}$ solves the maximization problem for impatient households, and $P_{i,t}(j)$ for $i = D, M$ and $j \in [0,1]$ solves the maximization problem for the domestic-input firm or the importer if the price can be adjusted in period t. Otherwise, $P_{i,t}(j)$ equals $P_{i,t-1}(j)$. $\{w_t, r_{K,t}, q_t, f_t, y_t, P_t, R_t, \Gamma_t\}$ is determined to satisfy the market clearing conditions (23)-(26) and the balance of payment (29) with the definition of each variable specified above. Households hold rational expectations of the

[14] As described above, the domestic-input firms and the importers share the same beliefs with patient households.

determination of $\{w_s,\, r_{K,s},\, q_s,\, f_s,\, y_s,\, P_s,\, R_s,\, \Gamma_s\}_{s=t}^{\infty}$ conditional on each realization of shocks and public signals. However, households form the subjective likelihood of the realization of future shocks on the basis of their time-invariant beliefs on the accuracy of public signals.

4 Solution method and parameter specification

In the following analysis, I will consider different sets of values of $(\nu_x^{'}, \nu_x^{''})$ for each shock x_t, seeking the specification that replicates the stylized pattern of housing-market boom-bust cycles described in Section 2.

I solve equilibrium dynamics by log-linearizing the equilibrium conditions described above around the deterministic steady state. I derive the solution to the log-linearized equilibrium conditions by the undetermined coefficient method. See Tomura (2009) for more details on the solution method.

I calibrate the model parameters to Canadian data. See data appendix for data source details. The unit of time in the model is a quarter. Table 3 shows the baseline parameter values. The capital share of income, α, is calculated from the standard method as described in data appendix. Since housing services are separated from the other value-added components in the model, α equals 0.26, which is smaller than the standard value used in the literature. The depreciation rate, δ, is 0.025, which is the average depreciation rate of non-residential capital stock. The import share of final good production, ω, is 0.3, which equals the share of the nominal value of imports in final domestic demand. Following the description of the Canadian mortgage market by Christensen, et al. (2008), the loan-to-value ratio for residential mortgages, m, is set to 0.75. The probability of price-adjustment, χ, is 0.5. This value is in accordance with Amirault, Kwan and Wilkinson (2004), who report that half of the Canadian firms changed their prices at least once every quarter during their survey period.

For the construction of the CPI, the weight on the housing-rent components, λ, is 0.218, which is taken from the Canadian CPI. In the baseline calibration, we adopt the specification (20) for determining the housing-rent components of the CPI. The parameter that controls for the elasticity of the housing-rent components of the CPI, κ, is 0.292, which is the correlation between the log-difference of the weighted sum of the housing-rent components of the CPI and the log-difference of the house price index.

For the following parameters, I adopt standard values used in the literature. The lead of public signals, n, is assumed to be 4 periods, which is standard in the news shock literature. As in Iacoviello (2005), the time discount rates of patient households (β') and impatient households (β'') equal 0.99 and 0.95, respectively. The fraction of credit-constrained households, $1-\mu$, is 0.2, which is the lower-bound of the estimate reported by Benito and Mumtaz (2006) for UK data. This value is a conservative assumption, since it is lower than the labour income share for credit-constrained households estimated by Christensen, et al. (2008) using Canadian data.[15] The cost of access to international credit markets, ζ_B, is assumed to be $1e-06$. The only purpose of imposing this cost is to make the equilibrium dynamics stationary around the deterministic steady state. The elasticity of substitution between varieties of inputs, θ, is 6, which implies a mark-up rate between 15 and 20 percent. The elasticity of export demand to the real exchange rate, τ, is 0.8. For these values of θ and τ, I follow Dib (2008), which estimates a small open economy model using Canadian data. Also for the monetary policy rule parameters, that is, ϕ_R, ϕ_π and ϕ_Y, I use the estimates reported by Dib (2008).[16]

I separately estimate the AR(1) coefficient of the shock process for labour augmenting technology, A_t, by OLS and those for the real world interest rate, $r_{F,t}$, by ML. I take the standard errors of the estimations for the values of σ_{ε_A} and $\sigma_{\varepsilon_{r_F}}$. In the regression, labour augmenting technology is log-linearly de-trended. For the real world interest rate, I use the U.S ex-post real 90-day treasury bill rate. I allow for structural breaks in the mean level of the interest rate (i.e. the constant term in the regression) and jointly estimate the structural breaks and the AR(1) coefficient using the method developed by Bai and Perron (1998).[17] The monetary policy shock is assumed to be i.i.d., so that ρ_ψ is 0. I adopt the standard deviation of the

[15] Christensen, et al. (2008) estimate an open economy version of the model presented in Iacoviello (2005), using Canadian data.

[16] Even though I have separately estimated the monetary policy rule with Canadian data, the estimation result implies that ϕ_π is almost zero. As this is not consistent with the inflation-targeting behaviour of the Bank of Canada, I use the estimates of Dib (2008).

[17] Garcia and Perron (1996) and Rapach and Wohar (2005) empirically identify structural breaks in the mean of the U.S ex-post real interest rates. I use the GAUSS code provided by Bai and Perron (2003) for the estimation in this paper.

monetary policy shock, σ_ψ, estimated by Dib (2008).

The deterministic steady-state value of the real world interest rate, $\overline{r_F}$, equals $1/\beta'$ so that trade is balanced at the steady state. The deterministic steady-state value of the export demand shock, $\overline{Y_F}$, is set to the level where the real price indices of domestic and imported inputs at the steady state are equal to each other, i.e. $P_D/P = P_M/P$.[18]

Given the parameter values described above, the value of γ is calibrated to match the ratio of the nominal aggregate housing value to quarterly nominal GDP at the steady state.[19] The values of ζ_K, ξ', ξ'', ρ_{Y_F} and σ_{Y_F} are chosen to minimize the sum of mean squared percent differences of the following second moments between the model and data: the standard deviations of average hours worked for young and old households; the standard deviation of total hours worked for all the households; the standard deviation of the CPI inflation rate; and the standard deviation and the lag-1 autocorrelation of de-trended real GDP. All the standard deviations except for de-trended GDP are divided by the standard deviation of de-trended GDP. I choose these moments as the target since ξ' and ξ'' determine elasticities of labour supply, and ζ_K, ρ_{Y_F} and σ_{Y_F} affect the persistence and the volatility of business fluctuations and the inflation rate.[20] Table 4 compares the second moments delivered by the model with those in the data. Since housing-market boom-bust cycles are infrequent events, I use the model without public signals when calculating the second moments of the model.

[18]This is ensured by setting the real exchange rate, s_t, equal to the marginal cost of production, f_t, at the steady state. The value of $\overline{Y_F}$ is a residual used to adjust the value of exports to satisfy the balanced trade.

[19]Precisely speaking, the values of γ, ζ_K, ξ', ξ'', ρ_{Y_F} and σ_{Y_F} jointly replicate the first and second moments listed in this paragraph. Given a value of γ, the ratio of aggregate housing value to quarterly GDP varies only slightly with the rest of four parameter values.

[20]I find the volatility of private business investment is not responsive to ζ_K. I choose the volatility of the inflation rate instead in order to replicate the nominal feature of the data.

5 Dynamics with heterogeneous beliefs on the accuracy of public signals: Technological Shocks

In what follows, I analyze the dynamics of the model in response to public signals when borrowers and lenders hold heterogeneous beliefs. I first show the equilibrium dynamics in response to a public signal of future technological progress, that is, an increase in A_{t+n}. The findings suggest that the stylized pattern of housing-market boom-bust cycles emerges if impatient households expect that future house prices will rise and this expectation is neither shared by patient households nor realized ex-post. I will describe the effects of the other types of signals in section 7.

5.1 Response to realized technological progress

Figure 7 shows the effects of a positive shock to current technology, A_t, in period 0. In this case, patient households increase their savings to consume part of the increased income in the future. This lowers the real interest rate, reducing the financing cost of housing investments. This development generates an appreciation in house prices. Thus, a public signal of a positive future technological shock implies that future house prices will rise.

5.2 Dynamics when only credit-constrained households expect future technological progress

I suppose that in period 0, agents receive a public signal of technological progress that will occur in 4 periods. The signal turns out to be wrong ex-post (i.e. $s_{A,0} > 0$ and $\epsilon_{A,4} = 0$). I consider the case in which impatient households believe the public signal to be true (i.e. $v''_A = 0$). In contrast, patient households do not believe the public signal to be true and expect no future technological progress (i.e. $v'_A = \infty$).

Figure 8 shows equilibrium dynamics. The dynamics replicate the stylized pattern of housing-market boom-bust cycles in industrialized countries: real GDP, consumption, investment, hours worked and house prices co-move; and the nominal policy interest rate and the CPI inflation rate fall during housing booms and rise as the house price falls.

The collateral constraints on residential mortgages play an important role in generating this pattern. When impatient households expect that future house prices will rise, they increase housing investments, which causes a housing boom. Since impatient households are credit-constrained, they work more to finance their housing investments during the boom.[21] At the same time, when patient households do not share the optimistic expectations of impatient households, they instead expect the boom to be temporary and increase savings for a future recession. The increases in labour supply and savings reduce real wages and the real interest rate, respectively.[22] Given sticky prices, a resulting fall in the marginal cost of production lowers the inflation rate, and, in response to this, the central bank cuts the policy rate.[23] When the impatient households' expectations are not realized in period 4, however, impatient households start dissaving the over-accumulated housing stock. This weakens housing demand, which causes a housing bust. Impatient households also reduce labour supply as they no longer have to raise funds for housing investments. At the same time, patient households withdraw savings to support their consumption. This development raises real wages and the real interest rate. As a consequence, the inflation rate rises, inducing a monetary policy tightening.

Figure 8 shows that patient households reduce their labour supply during the housing boom, but this is dominated by the increase in labour supply from impatient households. This is because the parameter specification implies that impatient households have higher elasticity of labour supply. This parameter specification is due to the fact that young households show higher volatility of labour supply than old households and the interpretation that impatient households are mortgage borrowers, who tend to be young, while patient households are owners of financial assets, who tend to be old.

[21]This effect is analyzed by Campbell and Hercowitz (2004) using a similar model with heterogeneous elasticities of labour supply between the patient and the impatient households.

[22]In the data, real wages can rise during a housing boom if the housing boom is accompanied by realized technological progress. The experiment described here shows that the effect of heterogeneous expectations on real wages is negative.

[23]This relationship between the real marginal cost of production and the inflation rate can be shown by the new-Keynesian phillips curves implied by the Calvo-pricing.

Quantitatively, the amplitude of the boom-bust cycles depends on the magnitude of heterogeneity in household beliefs. Keeping $v_A^{'} = \infty$, so that patient households do not believe public signals, the amplitude of the boom-bust cycles is proportional to $E''[\varepsilon_{A,t+n}|s_{A,t}]$ in the log-linearized model. As shown by Equation (34), the conditional expectation is proportional to the value of the signal, $s_{A,t}$, and a fraction that contains the noise-to-signal ratio, $(1 + v_A^{''}/\sigma_A)^{-1}$.

5.3 Dynamics with homogeneous expectations

In order to understand the role of heterogeneous expectations between patient and impatient households, I now consider the case of homogeneous expectations, which is standard in the news-shock literature. In particular, I assume that patient households share the impatient households' expectation of future technological progress (i.e. $v_A^{'} = v_A^{''} = 0$).

Figure 9 shows that boom-bust cycles are generated in both the goods and the housing markets, but the nominal interest rate rises during the housing boom. The increase in the nominal interest rate is linked to expectations of higher future income that subdue the need for savings by patient households. This increases the real interest rate, which raises the rental price of capital and thus increases the marginal cost of production.[24] Expectations of higher future income also reduce labour supply since households can finance current consumption by the spared savings. The resulting rise in the real wage adds to the increase in the marginal cost of production. As a consequence, the price-setting behaviour of domestic-input firms generates inflation, which induces the central bank to raise the nominal policy rate during the housing boom.

