A Policy Model to Analyze Macroprudential Regulations and Monetary Policy*

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November 2013

Abstract

We construct a small-open-economy New Keynesian DSGE model with real-financial linkages to analyze the effects of financial shocks and macroprudential policies on the Canadian economy. In the model, banks borrow short-term funds from saver households, and lend long-term to borrower households and entrepreneurs who are financing their housing and capital purchases. Due to financial frictions in bank funding and lending, ultimate borrowers face a spread relative to the policy rate, and this spread depends on the current and future leverage position of the borrowers themselves and that of the banks. Bank capital and LTV regulations affect the economy primarily through their effects on this spread. The model also features nominal and real rigidities that have become commonplace in the literature such as price and wage stickiness, inflation indexation, adjustment costs in investment, and habit formation in consumption. The model is calibrated to match dynamics in Canadian macroeconomic and financial data. We study the transmission of monetary policy and financial shocks in the model economy, and analyze the effectiveness of various policies in simultaneously achieving macroeconomic and financial stability. We find that, in terms of reducing household debt, more targeted tools such as LTV regulations are the most effective and least costly, followed by bank capital regulations and monetary policy, respectively.

Keywords: macroprudential policy, DSGE, real-financial linkages.

JEL Classification: E44, F41, E32, E17.

*We thank Robert Amano, Greg Bauer, Julien Bengui, Jean Boivin, Fabia Carvalho, Marcos Castro, Larry Christiano, Jose Dorich, Michael Johnston, Sharon Kozicki, Oleksiy Kryvtsov, Rhys Mendes, Enrique Mendoza, Tommasso Monacelli, Stephen Murchison, Brian Peterson, Alessandro Rebucci, Yasuo Tarejima, Alexander Ueberfeldt, Yahong Zhang, Yang Zhang, and seminar participants at Bank of Canada, EcoMod 2013 in Prague, and BIS CCA Research Network 2013 in Mexico City for comments. All errors are ours. The views expressed in this report are solely of those of the authors. No responsibility for them should be attributed to the Bank of Canada.

1 Introduction

The recent global financial crisis was a reminder that macroeconomic and financial stability are closely linked. In particular, the financial system can be a source of shocks hitting the economy, or can significantly amplify and propagate shocks originating elsewhere. As such, financial considerations cannot be ignored when evaluating current and future developments in the real economy, and when assessing the proper stance of monetary policy. On the theoretical front, the crisis has led to a renewed interest in incorporating real-financial linkages into business cycle models, which largely abstracted from these interactions until recently. On the policy front, there has also been new emphasis on the role of macroprudential regulations in helping achieve financial stability, and the possible coordination of these tools with monetary policy.

These issues relating to the *nexus* between monetary policy and financial stability have also been pertinent in the Canadian context, where monetary policy has faced important challenges and trade-offs after the crisis. In particular, the policy rate has remained low for a prolonged period to counter external headwinds, while low rates and safe-haven flows into Canada have led to a further increase in household indebtedness posing potential risks to financial stability (see Figure 1). Addressing these challenges require a better understanding of real-financial linkages, as well as assessing the effectiveness and costs of various macroprudential tools in dealing with financial imbalances. We have already made important progress at the Bank of Canada in incorporating real-financial linkages in our structural models in order to analyze some of these issues: In particular, Dorich et al. (2013) have introduced term and risk spreads, as well as a housing sector and household wealth, into ToTEM II, the main projection model used by the Canadian Economic Analysis department. The effects of banks' and borrowers' net worth positions on risk premia for business loans have been studied by Meh and Moran (2010), Christensen and Dib (2008), and Dib (2010a, 2010b), and the latter models' financial features were adapted into BoC-GEM-Fin, the structural policy model used in the International Economic Analysis department. Similarly, Basant Roi and Mendes (2007), Christensen et al. (2009), and Christensen and Meh (2011) have incorporated household balance sheet and debt in models featuring the housing market, and have studied the effects of exuberance in housing markets and loan-to-value (LTV) ratio regulations.[1] These models have been very useful in addressing key policy issues; for example, Boivin et al. (2010) have used these frameworks to study the nexus between monetary policy and financial stability in the context of the 2011 inflation targeting renewal. Similarly, as part of the Macroeconomic Assessment Group (MAG) of the Basel Committee on Banking Supervision, these frameworks were used to assess the effects of Basel III regulations and the G-SIFI capital surcharges on the Canadian economy.