I can show that when only the patient households respond to the signal (i.e. $(v_A^{'}, v_A^{''}) = (\infty, 0)$), the equilibrium dynamics are similar to those reported here. Thus, the co-existence of optimistic credit-constrained mortgage borrowers, represented by impatient households, and pessimistic savers, represented by patient households, is necessary to explain the stylized pattern of housing-market boom-bust cycles in industrialized

[24] In Figure 9, the rental price of capital rises despite the increase in investment in capital. This is because the real price of domestic inputs rises, which increases the returns on domestic production. On the flip side of the coin, the real price of imported inputs from the importers fall and an increase in the imported inputs in the final good production raises the productivity of capital stock embodied in domestic inputs for the final good production.

countries described in Section 2.

6 Policy experiments and sensitivity analysis

In this section, I focus on the cases in which households receive a public signal of technological progress that will occur in 4 periods. Only the impatient households expect future technological progress (i.e. $(v_A^{'}, v_A^{''}) = (0, \infty)$) and the signal is not realized ex-post (i.e. $s_{A,0} > 0$ and $\epsilon_{A,4} = 0$).

6.1 More weight on inflation in the monetary policy rule

Figure 10 compares the model's dynamics under the estimated monetary policy rule and a weaker anti-inflationary weight in the monetary policy rule ($\phi_\pi = 1.03$). The figure indicates that stronger policy responses to inflation amplify the boom-bust cycles. The intuition is that with a higher value of ϕ_π, the central bank cuts the policy rate more in response to the fall in the inflation rate during housing booms, and raises the policy rate more in response to the rise in the inflation rate when the house price falls.

6.2 Effect of higher loan-to-value ratios

Figure 11 compares the boom-bust cycles under different loan-to-value ratios for residential mortgages: high (0.9), benchmark (0.75) and low (0.5). The figure indicates that the amplitude of the boom-bust cycles significantly depends on the loan-to-value ratio. The impatient households' housing demand illustrates the mechanism behind this result:

$$\frac{\gamma c_t^{''}}{h_t^{''}} = q_t - \frac{mE_t'[\pi_{t+1} q_{t+1}]}{R_t} - E_t'' \left[\frac{\beta^{''} c_t^{''}}{c_{t+1}^{''}} (q_{t+1} - mE_t' q_{t+1}) \right]. \tag{35}$$

The left-hand side of the equation is the marginal utility derived from housing services and the right-hand side is the effective user cost of housing for impatient households. Roughly speaking, the user cost is determined by a weighted average of the present discounted values of housing for lenders and borrowers. As the loan-to-value ratio, m, increases, the user cost of housing is more sensitive to the patient household's evaluation of future housing value, represented by the second term on the right-hand side.[25] This contributes to reducing the user cost of housing one period before the realization of the signal (i.e. period 3) when lenders' pessimistic expectations induce them to increase savings and the real interest rate declines. Thus, higher loan-to-value ratios make housing investments cheaper for impatient households in period 3. This enhances the housing boom in period 3, which feeds back into house prices in periods 0-2. Hence, higher loan-to-value ratios increase the amplitude of housing-market boom-bust cycles.

Our results contribute to the literature on housing dynamics and business cycle. Kiyotaki, Michaelides and Nikolov (2007) document that the loan-to-value ratio does not significantly alter the dynamics of housing prices in their model. This result also holds in Iacoviello (2005). I show that with the presence of heterogeneous beliefs, the loan-to-value ratio plays an important role in determining the magnitude of boom-bust cycles in house prices.

6.3 Higher elasticity of the housing-rent components of the CPI

To generate the response of the housing-rent components of the CPI, I have so far used the specification (20). I find that the results reported above do not change even when I adopt an alternative specification as in (21). In the latter case, the value of κ is calibrated to 0.118, which is the correlation between the log-difference of the weighted sum of the housing-rent components of the CPI and the log-difference of the ex-post user cost of housing in Canadian data.[26]

For sensitivity analysis, I also consider a higher value of κ, 0.4, with the specification (21). In this case, the housing-rent components of the CPI respond to the housing boom more strongly. Figure 12 shows that, in the early periods of the housing boom, the CPI inflation rate and the nominal policy interest rate decline. In the subsequent periods of the boom, as house-price appreciation accelerates, the inflation rate

[25] To see this, replace $mE_t''q_{t+1}$ with mq_{t+1} on the right-hand side. This operation is valid at the first-order approximation. After the replacement, the last term of the right-hand side would have $(1-m)$ as one of its factors.

[26] For some periods, the ex-post user cost of housing takes negative values due to very strong house-price appreciations, for which the log of the user cost is not well-defined. I exclude these periods from the sample when I take the correlation. With the new value of κ, all the parameters are re-calibrated. But the re-calibration does not change the parameter values significantly.

of the housing-rent components of the CPI strongly rises. This results in an acceleration in CPI inflation towards the peak of the housing boom, which induces a gradual rise in the nominal policy interest rate. This dynamics of CPI inflation is consistent with the median pattern around the peaks of the past housing market booms reported in Figure 1, which shows that the total CPI inflation rate has tended to start rising before the peaks of housing booms.

Also, note that the difference between the inflation rate of final goods, π, and the total CPI inflation rate in the model is consistent with Figure 3, which shows that the inflation rate of the CPI excluding shelter costs fell during the housing boom in the late 1980s, while the inflation rate of the total CPI including shelter costs did not.

If I set very high values of κ, then the CPI inflation rate rises with house prices. This induces a counterfactual co-movement between house prices and the nominal interest rate. Thus, in order to explain the stylized behaviour of the nominal policy interest rate reported in Figure 1, it is important to take into account some degree of stickiness in the housing-rent components of the CPI.

7 Boom-bust cycles in response to other shocks

So far I have been focusing on a public signal of future technological progress as the source of boom-bust cycles in the housing market. In the model, there are three other types of shocks: monetary policy, real world interest rate and export demand shocks. I find that public signals of a future expansionary monetary policy shock and a future decline in the real world interest rate generate boom-bust cycles in the housing market, when only the impatient households believe the signals to be true and the shocks are not realized ex-post. The key feature of these signals is that they imply future appreciations in housing values. See Figures 13 and 14 for the boom-bust cycles that emerge from signals of future monetary policy and the real world interest rate.

On the contrary, I find that a signal of a future positive export-demand shock generates a recession-boom cycle. To understand this result, I start from describing the dynamics in response to a realized positive export-demand shock. Figure 15 shows that the real interest rate rises and the house price drops. These movements are generated by the dynamics of the real exchange rate, which immediately appreciates in response to the positive export-demand shock and then gradually depreciates returning to the steady state level. Given the fixed real world interest rate, the gradual depreciation of the home currency raises the domestic real interest rate through the uncovered interest-rate parity, which lowers house prices. Thus, a signal of a future positive export-demand shock generates expectations of future depreciations in housing values. This lowers current house prices in response to the signal. Figure 16 shows the model's dynamics in response to a signal of a future positive export-demand shock.

8 Conclusion

The model in this paper implies that the co-existence of optimistic credit-constraint borrowers and pessimistic savers, who respectively take and provide mortgage loans, generate expectation-driven boom-bust cycles in house prices, output, consumption, investment and hours worked in response to ex-post wrong public signals of favourable future fundamentals. These findings contribute to the news-shock literature, showing an alternative set-up that generates expectation-driven boom-bust cycles in a business cycle model.

Moreover, the nominal policy interest rate falls during booms and rises during busts, and the rise in the policy rate is accompanied by an increase in the inflation rate in the model. These equilibrium dynamics replicate the stylized features of housing-market boom-bust cycles in industrialized countries. Policy experiments demonstrate that greater anti-inflationary weight in the monetary policy rule amplifies fluctuations in the nominal policy interest rate during housing-market boom-bust cycles, which destabilizes house prices and thus aggregate economic activity. This result contributes to the policy debate on the conduct of monetary policy during asset-market booms. This paper also documents that higher loan-to-value ratios amplify housing-market boom-bust cycles by allowing for higher leverage in housing investments. This result contrasts with the previous literature on credit constraints on households and house-price dynamics, which finds that the loan-to-value ratio does not significantly alter the dynamics of housing prices in the models.

A Data appendix

A.1 Stylized pattern of housing-market boom-bust cycles

I follow the data appendix of Ahearne, et al. (2005). See their paper for the definition of the house-price peaks in each industrialized country. Real GDP growth rates come from the OECD database. The series are based on seasonally adjusted real GDP. The rates are annualized quarterly growth rates. For Germany, unified German data is used whenever possible. If not available, West German data is used. This is the same for the following data.

Total CPI inflation comes from the OECD database. These series give year-to-quarter increases in the price index as a percentage. The CPI excluding shelter costs for Canada (V41691234 from the Statistics Canada) is only available from 1984:4Q.

Nominal policy interest rates are short-term interest rates, which are 3-month nominal money-market rates, taken from the OECD database. These rates are normally highly correlated with the target rate adopted by the central bank. If short-term interest rates are not available from the OECD database, I use the money market rates from the IMF database. For a given peak, I always use a single source per country. I do this by counting the number of observations available from each source for that country around that peak and choosing the source to maximize this count. All short-term rates are expressed in percentage points on an annualized basis.

Hours worked are calculated as the product of two series from the OECD database: the total number of workers in the economy and the hours per employee. The growth rate is expressed in percentage points on a year-to-quarter basis. Belgium, Denmark, Spain, and Switzerland do not have data available at quarterly frequency. For these countries, I compute year-over-year growth rates, then interpolate quarterly values by estimating a cubic spine, using the year-over-year results as year-end values.

A.2 Figure 5

The figure shows U.S. data. The real house price growth rate is the first-order log difference of the nationwide house price index from the OFHEO divided by the GDP deflator. The Index of Consumer Expectations for young households are the average of the index for 18-34 years old (ice_a1834) and that for 35-44 years old (ice_a3544) in the University of Michigan Surveys of Consumers weighted by the numbers of householders in corresponding age groups from Table HH-3, the March CPS, U.S. Census Bureau. The Index of Consumer Expectations for old households are similarly constructed from ice_a4554, ice_a4564 and ice_a6597. "Difference between young and old" in the figure is the difference of the index for young households from the index for old households. The number of householders in each age group is only annually published. This series is converted into a quarterly series by linear interpolation.

A.3 Calibration

Table 5 shows data source details. Data sources are listed in alphabetical indices in the first column of the table. The share of capital in the production of home goods, α, is calculated by the average of (1-(c)/(GDP-(b)-(d)-(e))) over 1961:1Q-2007:1Q. GDP is the nominal value of GDP contained in (a). The share for import goods in final domestic demand, γ, is the average of ((f)/(C+I+G)) over 1961:1Q-2007:1Q. C+I+G is the sum of the nominal values of consumption, investment and government expenditure contained in (a). The depreciation rates, δ, is the sample average of (V4419837)/(V4419841) over 1943-2006. As (V4419841) is the end-year value of capital stock, the denominator is lagged by a year.

I estimate labour augmenting technology using the Solow residuals. We construct a chained-dollar index of GDP excluding rents from the nominal values of the demand-side components of GDP contained in (a) and the Table 380-0009 (the components of private consumption expenditure), and the corresponding deflators. Quarterly data of hours worked (V4391505) is only available from 1976:1Q, so I extend it for 1961-1976 by the annual data of hours worked (V716818). I apply linear interpolation to the annual data in order to obtain quarterly data. The amount of capital stock is calculated by dividing (h) by the deflator for non-residential investment contained in (i). Since (h) is annual data, I interpolate (h) by the quarterly accumulation of new capital stock implied by the chained-dollar real values of non-residential investment contained in (a). I apply the value of α for the capital share in the Cobb-Douglas production function.