In this paper, we add to this line of work by constructing a policy model in the DSGE tradition that can be used to analyze real-financial linkages and nexus issues within a unified framework

[1] See the special issue on "Real-Financial Linkages" of the Bank of Canada Review in Summer 2011 for a brief summary of these models. There has also been important empirical work studying real-financial linkages issues at the Bank. See for example Allen et al. (2012), Kartashova and Tomlin (2013), Faruqui and Torchani (2012), Chen et al. (2012), Djoudad (2012), Gauthier et al. (2011), and Beaton and Desroches (2011).

featuring non-trivial interactions between the balance sheet positions of households, firms and banks. This framework would allow us to analyze key issues such as the effects of a house price decline on household indebtedness, and its spillover to the business sector and the broader economy through its impact on the financial sector. The unified framework would also allow us to analyze the interactions between targeted macroprudential instruments (such as regulatory LTV and mortgage amortization rules) and broader tools (such as bank capital requirements), and consider the appropriate mix between macroprudential and monetary policies in dealing with household indebtedness.

Our model is a medium-scale small-open-economy New Keynesian DSGE model with real, nominal and financial frictions. It features four key agents: patient households (savers), banks (intermediaries), impatient households and entrepreneurs (borrowers). Due to financial frictions, modeled similar to Curdia and Woodford (2011), Bernanke et al. (1999), and Iacoviello (2013), banks face a spread on their short-term funding rate based on their capital position. Similarly, borrowers face spreads based on their leverage positions when they receive bank loans to finance their housing and capital purchases. Bank capital and LTV regulations affect the economy primarily through their effects on these funding and lending spreads. Bank loans to households and entrepreneurs are modeled as long-term bonds paying decaying coupon payments as in Alpanda and Dorich (2013), which in turn is based on Woodford (2001) and Curdia et al. (2012). Elements of the risk-taking channel are introduced through the effects of aggregate liquidity on the risk appetite of savers, whereby an increase in risk aversion induces agents to rebalance their portfolio towards risk-free assets, lowering asset prices and amplifying the effects of adverse shocks on the economy. The model also features nominal and real rigidities that have become commonplace in the literature such as price and wage stickiness, inflation indexation, adjustment costs in investment, and habit formation in consumption as in Christiano et al. (2005) and Smets and Wouters (2007); these backward-looking features are crucial to adequately capture business cycle dynamics in the data as suggested by various VAR analyses. The small open economy features are similar to those in Gali and Monacelli (2005), Gertler et al. (2007), and Adolfson et al. (2008). In particular, we allow for a more flexible form of the UIP condition, also utilized in ToTEM, and take into account the partial pass-through of exchange rate movements to import and export prices. The model is calibrated to match dynamics in Canadian macroeconomic and financial data. We study the transmission of monetary policy and the effects of macroeconomic and financial shocks, and consider the effectiveness of macroprudential and macroeconomic policies to achieve macroeconomic and financial stability goals.

For reducing household indebtedness, we find that targeted policies such as LTV regulations are the most effective and least costly, followed by bank capital regulations and monetary policy respectively. In particular, 5 p.p. tightening in regulatory LTV decreases household debt by 1.1% in the first year of the policy change and reduces it by another 6.5% during the transition, while its output impact at the peak is about 0.5%. In contrast, a 1% increase in capital requirements reduces household debt by about 1.8% and reduces output by about 0.27% at the peak. Hence, reducing household debt by the same amount of LTV would require about a 4 p.p. increase in capital requirements, leading to a 1% decline in output. Similarly, 100 bps. temporary increase in the policy rate reduces household debt by about 1.8% at the peak as well, but this comes at an output cost of about 0.5%, offering an even worse tradeoff than capital requirements in terms of reducing household debt.

The next section surveys the main themes in the recent literature on real-financial linkages. Section 3 introduces the model, and Section 4 discusses the calibration of model parameters. The main implications of the model are discussed in Section 5, and Section 6 concludes.

2 Main themes in the recent literature on real-financial linkages

The literature on real-financial linkages has emphasized that the main link from financial developments to the real side of the economy is through the effects of asset prices on the balance sheet conditions of lenders and borrowers (Bernanke and Gertler, 1999; Basel Committee on Banking Supervision, 2011). The traditional wealth effects of financial assets on consumption are thought to be more muted, since most stock and real estate wealth is held in illiquid form (i.e. as pensions and houses). Below, we provide a brief overview of the recent literature on real-financial linkages, focusing on the former theme.

2.1 Balance sheet channel

The balance sheet channel posits that the leverage position of borrowers are key for their borrowing conditions, and shocks are amplified through their effects on asset prices and the net worth position of borrowers. There are mainly two types of models in this literature: the *agency cost model* (Carlstrom and Fuerst, 1997; Bernanke et al., 1999) and the *collateral model* (Kiyotaki and Moore, 1997; Iacoviello, 2005).

The agency cost model features asymmetric information between banks and borrowers. In particular, borrowers are subject to idiosyncratic shocks on their capital quality which lead some of them to default on their loans. In equilibrium, defaults are increasing in the leverage position of the borrowers; thus, banks charge a risk premium on loans based on the leverage position of borrowers. An increase in asset prices strengthens the borrowers' balance sheets by increasing their net worth and reducing their leverage. This in turn reduces the agency costs faced by lenders and the cost-of-debt faced by borrowers, which stimulates borrowing and investment activity above and beyond the effects of the shock in the absence of asset price movements. This effect is called the *financial accelerator* in the literature.

In the collateral model, assets are used as collateral against borrowing, as well as provide consumption services and are used as an input in production. An increase in asset prices raise the collateral value of these assets, which relaxes the borrowing constraints of households and firms, and amplifies the original effects of the shock (i.e. financial accelerator). Unlike the agency cost model, the collateral model does not feature an endogenous lending spread, but how tight the borrowing constraint binds provides a shadow cost between cost-of-capital faced by borrowers and the risk-free rate.[2]

2.2 Bank capital channel

The balance sheet channel discussed above focuses on the balance sheet position of borrowers, while the bank capital channel focuses on the balance sheet position of the lenders, and how this may impact banks' funding conditions and loan supply. In particular, better capitalized banks are able to attract funds at cheaper rates, which allows them to lend to households and businesses at reduced rates as well. This channel is all the more relevant in a world where banks increasingly fund themselves through market-based wholesale funding as opposed to retail deposits. Retail deposits are by-and-large insured by the government, and therefore, are not that sensitive to the capital position of banks. On the other hand, problems related to the solvency and liquidity of banks can quickly lead to sharp increases in wholesale funding rates, and dry up banks' short-term funding sources. This would force banks to liquidate assets prematurely, and cut back on new loans, with adverse effects on the financial system and macroeconomic conditions.

The models in this literature typically feature a moral hazard problem between savers and banks. In the *double moral hazard model* of Holmstrom and Tirole (1997), Chen (2001), and Meh and Moran (2010), households would not deposit funds to banks unless banks partly use their own capital to fund their lending. If banks do not have sufficient "skin in the game", they are not induced to monitor their borrowers, which in turn leads borrowers to divert funds away from projects for their own gain. Thus, bank capital plays a crucial role in determining bank funding and lending conditions. In the model, the required return on bank capital is assumed to be higher than the deposit rate; thus, when banks are required to commit more capital through regulations, the cost of debt for borrowers also increases. Similarly, in the *endogenous borrowing constraint model* of Gertler and Karadi (2011) and Gertler and Kiyotaki (2010), bankers can divert funds for their own benefit instead of financing capital purchases of entrepreneurs. This moral hazard leads to an endogenous borrowing constraint for banks; the availability of bank capital relaxes this constraint, and eases funding conditions for banks.

Aikman and Paustian (2006) and Davis (2010) extend the agency cost model of Bernanke et al. (1999) to also include asymmetric information between savers and banks. In particular, banks are subject to idiosyncratic shocks on their assets which lead some of them to default on their depositors. In equilibrium, defaults are increasing in the leverage position of the banks; thus, savers charge a risk premium on short-term bank funding based on the leverage position of banks. Thus, this model features two financial accelerators (between savers and banks and between banks and borrowers), which lead to the so-called *adverse feedback loop* mechanism, where deterioration in borrower balance sheets also lead to deterioration in bank balance sheets. This generates comovement between bank

[2] The literature on the financial accelerator is too vast to list here; c.f. Gilchrist et al. (2009), Christiano et al. (2010), and the references listed therein. For specific applications to housing, c.f. Aoki et al. (2004), Iacoviello (2005), Basant Roi and Mendes (2007), Iacoviello and Neri (2010), Christensen and Meh (2011), Chatterjee and Eyigungor (2011), and Alpanda and Zubairy (2013).

lending and bank funding spreads, and exacerbates the adverse effects of asset price declines in recessions.[3]

A moderating factor in the strength of the bank capital channel is the speed with which asset price fluctuations are passed through to bank capital. The asset side of bank balance sheets, especially of larger banks, are now dominated by holdings of equity and debt securities linked directly and indirectly to corporate and real estate values. Asset price fluctuations, especially with mark-to-market accounting, thus rapidly and directly affect the net worth of banks. With more traditional loans, the effects of assets prices on bank capital are more gradual given that borrowers default with a lag, and it takes time for banks to write-off these loans from their balance sheets.