The weight on the housing-rent components of the CPI, λ, is 0.218, which is taken from the 2005 basket for the Canadian CPI. The weights for this basket are provided by the Statistics Canada (`http://www.statcan.ca/english/sdds/document/2301_D34_T9_V1_B.pdf`). The housing-rent components of the CPI are Rented accommodation (V41691051) and Owned accommodation (V41691055). The nominal house-price index is the Royal LePage House Price Index, which covers the prices of both new and existing houses. See Tomura (2008) for more details on the construction of the nominal house-price index. For the baseline calibration, the parameter that controls for the elasticity of the housing-rent components of the CPI, κ, is the correlation between the log-difference of the weighted sum of the housing-rent components of the CPI and the log-difference of the nominal house-price index for 1975:2Q-2007:1Q. It is convenient to use the correlation between the nominal variables for a proxy to the value of κ, since it does not require a CPI series that excludes the housing-rent components for the long sample period for denominating nominal variables. The correlation between the log-differences of the real housing-rent components and the real house-price index denominated by the total CPI shows similar values of κ, ranging from 0.1 to 0.4, depending on the choice of the sample period. When I calibrate κ for the specification (21), I construct the ex-post nominal user cost of housing, u_t, from the Royal LePage House Price Index and the average nominal interest rate for 5-year mortgage loans in Canada. Then I calculate the correlation between the log-difference of the weighted sum of the housing-rent components of the CPI and the log-difference of the ex-post nominal user cost of housing for 1975:2Q-2006:4Q.

The ratio of nominal aggregate housing value to quarterly GDP is 1.47, which is the average of ((k)+(l))/GDP over 1961:1Q-2006:4Q. GDP in the denominator of these ratios excludes the values of imputed and paid rents (b). The data (k) and (l) are taken from the wealth account of persons and unincorporated business in the National Account.

For the second moments in Table 4, seasonally-adjusted chained-dollar real GDP in (a) and aggregate hours worked (V4391505) for 1980:1Q-2007:1Q are log-linearly de-trended. The average hours worked of young households in the table is calculated from the actual hours worked of households with age between 25 and 44 years old (V3494776) divided by the population of these ages. The actual hours worked are seasonally-adjusted by the X12 command in RATS. I normalize the actual hours worked by the population, since ξ' and ξ'' determine elasticities of labour supply at each household level. The quarterly population estimate in the denominator is constructed by multiplying the quarterly total population (V1) with the annual share for the age group in the population of all the age groups ((V466680)/(V466965 + V466980 + V466680 + V466683 + V466686)). The average hours worked of old households is similarly calculated from the data for the age group over 45 years old. I divide the young by the old – i.e. above 45 years old– as there is no more age groups categories in data. The sample period for hours worked data for each age group is for 1976:1Q-2007:1Q. When calculating the standard deviations, the log of the average hours worked series for each household type are de-trended by the time dummy and the time-squared dummy. I include the time-squared dummy here as the average hours-worked series for old households show a U-shape. I take this long-run trend as driven by some institutional changes that are not considered in my model. Similarly, I identify structural breaks in the time-varying mean of the log of the CPI inflation rate by the Bai and Perron (1998) method, and calculate the standard deviation using the deviation of the log of the CPI inflation rate from the time-varying mean. For the structural break estimation, I use the code provided by Bai and Perron (2003).

References

[1] Ahearne, A.G., J. Ammer, B.M. Doyle, L.S. Kole and R.F. Martin. 2005. "House Prices and Monetary Policy: A Cross-Country Study." International Finance Discussion Papers No. 841. Board of Governors of the Federal Reserve System.

[2] Amirault, D., C. Kwan, and G. Wilkinson. 2004. "A Survey of the Price-Setting Behaviour of Canadian Companies." *Bank of Canada Review* Winter 2004-2005:29-40.

[3] Bai, J. and P. Perron. 1998. "Estimating and Testing Linear Models with Multiple Structural Changes." *Econometrica*, 66(1): 47-78.

[4] Bai, J., and P. Perron. 2003. "Computation and Analysis of Multiple Structural Change Models." *Journal of Applied Econometrics*, 18:1-22.

[5] Basant Roi, M. and R.R. Mendes. 2007. "Should Central Banks Adjust Their Target Horizons in Response to House-Price Bubbles?." Bank of Canada Discussion Paper No. 2007-4.

[6] Beaudry, P., and F. Portier. 2004. "An exploration into Pigou's theory of cycles." *Journal of Monetary Economics*, 51:1183-1216.

[7] Beaudry, P. and F. Portier. 2007. "When can Changes in Expectations Cause Business Cycle Fluctuations in Neo-classical Settings?." *Journal of Economic Theory*, 135(1): 458-477.

[8] Benito, A., and H. Mumtaz. 2006. "Consumption Excess Sensitivity, Liquidity Constraints and the Collateral Role of Housing." Bank of England Working Paper No. 306.

[9] Bernanke B. and M.Gertler. 1999. "Monetary Policy and Asset Price Volatility". *Federal Reserve Bank of Kansas City Economic Review*, Fourth Quarter 1999:17-51

[10] Bolton, P., Scheinkman, J., Xiong, W. 2006. "Executive Compensation and Short-Termist Behaviour in Speculative Markets." *Review of Economic Studies*, 73(3):577-610.

[11] Campbell, J.R., and Z. Hercowitz. 2004. "The Role of Collateralized Household Debt in Macroeconomic Stabilization." Federal Reserve Bank of Chicago Working Paper No. 2004-24.

[12] Cecchetti, S., H. Genberg and S. Wadhwani. 2003. "Asset Prices in a Flexible Inflation Targeting Framework." In *Asset Price Bubbles: The Implications for Monetary, Regulatory and International Policies*, 427-44. Cambridge, MA: MIT Press.

[13] Christiano, L., C. Ilut, R. Motto, and M. Rostagno. 2007. "Monetary Policy and Stock Market Boom-Bust Cycles." Mimeo. `http://faculty.wcas.northwestern.edu/~lchrist/research.htm`.

[14] Christensen, I., P. Corrigan, C. Mendicino, and S. Nishiyama. 2008. "Housing Collateral, Residential Investment and the Canadian Business Cycle." Mimeo. Bank of Canada.

[15] Den Haan, W.J., and G. Kaltenbrunner. 2007. "Anticipated Growth and Business Cycles in Matching models." CEPR Discussion Paper No. 6063.

[16] Dib, A. 2008. "Welfare Effects of Commodity Price and Exchange Rate Volatilities in a Multi-Sector Small Open Economy Model." Bank of Canada Working Paper No. 2008-8.

[17] Floden, M., 2007. "Vintage Capital and Expectations Driven Business Cycles." CEPR Discussion Paper No. 6113.

[18] Garcia, R., and P. Perron. 1996. "An Analysis of the Real Interest Rate Under Regime Shifts." *Review of Economics and Statistics*, 78(1):111-125.

[19] Hong, H., and J.C. Stein. 2007. "Disagreement and the Stock Market." *Journal of Economic Perspectives*, 21(2):109-128.

[20] Iacoviello, M. 2005. "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle." *American Economic Review*, 95(3):739-64.

[21] Jaimovich, N. and S. Rebelo. ,2006. "Can News about the Future Drive the Business Cycle?", NBER Working Paper No. 12537.

[22] Kiyotaki, N., and J. Moore. 1997. "Credit Cycles." *Journal of Political Economy*, 105(2):211-248.

[23] Kiyotaki, N., A. Michaelides, and K. Nikolov. 2007. "Winners and Losers in Housing Markets." Mimeo. `http://www.princeton.edu/~kiyotaki/`.

[24] Kobayashi, K., T. Nakajima and M. Inaba. 2007. "Collateral Constraint and News-driven Cycles." Discussion paper No. 07013, Research Institute of Economy, Trade and Industry (RIETI).

[25] Mankiw, N.G., R. Reis, J. Wolfers. 2003. "Disagreement about Inflation Expectations." In: Gertler, M., Rogoff, K. (Eds.). NBER Macroeconomics Annual 2003.

[26] Meh, C.A., and Y. Terajima. 2008. "Inflation, Nominal Portfolios, and Wealth Redistribution in Canada." Bank of Canada Working Paper 2008-19.

[27] Piazzesi, M., and M. Schneider. 2008. "Inflation and the Price of Real Assets." Mimeo. `http://homepages.nyu.edu/~ms1927/`.

[28] Rapach, D.E., and M.E. Wohar. 2005. "Regime Changes in International Real Interest Rates: Are They a Monetary Phenomenon?" *Journal of Money, Credit, and Banking*, 37(5):887-906.

[29] Schmitt-Grohé, S., and M. Uribe. 2003. "Closing Small Open Economy Models." *Journal of International Economics*, 61:163-185.

[30] Tomura, H. 2008. "A Model of Housing Boom and Bust in a Small Open Economy." Bank of Canada Working Paper No. 2008-9.

[31] Tomura, H. 2009. "Heterogeneous Beliefs and Housing-Market Boom-Bust Cycles." mimeo. Bank of Canada.

Table 1: Correlation coefficients between the linearly de-trended real house price index and the average hours worked of different age groups in Canada

	Non de-trended hours worked	Linearly de-trended hours worked	Quadratically de-trended hours worked
Less than 45 years old	0.371	0.499	0.482
45 years old and over	-0.047	-0.055	0.182
45-65 years old	0.057	0.100	0.279

Notes: Each figure in the table is the correlation coefficient between the real house price index and the average hours worked in question. The real house price index is the natural log of the Royal LePage House Price Index deflated by the total CPI, and the linear time trend is excluded from the log. The average hours worked are the natural log of hours worked per population per week for each age group. The linear time-trend is excluded in the second column. The quadratic time-trend is excluded in the third column. The sample period is for 1976:1 to 2007:1.

Table 2: Regressions of the real house price growth rate on the difference in consumer expectations between young and old households in Canada

Dependent Variable: Δ ln(Real house price).

Sample period: From 1990:04 To 2007:01.

Regressor	Regression 1		Regression 2		Regression 3	
EXP(< 45) - EXP(≥ 45)	-0.000527*	(0.000299)	-0.000538**	(0.000246)	-0.000303	(0.000241)
EXP(< 45) - EXP(≥ 45) (-1)	0.000133	(0.000299)	-0.0000144	(0.000252)	0.0000849	(0.000240)
EXP(< 45) - EXP(≥ 45) (-2)	0.000522*	(0.000299)	0.000614**	(0.000244)	0.000597**	(0.000236)
EXP(< 45) - EXP(≥ 45) (-3)	0.000283	(0.000304)	0.000102	(0.000270)	-0.00000616	(0.000259)
Constant	-0.00779	(0.0126)	0.00143	(0.0162)	-0.00799	(0.0157)
EXP					0.000168	(0.000140)
EXP (-1)					0.000359**	(0.000163)
EXP (-2)					-0.000355**	(0.000168)
EXP (-3)					-0.0000408	(0.000144)
Δ ln(Real house price) (-1)			0.223*	(0.131)	0.169	(0.136)
Δ ln(Real house price) (-2)			-0.0415	(0.123)	0.0657	(0.134)
Δ ln(Real house price) (-3)			0.0190	(0.122)	0.0679	(0.122)
Δ ln(Real GDP)			1.07***	(0.373)	0.821**	(0.378)
Δ ln(Real GDP) (-1)			-0.654	(0.472)	-0.526	(0.443)
Δ ln(Real GDP) (-2)			0.167	(0.469)	0.140	(0.438)
Δ ln(Real GDP) (-3)			0.0535	(0.401)	0.0333	(0.382)
Real interest rate			-0.00407	(0.00318)	-0.00212	(0.00302)
Real interest rate (-1)			0.00745**	(0.00316)	0.00916***	(0.00303)
Real interest rate (-2)			-0.00905***	(0.00315)	-0.00519	(0.00327)
Real interest rate (-3)			-0.00470	(0.00320)	-0.00629*	(0.00330)
R^2	0.175		0.636		0.704	

Notes: The coefficients are estimated by OLS. The standard errors are in parentheses beside the coefficient values. *, ** and *** indicate that the coefficient in question is signigicant at the 10%, 5%, and 1% levels, respectively. The minus values in parentheses in the first column indicate lagged regressors. 'EXP (< 45)' is the index of household expectations for less than 45 years old and 'EXP (≥ 45)' for 45 years old and over. 'EXP' is the index of household expectations for all ages. The real house price is the Royal LePage House Price Index denominated by the total CPI. The real GDP and the real interest rate are also denominated by the total CPI. The real interest rate is the ex-post interest rate. Δ ln(·) indicates first-order log difference.