2.3 Liquidity, risk-taking, and exuberance

As argued before, wholesale funds, as opposed to retail deposits, have become the main source of banks' funding at the margin, especially for large and systemically important banks (Adrian and Shin, 2010; Kiyotaki and Moore, 2012). The prevalance of funding liquidity, coupled with the opportunity to securitize assets, have provided banks with more flexibility in adjusting their balance sheet size. Brunnermeier and Pedersen (2008) have emphasized that liquidity in funding markets also affects the price of risk in financial markets through its effect on the market liquidity of financial assets, and the reduction in margin requirements for traders. The recent financial crisis has demonstrated that the reliance of banks on market-based wholesale funding can create vulnerabilities in the system. Similar to a traditional bank-run on retail deposits, a liquidity shortage in wholesale markets can lead to banks' losing their short-term funding sources. Unable to rollover their funding, banks would then be forced to dispose of assets and foreclose on loans. This can create systemic effects due to correlated positions of banks, interconnectedness across banks, and fire-sale externalities on asset prices (Diamond and Rajan, 2005; De Nicolo et al, 2012; Woodford, 2012).

Excess liquidity in funding markets due to low short-term interest rates and safe-haven flows, coupled with the compensation schemes in financial institutions, have emerged as key factors in the build-up of risks in the financial system. As Rajan (2006) points out, portfolio managers are typically compensated on the basis of nominal returns. A low interest rate environment, especially if *too-low-for-too-long*, can thus induce search-for-yield behavior, and lead to higher risk-taking in bank and institutional-investor asset portfolios, increasing risks on the asset side of financial institutions. Similarly, a low interest rate environment can lead to build-up of risks on the liability side of bank balance sheets by steepening the yield curve, which increases the profitability of banks and strengthens banks' capital position. Banks are then further induced to enlarge their balance sheet, financing new assets through short-term borrowing in wholesale funding markets (Adrian and Shin, 2010). The build-up of risks on both the asset and the liability sides of banks' balance sheets

[3] See Iacoviello (2013) for a double collateral constraint model to capture the same mechanism. The literature on bank capital channel also includes models that feature bank capital due to regulatory constraints (c.f. Van den Heuvel, 2008; Gerali et al., 2010).

during low interest rate episodes has been dubbed the "risk-taking channel" of monetary policy.

Easy funding and the availability of securitization, along with loosening of lending standards, have led to a precipitious increase in bank lending, and have brought about sharp increases in asset prices. For example, the U.S. stock market values have more than doubled relative to GDP between 1995-2000, and U.S. house values have increased by about 50% relative to GDP between 2000-2005. According to the Case-Shiller/S&P index, house prices in major U.S. metropolitan areas increased by about 100% in the same period. The fact that asset prices increased so much and so fast, and far out-of-line with historical norms, has led many to believe that these reflect *irrational exuberance* on the part of market participants (c.f. Shiller, 2000). Following the booms, asset prices declined by almost the same order of magnitude, and with equaling speed, in these episodes. In particular, stock prices were halved by 2002, only two years after their peak, and house values declined to pre-boom magnitudes by the end of the decade. In many minds, this has served as proof that the booms were caused by exuberance.[4] Once agents realized that their views on future returns were overly optimistic and would fail to materialize, asset prices quickly reverted back to their previous levels.[5] These exuberance episodes are arguably less likely to occur without the ample availability of funding liquidity.

2.4 The case for macroprudential regulations

In principle, market-determined spreads and market-imposed borrowing constraints on banks and borrowers provide adequate solutions for financial frictions, and markets could deliver second-best social optimum solutions in the absence of regulation. The case for macroprudential policies (such as regulatory bank capital requirements and loan-to-value ratios on mortgages) hinges on the presence of externalities, moral hazard arising from government guarantees, and asset price exuberance. These prevent market outcomes to reach the second-best social optimum, causing banks and borrowers to get over-leveraged during booms, which increases the probability of an eventual financial crisis with severe implications for macroeconomic and financial stability.

As stressed before, the reliance of banks on uninsured wholesale funds have increased the rollover risk of banks' funding. A liquidity shortage, similar to what was observed in the recent crisis, can have systemic effects due to correlated positions across banks, fire-sale of bank assets, and the uncertainty regarding the exposure of financial institutions to banks that are directly affected by the liquidity shortage. Thus, a liquidity shortage initially involving only a handful of financial institutions could quickly develop into a system-wide crisis due to these aforementioned externalities (De Nicolo et al., 2012; Woodford, 2012; Bianchi and Mendoza, 2010).[6] Note also that moral hazard

[4] There is a growing literature that studies the role of exuberant expectations and relaxed borrowing constraints on asset prices (c.f. Bernanke and Gertler, 1999; Basant Roi and Mendes, 2007; Carriga et al., 2012; and Granziera and Kozicki, 2012).