Table 3: Baseline parameter values

$(\beta', \beta'') = (0.99, 0.95)$	Time discount rates
$\gamma = 0.0166$	Housing weight in preference
$(\xi', \xi'') = (19.4,\ 1e - 14)$	Elasticity of labour supply
$\mu = 0.8$	Patient's fraction of population
$\alpha = 0.26$	Capital share in production
$\zeta_K = 19.8$	Capital adjustment cost
$\delta = 0.025$	Depreciation rate of capital stock
$\theta = 6$	Elasticity of substitution
$\omega = 0.3$	Import share in final domestic demand
$m = 0.75$	Loan-to-value ratio
$\chi = 0.5$	Probability of price-adjustment
$\zeta_B = 1e - 06$	Access to international credit markets
$\tau = 0.8$	Elasticity of export demand
$\lambda = 0.218$	Weight on the housing-rent components of CPI
$\kappa = 0.292$	Elasticity of the housing-rent components of CPI
$(\phi_R, \phi_\pi, \phi_Y) = (0.73,\ 1.81,\ 0.05)$	Monetary policy rule
$(\rho_A, \rho_\psi, \rho_{r_F}, \rho_{Y_F}) = (0.93,\ 0,\ 0.43,\ 0)$	AR(1) coefficients for shocks
$(\sigma_{\varepsilon_A}, \sigma_{\varepsilon_\psi}, \sigma_{\varepsilon_{r_F}}, \sigma_{\varepsilon_{Y_F}}) = (0.008,\ 0.0037,\ 0.011,\ 0.11)$	Standard deviations of shocks

Table 4: Second moments targeted by calibration of the capital adjustment cost (ζ_K), the elasticities of labour supply (ξ', ξ''), and the moments of export-demand shocks (ρ_{Y_F}, σ_{Y_F})

a. Standard deviations of the CPI inflation rate and labour supply (relative to de-trended GDP)

	Model	Data
CPI inflation rate	0.14	0.13
Average hours worked for old households (Age≥45)	0.97	0.69
Average hours worked for young households (Age<45)	1.14	1.25
Aggregate hours worked	0.82	0.91

b. Standard deviation and autocorrelation of de-trended GDP

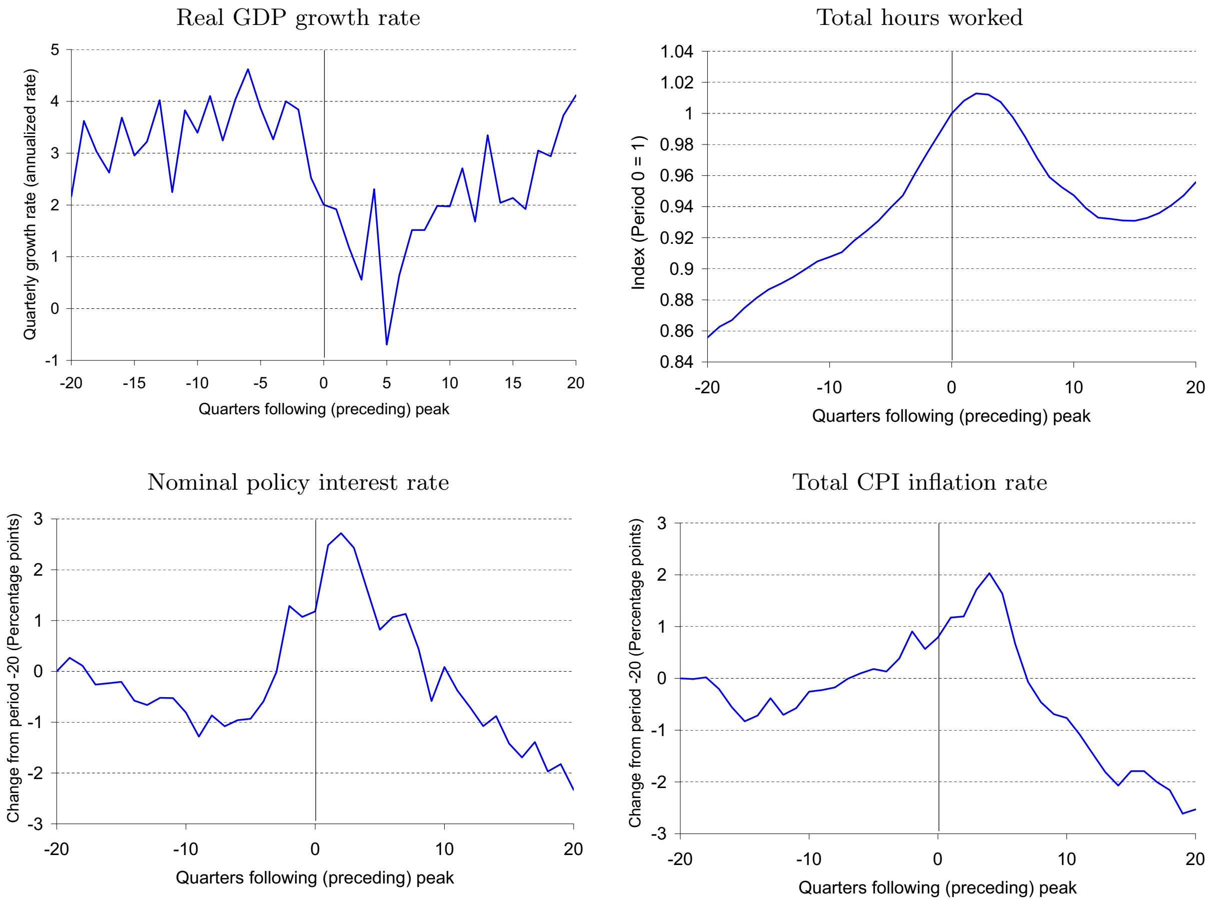
	Model	Data
Standard deviation	0.05	0.03
Lag-1 autocorrelation	0.94	0.96

Table 5: Data source table

	Data name	Data source
(a)	Demand components of GDP (Nominal & Chained 2002 $)	Table 380-0002
(b)	Paid and imputed rents (Nominal)	V498532+V498533
(c)	Compensation of employees (Nominal)	V498076
(d)	Indirect taxes (Nominal)	V1992216 + V1997473
(e)	Proprietors' income (Nominal)	V498080 + V498081
(f)	Value of import (Nominal)	V498106
(g)	Depreciation rate of capital stock (Chained 2002 $)	V4419837, V4419841
(h)	Capital stock (Nominal)	V34738+V34739
(i)	Deflator for non-residential investment	V498097, V1992054
(j)	Actual hours worked	V4391505, V716818
(k)	Value of housing land owned by households	V33469
(l)	Value of residential structure owned by households	V33464
(m)	Actual hours worked for households between 25 and 44 years old	V3494776
(n)	Actual hours worked for households over 45 years old	V3494781
(o)	Quarterly total population estimate	V1
(p)	Annual population estimates for age groups	V466965,V466980,V466680
		V466683, V466686

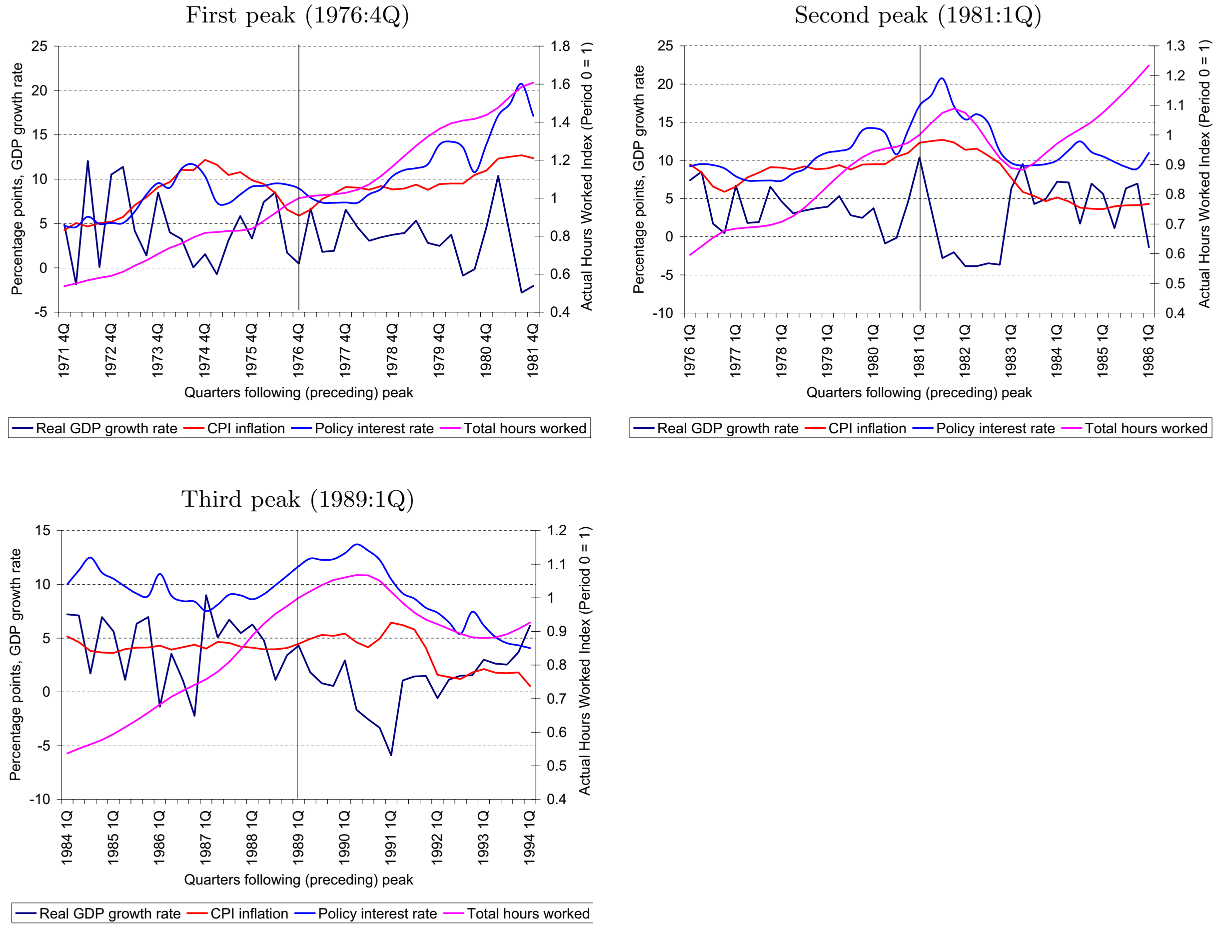
Note: The data labels and the table name are from Statistics Canada.

Figure 1: Median dynamics around the peaks of housing-market boom-bust cycles in industrialized countries



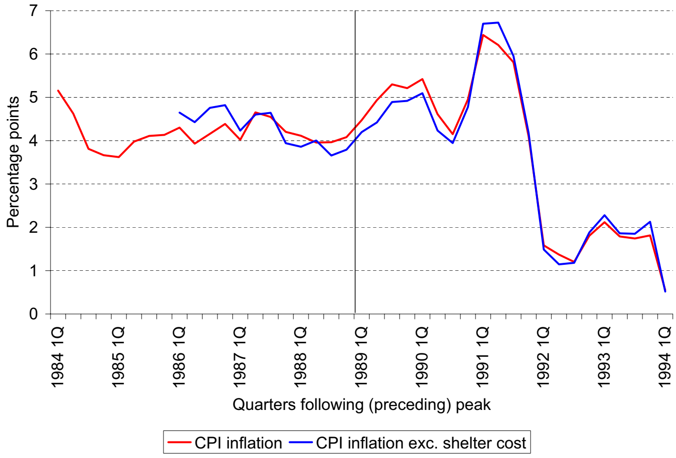
Notes: The figure takes the median of the variable in question in each quarter around the peaks of past housing booms in industrialized countries in North-America, Europe and Asia-Pacific since 1970. Total hours worked are the levels constructed from the medians of hours worked growth rates. Period 0 corresponds to the peaks of housing booms. See data appendix for more details.