[5] Compare this, for example, to the stock market crash of 1973-74 which was as fierce in magnitude and speed; yet it took about two decades for stock values to revert back to pre-crash levels, suggesting that changes in fundamentals, rather than pure exuberance, was the culprit for the crash. For more on this stock market episode, see Greenwood and Jovanovic (1999), McGrattan and Prescott (2005), and Alpanda and Peralta-Alva (2010).

[6] Note that individual agents do not take into account the effects of their actions on asset prices. To the extent that

arising from deposit insurance, and implicit government guarantees based on *too-big-to-fail*, provide banks with the incentive to enlarge balance sheets and take excessive risks (Kareken and Wallace, 1978; Farhi and Tirole, 2012; Chari and Kehoe, 2009). Similarly, mispricing in complicated and non-transparent financial instuments, such as certain derivatives and asset-backed securities, may lead to false valuations of bank collateral, and result in excessive risk-taking by banks (Cociuba et al., 2011). The presence of externalities cited above, moral hazard issues based on government explicit and implicit guarantees, as well as mispricing and exuberance in asset prices, provide the case for putting macroprudential regulations in place (Galati and Moessner, 2010; Dell'Ariccia et al., 2012).

3 Model

The model is a medium-scale small-open-economy DSGE model with real, nominal and financial frictions (see Figure 2 for a brief overview). The model features four types of key agents: patient households (i.e. savers), banks who intermediate between savers and borrowers, and impatient households and entrepreneurs who borrow from banks to help finance their purchases of housing and capital respectively. On the production side, domestic producers rent capital and labor services to produce the domestic output good, which is aggregated with imported goods to produce the five types of final goods (i.e. consumption, business investment, residential investment, government expenditure and export goods). Importers and exporters are introduced as separate agents in the model to capture the partial pass-through of exchange rate movements to import and export prices at the retail level. The model also features capital and housing producers, as well as monetary, fiscal and macroprudential policy. In what follows, we analyze agents in the model in blocks.

3.1 Main agents in the model

3.1.1 Patient households

The economy is populated by a unit measure of infinitely-lived patient households indexed by i whose intertemporal preferences over consumption, $c_{P,t}$, housing, $h_{P,t}$, and labor supply, $l_{P,t}$, are described by the following expected utility function:

$$E_t \sum_{\tau=t}^{\infty} \beta_P^{\tau-t} \upsilon_\tau \left\{ \log\left[c_{P,\tau}(i) - \zeta c_{P,\tau-1}\right] + \xi_{hP} \widetilde{\varepsilon}_{h,\tau} \log h_{P,\tau}(i) - \xi_{lP} \widetilde{\varepsilon}_{l,\tau} \frac{l_{P,\tau}(i)^{1+\vartheta}}{1+\vartheta} \right\}, \tag{1}$$

where t indexes time, β_P is the time-discount parameter, ζ is the external habit parameter for consumption, ϑ is the inverse of the Frisch-elasticity of labor supply, and ξ_{hP} and ξ_{lP} are level

asset prices affect economy-wide spreads and collateral constraints, there are pecuniary externalities arising from asset prices. These externalities lead to over-borrowing in booms, and can be internalized via a tax on lending (Bianchi and Mendoza, 2010; Cesa-Bianchi and Rebucci, 2013).

parameters for housing and labor, respectively. The preference shock, υ_t, is an AR(1) process:

$$\log \upsilon_t = \rho_\upsilon \log \upsilon_{t-1} + \varepsilon_{\upsilon,t}, \tag{2}$$

where ρ_υ is the persistence parameter and $\varepsilon_{\upsilon,t}$ is an i.i.d. innovation with standard deviation equal to σ_υ. The housing demand shock, $\widetilde{\varepsilon}_{h,t}$, and the labor supply shock, $\widetilde{\varepsilon}_{l,t}$, are modeled in a similar fashion.

Labor services are heterogeneous across the patient households, and are aggregated into a homogenous labor service by perfectly-competitive labor intermediaries, who in turn rent these labor services to domestic producers. The labor intermediaries use a standard Dixit-Stiglitz aggregator; therefore, the labor demand curve facing each patient household is given by

$$l_{P,t}(i) = \left(\frac{W_{P,t}(i)}{W_{P,t}} \right)^{-\eta_{l,t}} l_{P,t}, \tag{3}$$

where $W_{P,t}$ and $l_{P,t}$ are the aggregate nominal wage rate and labor services for patient households, respectively, and $\eta_{l,t}$ is a time-varying elasticity of substitution between the differentiated labor services. To capture cost-push shocks on wages, we specify an exogenous AR(1) process on $\theta_{w,t} = \eta_{l,t}/(\eta_{l,t}-1)$ as:

$$\log \theta_{w,t} = (1-\rho_w) \log \theta_w + \rho_w \log \theta_{w,t-1} + \varepsilon_{w,t}, \tag{4}$$

where θ_w is the gross mark-up of real wage over the marginal rate of substitution at the steady-state.

The patient households' period budget constraint is given by

$$\begin{aligned} & c_{P,t}(i) + q_{h,t}\left[h_{P,t}(i) - (1-\delta_h)\psi_{h,t} h_{P,t-1}(i)\right] \\ & \quad + q_{k,t}\left[k_{P,t}(i) - (1-\delta_k)\psi_{k,t} k_{P,t-1}(i)\right] + (1+\Upsilon_{d,t})\frac{D_t(i)}{P_t} + \frac{1}{\varkappa_t}\left[\frac{B_t(i)}{R_t P_t} + \frac{e_t B_t^*(i)}{\Phi_t R_t^* P_t}\right] \\ & \leq (1-\tau_{l,t})\frac{W_{P,t}(i)}{P_t} l_{P,t}(i) + (1-\tau_{k,t}) r_{kP,t}\psi_{k,t} k_{P,t-1}(i) + \tau_{k,t}\delta_k \psi_{k,t} k_{P,t-1}(i) + R_{d,t-1}\frac{D_{t-1}(i)}{P_t} \\ & \quad + \frac{B_{t-1}(i)}{P_t} + \frac{e_t B_{t-1}^*(i)}{P_t} + \frac{TR_{P,t}}{P_t} + \frac{D_{B,t}}{P_t} + \frac{D_{E,t}}{P_t} + \frac{\Pi_{d,t}}{P_t} + \frac{\Pi_{m,t}}{P_t} - \text{ adj. costs}, \end{aligned} \tag{5}$$

where P_t denotes the price level. Patient households use their savings to accumulate physical assets in the form of housing, $h_{P,t}$, and capital, $k_{P,t}$, and financial assets in the form of bank deposits, D_t, domestic government bonds, B_t, and foreign government bonds, B_t^*. $q_{h,t}$ and $q_{k,t}$ are the relative prices of housing and capital respectively, and δ_h and δ_k are their corresponding depreciation rates. $\psi_{h,t}$ and $\psi_{k,t}$ are aggregate housing and capital quality shocks similar to Gertler and Karadi (2011), and are specified as exogenous AR(1) processes. These shocks work similar to a change in the physical depreciation rate by affecting the effective units of assets brought from the previous period; as such, they capture economic depreciation or "quality" of these assets. $\Upsilon_{d,t}$ are monitoring costs incurred for short-term funding of banks, Φ_t is the country risk-premium, and $\varkappa_t$ is a portfolio preference term. These features are explained in more detail below.

On the income side, households earn wage income, $W_{P,t}$, and rental income on their capital holdings, $r_{kP,t}$, for which they pay proportional taxes at exogenously-determined rates of $\tau_{l,t}$ and $\tau_{k,t}$, respectively (modulo depreciation allowance on capital income tax). They receive interest income from bank deposits at a gross nominal rate of $R_{d,t}$, and from their holdings of domestic and foreign bonds. Households also receive transfers from the government, $TR_{P,t}$, dividends from banks and entrepreneurs, $D_{B,t}$ and $D_{E,t}$, and profits of domestic and import firms, $\Pi_{d,t}$ and $\Pi_{m,t}$, in a lump-sum fashion.

Wage-stickiness is introduced via a quadratic cost of wage adjustment similar to Rotemberg (1982),

$$\frac{\kappa_w}{2}\left(\frac{W_{P,t}\left(i\right)/W_{P,t-1}\left(i\right)}{\pi_{t-1}^{\varsigma_w}\pi^{1-\varsigma_w}}-1\right)^2\frac{\left(\eta_{l,t}-1\right)\left(1-\tau_{l,t}\right)W_{P,t}}{P_t}l_{P,t}, \tag{6}$$

where κ_w is a level parameter, $\pi_t = P_t/P_{t-1}$ is the aggregate inflation factor, and ς_w determines indexation of wage adjustments to past inflation. There are also quadratic costs of adjustment for housing and capital, with level parameters κ_{hP} and κ_{kP} respectively.

Short-term funding of banks and the bank capital channel In the model, bank deposits are best viewed as wholesale funding (i.e. non-personal deposits and repos) which are not covered by deposit insurance, and are subject to problems that arise from moral hazard and asymmetric information. As such, patient households also play the role of institutional investors in the economy who trade assets with foreigners and are the source of wholesale funds.[7]

Patient households incur monitoring costs when extending funds to banks, and in return receive full repayment of their lending next period. Although this formulation abstracts from bank default *per se*, these monitoring costs can be interpreted as the fraction of funds that are defaulted upon by the banks (i.e. "bad loans") following Curdio and Woodford (2011). Another interpretation of these monitoring costs is that they reflect the cost of purchasing default insurance on funds extended to banks similar to a credit default swap (Amdur, 2010). These monitoring costs help generate a spread between the funding rate of banks and the risk-free rate (i.e. the funding spread) along the lines of Curdia and Woodford (2011).