Figure 2: Macroeconomic indicators around the peaks of housing-market boom-bust cycles in Canada



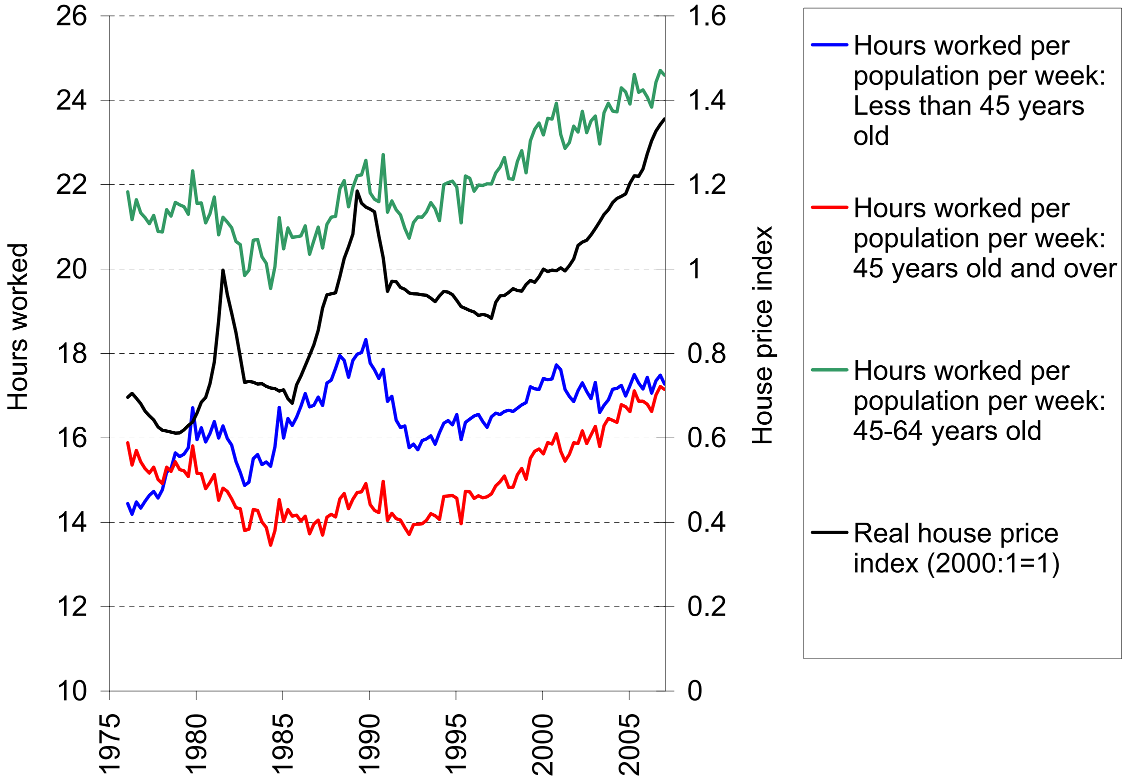
Notes: Ahearne, et al. (2005) identify the three peaks of housing booms since 1970 in Canada. In each panel, the peak is indicated by the vertical line. See data appendix for data sources.

Figure 3: Sensitivity of the CPI to inclusion of shelter costs around the peak of the housing boom in 1989:1Q in Canada



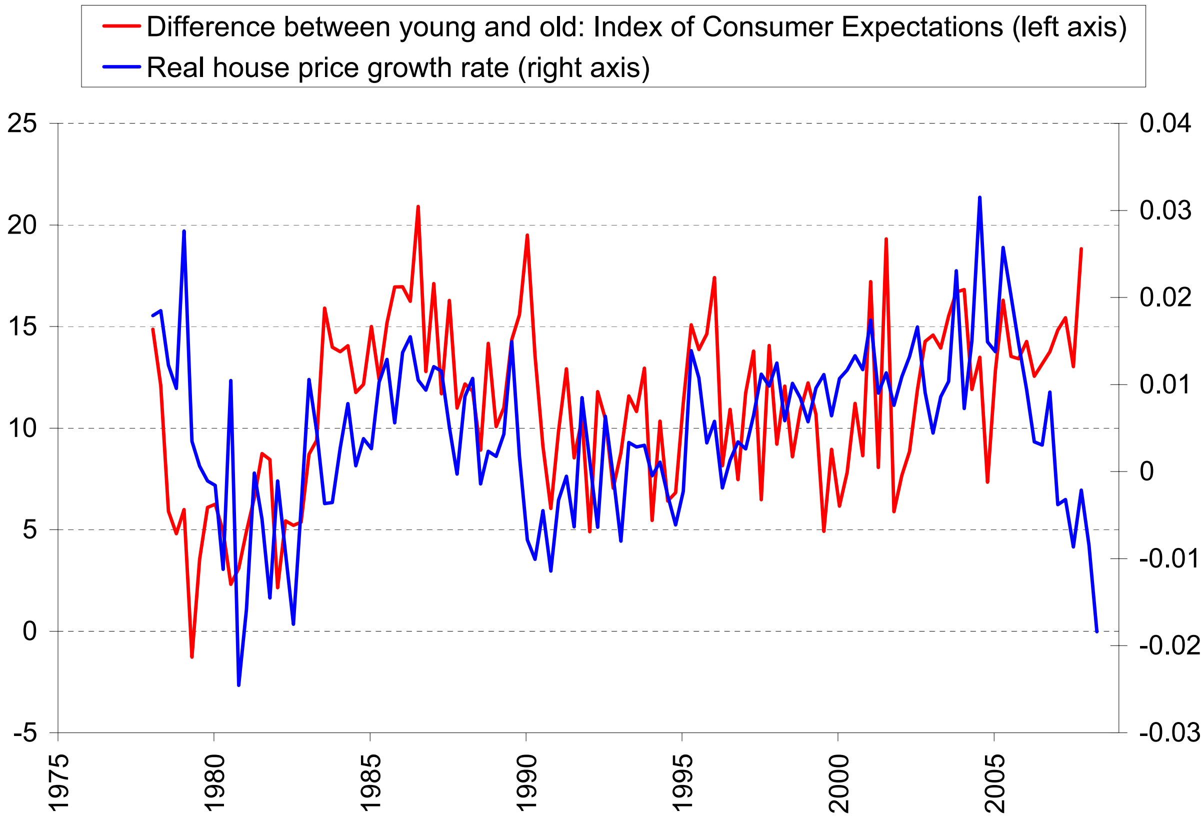
Notes: Ahearne, et al. (2005) identify three peaks of housing booms since 1970 in Canada. The third peak is 1989:1Q, which is indicated by the vertical line. The CPI excluding shelter costs is only available from 1984:4Q. The inflation rates in the figure are 4-quarter percentage changes. See data appendix for the data sources.

Figure 4: House prices and hours worked of different age groups in Canada



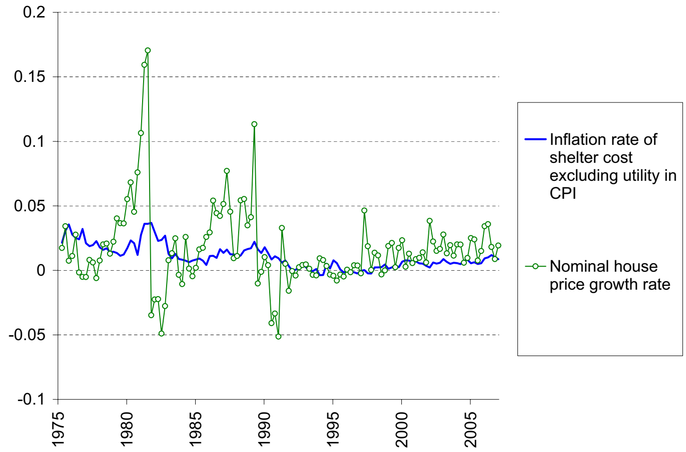
Notes: Labour supply data are from the Statistics Canada. Real house price index is the Royal LePage House Price Index deflated by the total CPI.

Figure 5: Real house price growth rates and differences in the Index of Consumer Expectations between young and old households in U.S.



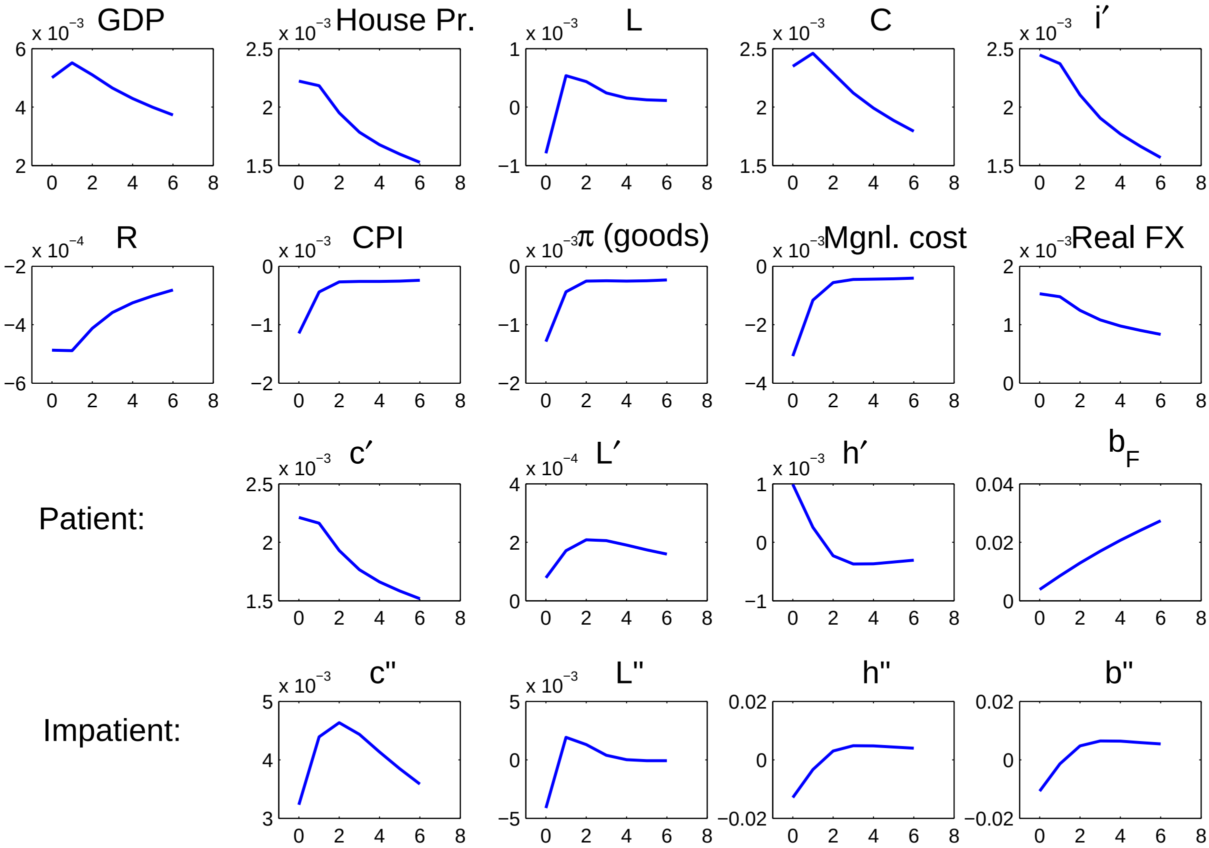
Notes: Positive values of "Difference between young and old" in the figure indicate that young households (44 years old or less) have stronger expectations for future economic conditions than old households (45 years old or more). See the data appendix for data sources.