We posit that monitoring costs of investors depend on the leverage position of banks; in particular, banks are able to attract funds at a cheaper rate if they are well-capitalized relative to the capital requirements imposed on their risk-weighted assets:

$$1+\Upsilon_{d,t}=\chi_{d1}\left(\frac{\gamma_t\left[\omega_{I,t}P_{I,t}b_{I,t}+\omega_{E,t}P_{E,t}b_{E,t}\right]}{A_t}\right)^{\chi_{d2}}\widetilde{\varepsilon}_{d,t}, \tag{7}$$

where $P_{I,t}b_{I,t}$ and $P_{E,t}b_{E,t}$ are the market value of long-term bank loans extended to impatient households and entrepreneurs respectively, and A_t is bank capital in nominal terms. γ_t is the capital requirement ratio on banks, while $\omega_{I,t}$ and $\omega_{E,t}$ are the regulatory risk-weights applied to

[7] We could instead separate these two roles by introducing another financial intermediary in between. See, for example, Dib (2010a, 2010b) for an example of this.

household and business loans respectively. $\chi_{d1} > 1$ is a level parameter determining the funding spread at the steady-state, while χ_{d2} regulates the elasticity of funding spread with respect to bank leverage. $\widetilde{\varepsilon}_{d,t}$ is an AR(1) shock capturing changes in the riskiness of bank assets not reflected in the regulatory risk-weights, perhaps due to a change in the market perception of their collateral value or the assets' market liquidity. Note that our formulation above translates the quantity constraint imposed by capital requirements into a funding spread, and allows bank leverage to temporarily deviate from its regulatory ratio, $1/\gamma_t$.[8]

Country risk-premium Domestic and foreign bonds trade at a discount R_t and $\Phi_t R_t^*$ respectively, where R_t and R_t^* are the policy rates in the domestic and foreign economies, while Φ_t is the country risk-premium. The specification for the country risk-premium is:

$$\Phi_t = \exp\left[-\Phi_a\left(nfa_t - \overline{nfa}\right) - \Phi_e\left(\frac{E_t e_{t+1}}{e_t}\frac{e_t}{e_{t-1}} - 1\right) + \widetilde{\Phi}_t\right], \tag{8}$$

where the first term captures the negative relationship between the country risk-premium and the net foreign asset position of the home country, $nfa_t = e_t B_t^* / \varkappa_t \Phi_t R_t^* P_t y_{d,t}$, with Φ_a being an elasticity parameter. This debt-elastic country risk specification follows Schmitt-Grohe and Uribe (2003), and is necessary to ensure that the stochastic discount factor of patient households is non-stationary. The second component of the country risk-premium depends on the current and the expected depreciation rate, with Φ_e determining the relevant elasticity. This specification is due to Adolfson et al. (2008), and allows for a negative relationship between the country risk premium and the expected depreciation rate, which can account for the forward premium puzzle observed in the data. The third component of the country risk-premium, $\widetilde{\Phi}_t$, is exogenous and follows an AR(1) process. Finally, e_t refers to the nominal exchange rate quoted in terms of Canadian dollars per unit of foreign currency.

Portfolio preference and the risk-taking channel The discounting for the risk-free asset returns is additionally impacted by the term, $\varkappa_t$, which is modeled as a time-varying "tax wedge" on risk-free bond returns (Smets and Wouters, 2007; Chari et al., 2007; Alpanda, 2013). An increase in $\varkappa_t$ induces patient households to rebalance their asset portfolios away from "risky" assets such as bank deposits and capital, and towards "safe" assets such as domestic and foreign bonds (i.e. "flight-to-quality"). Similarly, a decrease in $\varkappa_t$ results in agents switching their portfolios towards riskier assets (i.e. "search-for-yield"). As such, $\varkappa_t$ captures changes in the risk-appetite of investors and induces the related portfolio adjustments.

[8] In our model, we capture the effects of financial frictions and regulations through endogenously-determined spreads rather than always-binding borrowing constraints. Thus, regulations do not necessarily bind every period, and the quantity effects of regulations are translated into spreads. This modeling of financial frictions in a tractable and flexible manner through monitoring costs allows us to more easily capture different themes in the recent literature (see Section 2). This also allows us to abstract from technical issues that arise in more standard formulations (e.g. Bernanke et al., 1999; Davis, 2010) when one introduces long-term debt contracts and risk-averse borrowers.