Figure 6: The inflation rate of the housing-rent components of CPI and the rate of growth of the nominal house price index



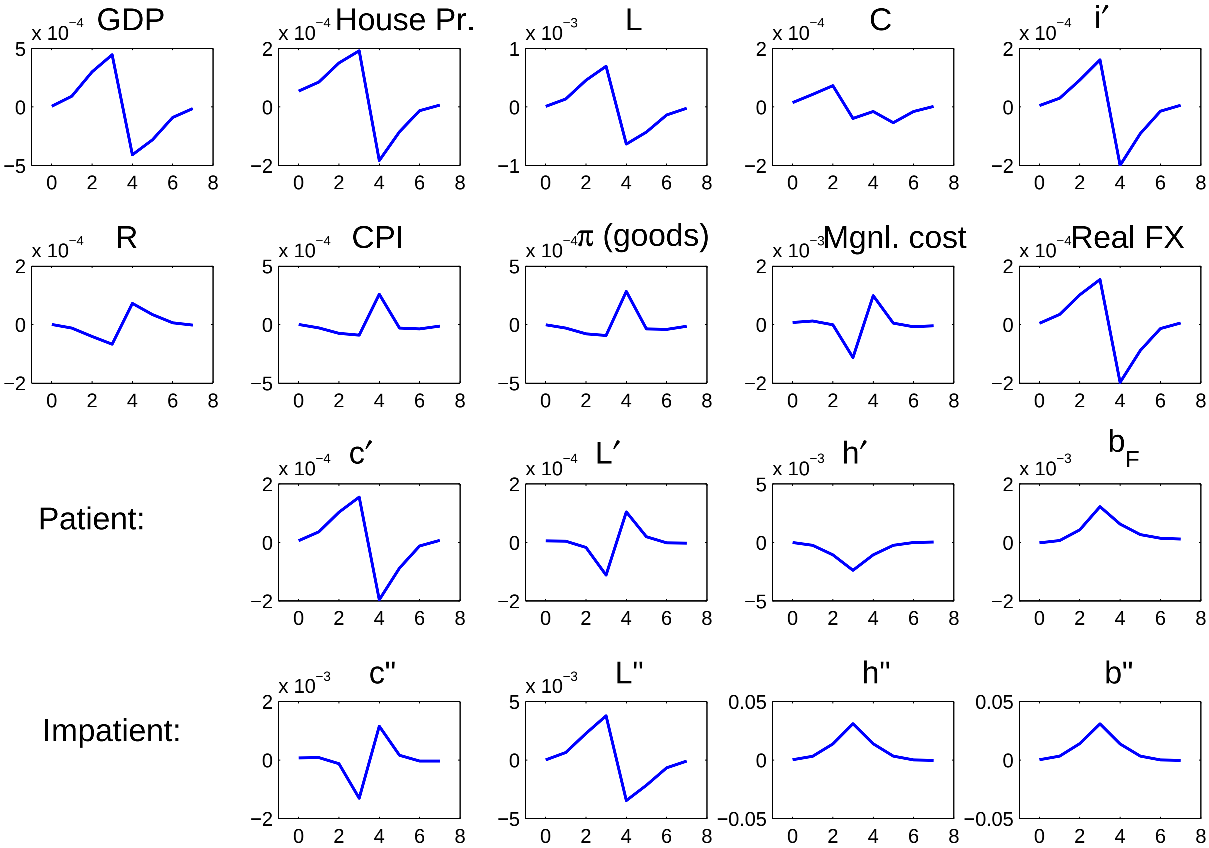
Notes: The rates in the figure are Quarter-on-quarter changes. The nominal house price index is the Royal LePage House Price Index. See data appendix for more details.

Figure 7: Response to a current positive technological shock



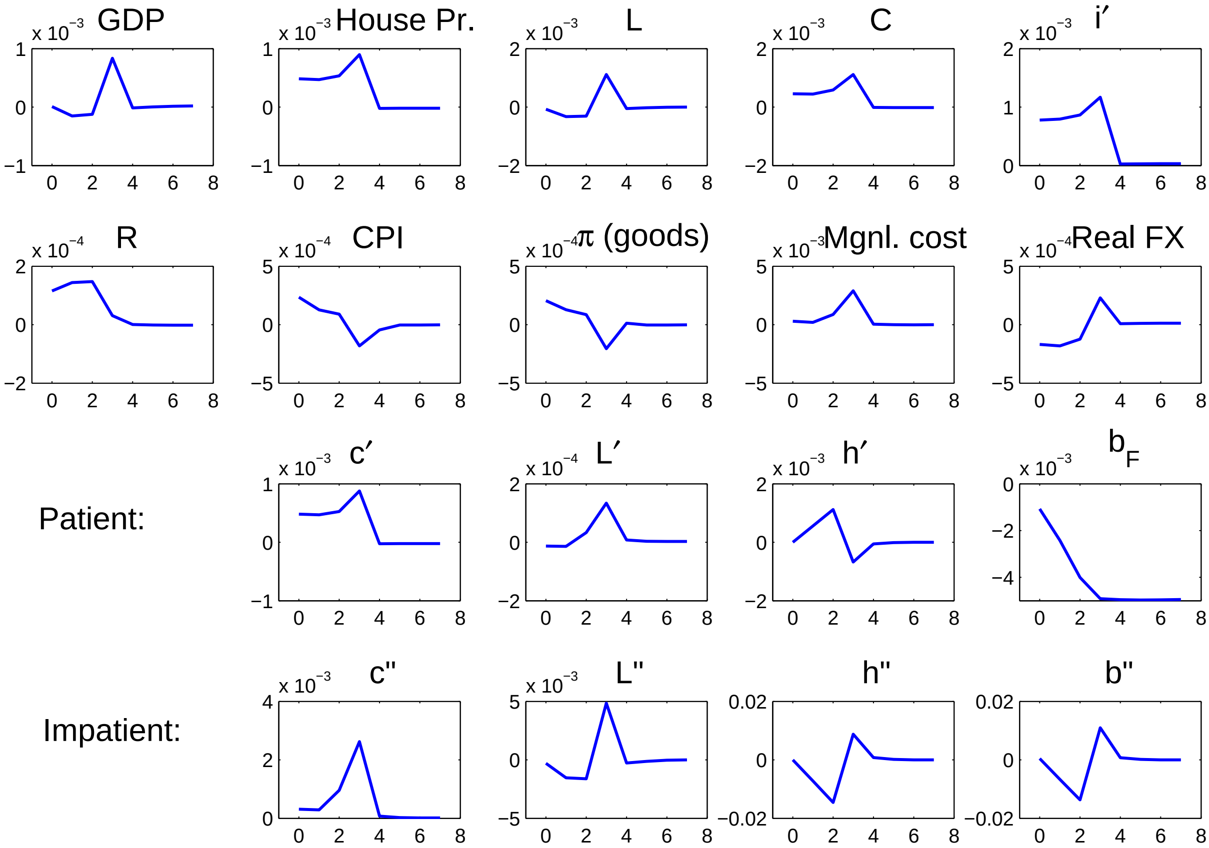
Notes: Figures are log deviations from the deterministic steady-state values except $b_{F,t}$, which is a difference from the steady-state value. The shock hits in period 0, i.e. $\varepsilon_{A,0} = \sigma_{\varepsilon_A}$, and the economy is at the steady state before the shock. In the first and second rows, C and L are aggregate consumption and labour supply, respectively. "House Pr." is the house price, q_t, "CPI" is the CPI inflation rate, $dCPI_t$, "π (goods)" is the inflation rate of final goods, π_t, "Real FX" is the real exchange rate, s_t, and "Mgnl. cost" is the marginal cost of production, f_t. The third and the forth rows respectively show the actions of the patient and the impatient households.

Figure 8: Response to a signal of future technological progress when only the impatient households expect the progress, but the signal is not ex-post realized



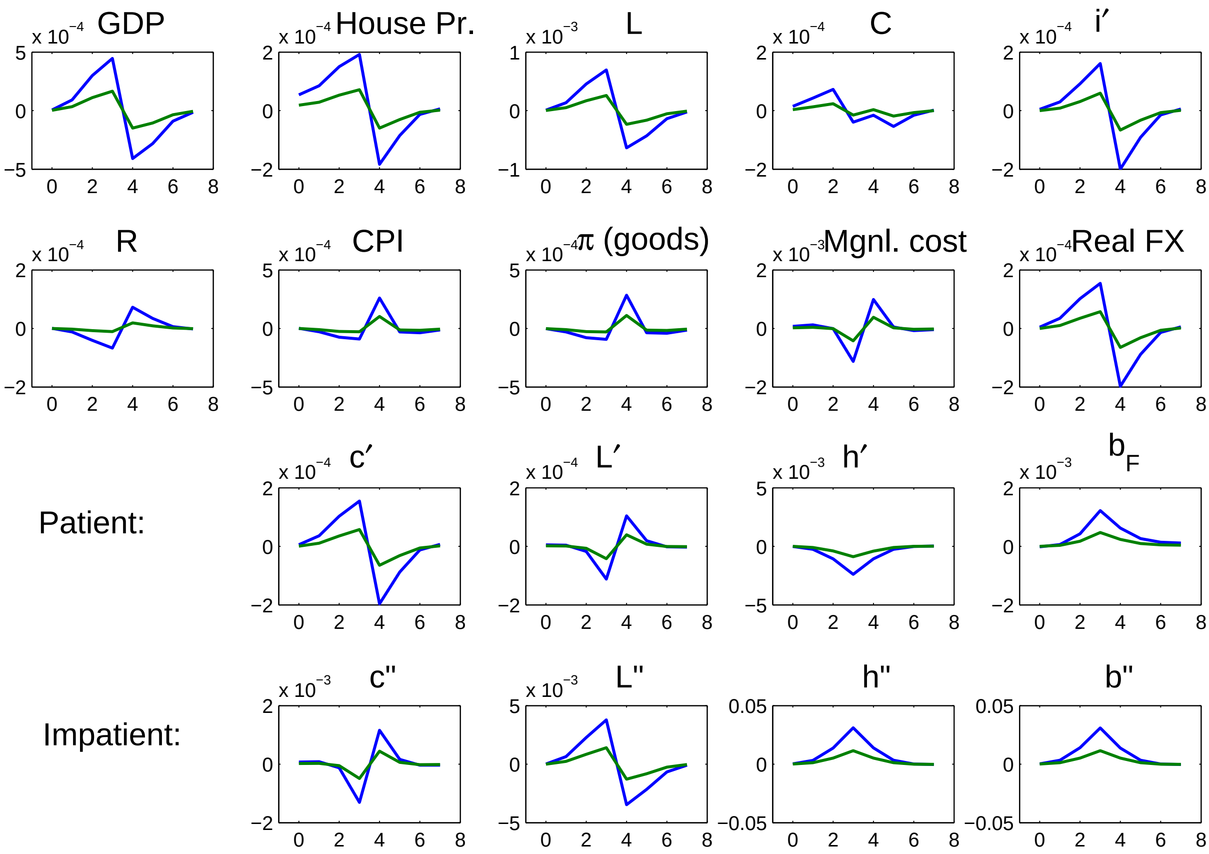
Notes: Figures are % deviations from the deterministic steady-state values except $b_{F,t}$, which is a difference from the steady-state value. The signal is received in period 0, but is not realized in period 4, i.e. $s_{A,0} = \sigma_{\varepsilon_A}$ and $\varepsilon_{A,4} = 0$. The economy is at the steady state before period 0. Only the impatient households expect the progress, i.e. $\nu'_A = \infty$ and $\nu''_A = 0$. In the first and second rows, C and L are aggregate consumption and labour supply, respectively. "House Pr." is the house price, q_t, "CPI" is the CPI inflation rate, $dCPI_t$, "π (goods)" is the inflation rate of final goods, π_t, "Real FX" is the real exchange rate, s_t, and "Mgnl. cost" is the marginal cost of production, f_t. The third and the forth rows respectively show the actions of the patient and the impatient households.

Figure 9: Response to a signal of future technological progress when all the households expect the progress, but the signal is not ex-post realized



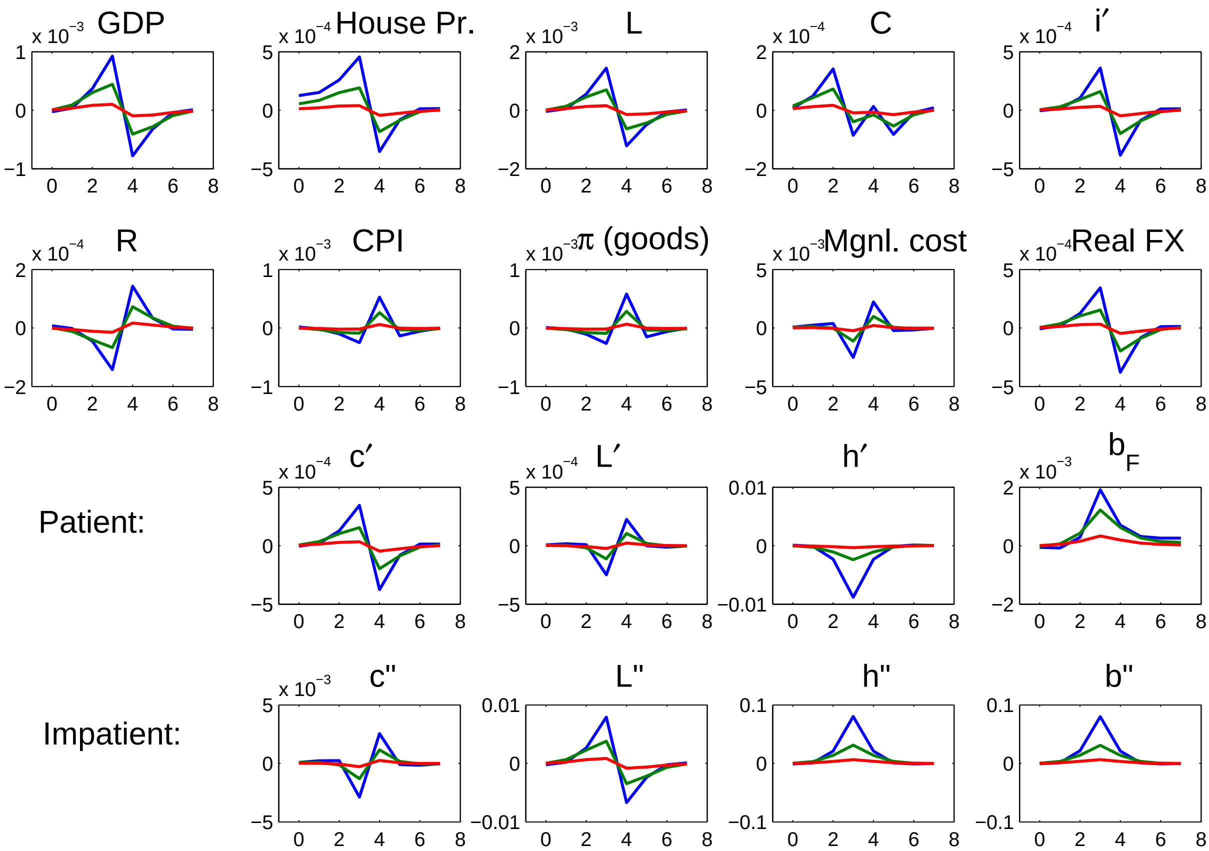
Notes: Figures are % deviations from the deterministic steady-state values except $b_{F,t}$, which is a difference from the steady-state value. The signal is received in period 0, but is not realized in period 4, i.e. $s_{A,0} = \sigma_{\varepsilon_A}$ and $\varepsilon_{A,4} = 0$. The economy is at the steady state before period 0. All the households expect the progress, i.e. $\nu'_A = 0$ and $\nu''_A = 0$. In the first and second rows, C and L are aggregate consumption and labour supply, respectively. "House Pr." is the house price, q_t, "CPI" is the CPI inflation rate, $dCPI_t$, "π (goods)" is the inflation rate of final goods, π_t, "Real FX" is the real exchange rate, s_t, and "Mgnl. cost" is the marginal cost of production, f_t. The third and the forth rows respectively show the actions of the patient and the impatient households.

Figure 10: Effect of higher anti-inflationary weight in the monetary policy rule on housing-market boom-bust cycles.



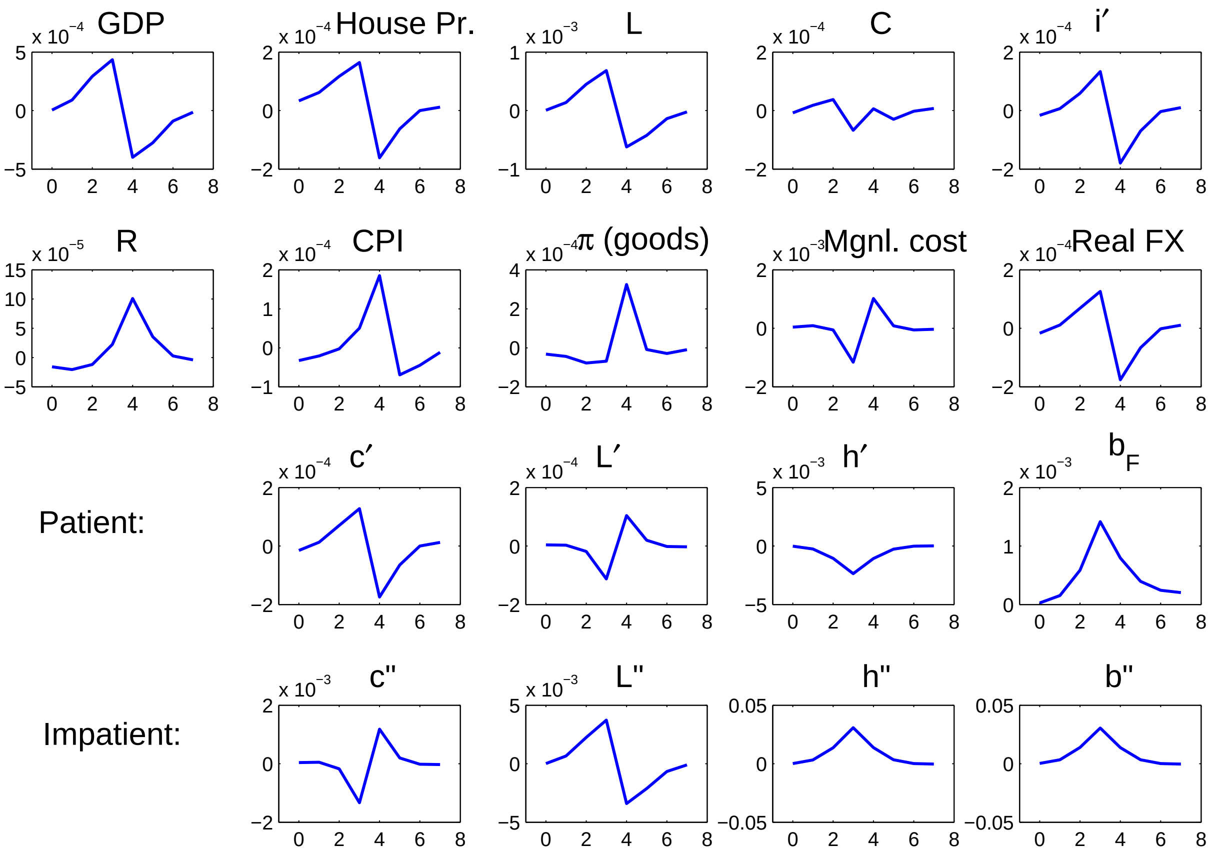
Notes: See the notes of Figure 8 for the set-up. The weight on the inflation rate in the monetary policy rule ϕ_π is 1.81 in the blue line and 1.03 in the green line.

Figure 11: Effect of higher loan-to-value ratios on housing-market boom-bust cycles.



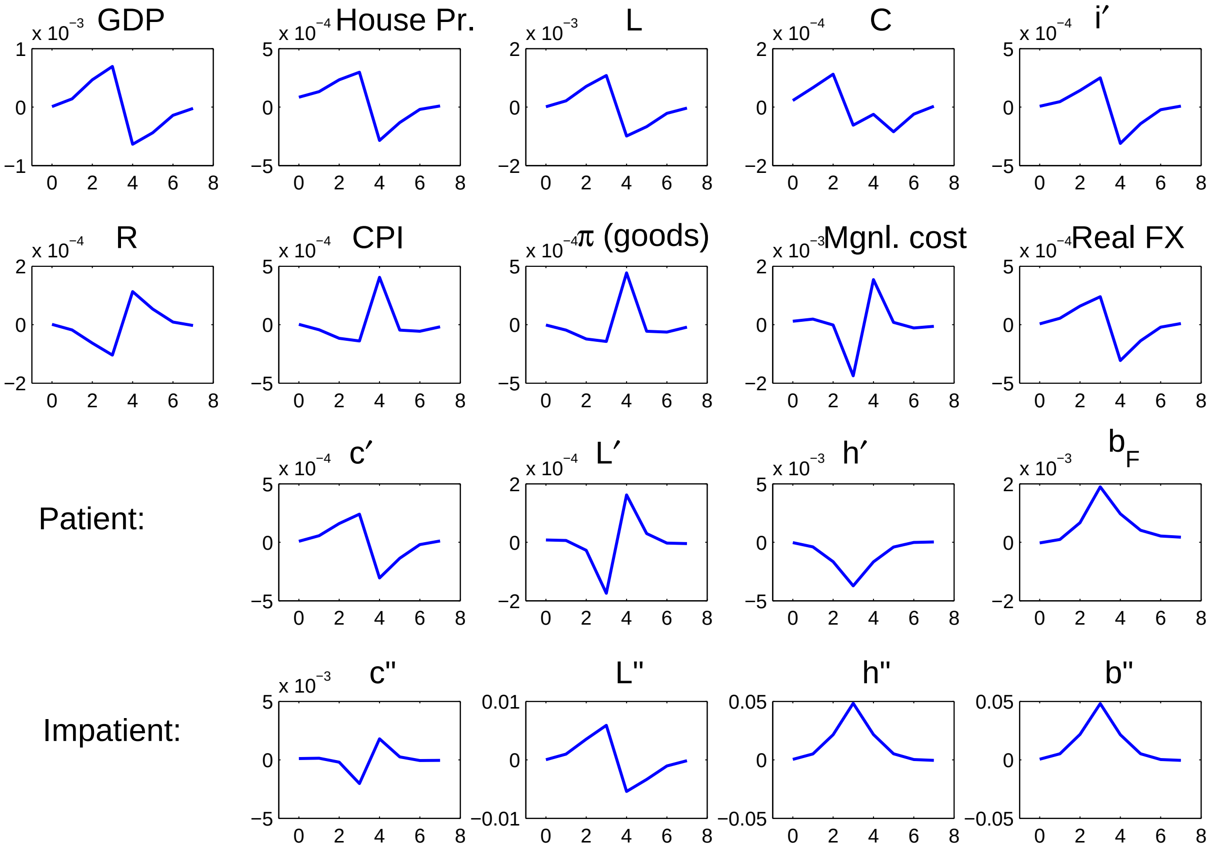
Notes: See the notes of Figure 8 for the set-up. The loan-to-value ratio m is 0.9 in the blue line, 0.75 in the green line, and 0.5 in the red line.

Figure 12: Effect of higher elasticity of the housing-rent components of CPI on housing-market boom-bust cycles.



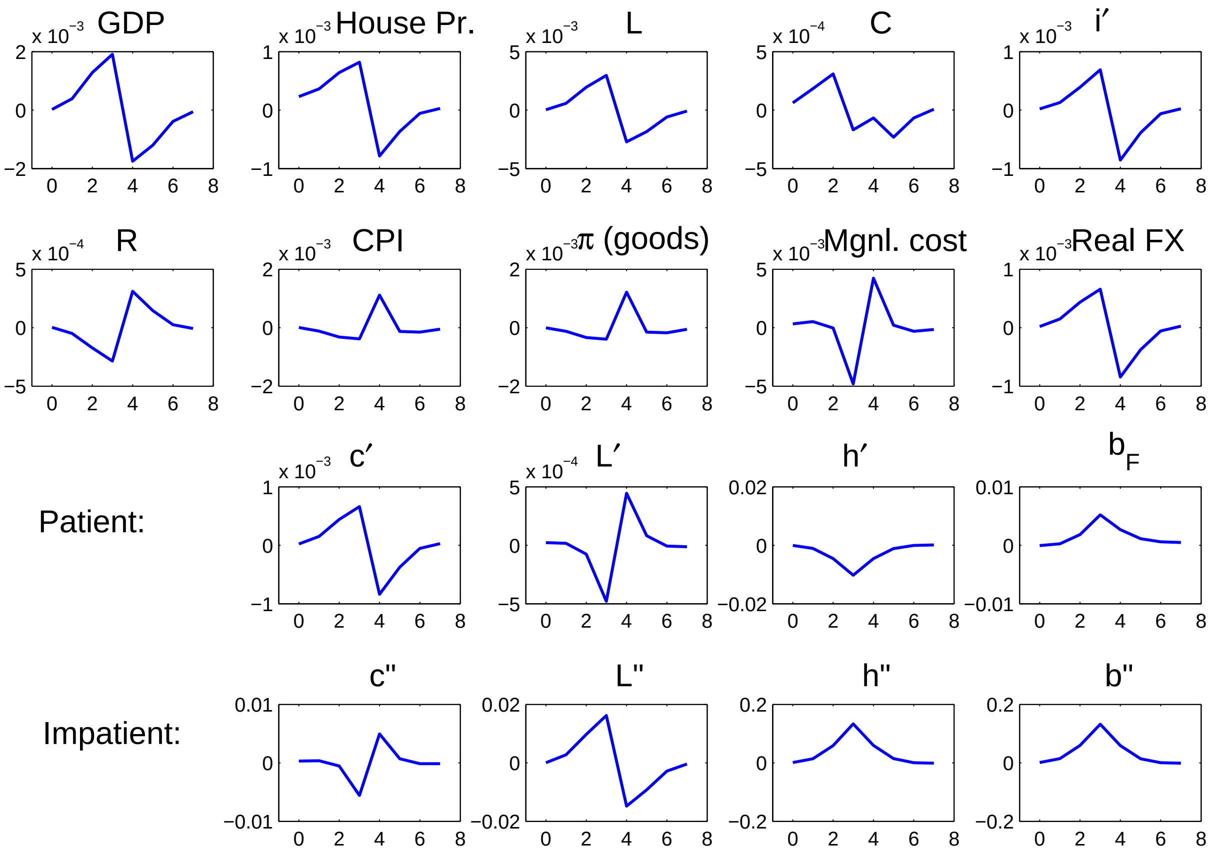
Notes: See the notes of Figure 8 for the set-up. The specification (21) is adopted for generating the responses of the housing-rent components of the CPI. $\kappa = 0.4$.

Figure 13: Response to a signal of a future expansionary monetary policy shock when only the impatient households expect the shock, but the signal is not ex-post realized



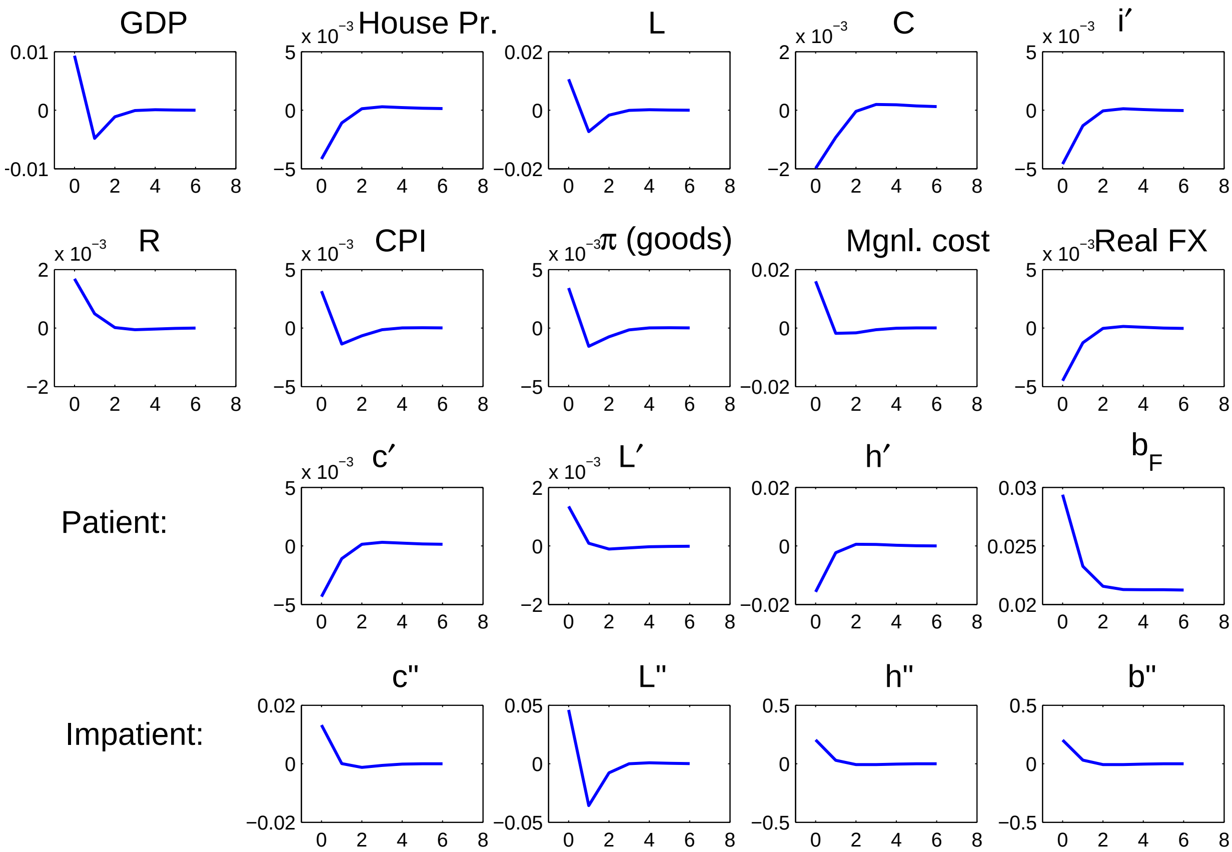
Notes: Figures are % deviations from the deterministic steady-state values except $b_{F,t}$, which is a difference from the steady-state value. The signal is received in period 0, but is not realized in period 4, i.e. $s_{\psi,0} = -\sigma_{\varepsilon_\psi}$ and $\varepsilon_{\psi,4} = 0$. The economy is at the steady state before period 0. Only the impatient households expect the shock, i.e. $\nu'_\psi = \infty$ and $\nu''_\psi = 0$. In the first and second rows, C and L are aggregate consumption and labour supply, respectively. "House Pr." is the house price, q_t, "CPI" is the CPI inflation rate, $dCPI_t$, "π (goods)" is the inflation rate of final goods, π_t, "Real FX" is the real exchange rate, s_t, and "Mgnl. cost" is the marginal cost of production, f_t. The third and the forth rows respectively show the actions of the patient and the impatient households.

Figure 14: Response to a signal of a future decline in the real world interest rate when only the impatient households expect the decline, but the signal is not ex-post realized



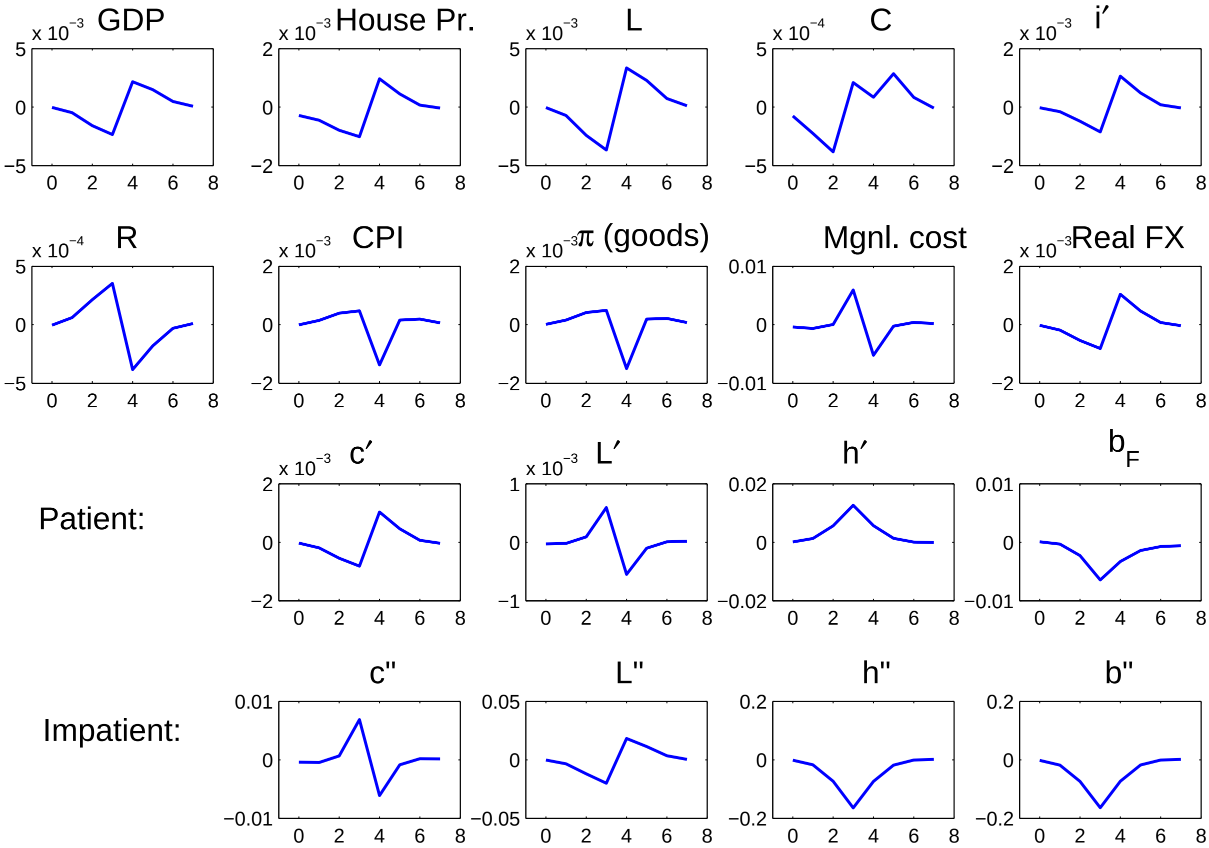
Notes: Figures are % deviations from the deterministic steady-state values except $b_{F,t}$, which is a difference from the steady-state value. The signal is received in period 0, but is not realized in period 4, i.e. $s_{r_F,0} = -\sigma_{\varepsilon_{r_F}}$ and $\varepsilon_{r_F,4} = 0$. The economy is at the steady state before period 0. Only the impatient households expect the decline, i.e. $\nu'_{r_F} = \infty$ and $\nu''_{r_F} = 0$. In the first and second rows, C and L are aggregate consumption and labour supply, respectively."House Pr." is the house price, q_t, "CPI" is the CPI inflation rate, $dCPI_t$, "π (goods)" is the inflation rate of final goods, π_t, "Real FX" is the real exchange rate, s_t, and "Mgnl. cost" is the marginal cost of production, f_t. The third and the forth rows respectively show the actions of the patient and the impatient households.

Figure 15: Response to a current positive export demand shock



Notes: Figures are % deviations from the deterministic steady-state values except $b_{F,t}$, which is a difference from the steady-state value. The shock hits in period 0, i.e. $\varepsilon_{Y_F,0} = \sigma_{\varepsilon_{Y_F}}$, and the economy is at the steady state before the shock. In the first and second rows, C and L are aggregate consumption and labour supply, respectively. "House Pr." is the house price, q_t, "CPI" is the CPI inflation rate, $dCPI_t$, "π (goods)" is the inflation rate of final goods, π_t, "Real FX" is the real exchange rate, s_t, and "Mgnl. cost" is the marginal cost of production, f_t. The third and the forth rows respectively show the actions of the patient and the impatient households.

Figure 16: Response to a signal of a future positive export demand shock when only the impatient households expect the shock, but the signal is not ex-post realized



Notes: Figures are % deviations from the deterministic steady-state values except $b_{F,t}$, which is a difference from the steady-state value. The signal is received in period 0, but is not realized in period 4, i.e. $s_{Y_F,0} = \sigma_{\varepsilon_{Y_F}}$ and $\varepsilon_{Y_F,4} = 0$. The economy is at the steady state before period 0. Only the impatient households expect the shock, i.e. $\nu'_{Y_F} = \infty$ and $\nu''_{Y_F} = 0$. In the first and second rows, C and L are aggregate consumption and labour supply, respectively."House Pr." is the house price, q_t, "CPI" is the CPI inflation rate, $dCPI_t$, "π (goods)" is the inflation rate of final goods, π_t, "Real FX" is the real exchange rate, s_t, and "Mgnl. cost" is the marginal cost of production, f_t. The third and the forth rows respectively show the actions of the patient and the impatient households.