As argued in the introduction, higher liquidity in wholesale funding markets has been shown to reduce the "market price of risk" in financial markets, and have affected the overall attitudes towards risk of investors and financial intermediaries (Brunnermeier and Pedersen, 2008; Adrian and Shin, 2010). To capture this element of the *risk-taking channel*, we let part of the portfolio preference term, $\varkappa_t$, to be endogenously determined based on overall funding conditions. In our framework, we proxy overall funding liquidity by the availability of bank deposits, d_t, relative to its long-run trend; hence we let

$$\varkappa_t = \left(\frac{d_t}{d}\right)^{-\varrho_\varkappa} \widetilde{\varepsilon}_{\varkappa,t}, \tag{9}$$

where $\varrho_\varkappa$ is an elasticity parameter, and $\widetilde{\varepsilon}_{\varkappa,t}$ is an exogenous AR(1) process.

This feature, when $\varrho_\varkappa > 0$, adds an additional amplification mechanism into the model, where a favorable shock that leads to an increase in bank deposits is further reinforced by the increase in the risk appetite of investors. This leads to an increase in asset prices above and beyond what would be observed in the absence of this feature. Banks are able fund themselves at cheaper rates which allows them to enlarge their balance sheet size, while monitoring costs and risk-premia are also reduced due to the effects of asset prices on the net worth position of borrowers.

Optimality conditions The patient households' objective is to maximize utility subject to the budget constraint, the labor demand curve of labor intermediaries, and appropriate No-Ponzi conditions. The first-order-condition with respect to consumption equates the marginal utility gain from consumption to the marginal cost of spending a unit out of the budget (i.e. $\lambda_{P,t}$, Lagrange multiplier on the budget constraint).

The optimality condition for housing equates the marginal cost of acquiring a unit of housing to the marginal utility gain from housing services and the discounted value of expected capital gains, which (ignoring adjustment costs) can be written as:

$$q_{h,t} = \xi_{hP} \widetilde{\varepsilon}_{h,t} \frac{c_{P,t} - \zeta c_{P,t-1}}{h_{P,t}} + E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) (1 - \delta_h) \psi_{h,t+1} \varkappa_{h,t} q_{h,t+1} \right]. \tag{10}$$

Note that the expected capital gains has an additional term, $\varkappa_{h,t}$, capturing pure exuberance which drives a wedge between the observed asset price and its "fundamental value" similar to Bernanke and Gertler (1999) and Basant Roi and Mendes (2007). Unlike the housing quality shock, $\psi_{h,t}$, which is expected ex-ante and realized ex-post, the housing exuberance shock is expected ex-ante, but not realized afterwards. Therefore, it can be thought as an unrealized news shock on future housing quality as in Gertler and Karadi (2011).

Similarly, the optimality condition for capital equates the marginal cost of acquiring a unit of capital to the expected marginal gains from rents and capital gains, which (ignoring adjustment costs) can be written as:

$$q_{k,t} = E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \left[(1 - \delta_k) q_{k,t+1} + (1 - \tau_{k,t}) r_{kP,t+1} + \tau_{k,t} \delta_k \right] \psi_{k,t+1} \varkappa_{k,t} \right], \tag{11}$$

where $\varkappa_{k,t}$ is an exuberance shock for expected capital returns, similar to the one on housing. The exuberance shocks for housing and capital returns are specified as exogenous AR(1) processes.

Arbitrage between domestic bonds and bank deposits imply (after log-linearization):

$$\widehat{R}_{d,t} - \widehat{R}_t = \widehat{\varkappa}_t + \widehat{\Upsilon}_{d,t}, \tag{12}$$

which relates the funding spread of banks to the risk-appetite of investors and banks' leverage ratios. Note that an increase in deposits leads to an increase in the funding spread faced by banks, but when the risk-taking channel is turned on, this effect is partially offset by the endogenous component of the risk-appetite term, $\widehat{\varkappa}_t$. In principle, we could observe small movements in the funding spread despite large changes in banks' leverage ratios provided that bank leverage is accompanied by increasing risk-appetite. Also note that, changes in the regulatory bank capital ratio feeds into the funding spread of banks; in particular, a 1 percent increase in the bank capital requirement ratio increases the funding spread of banks by $\chi_{d2}\gamma$ percent, all else equal.

Arbitrage between domestic and foreign bonds implies the uncovered-interest-parity (UIP) condition (after log-linearization):

$$\widehat{e}_t = (1 - \Phi_e) E_t \widehat{e}_{t+1} + \Phi_e E_t \widehat{e}_{t-1} - \left(\widehat{R}_t - \widehat{R}^*_t\right) - \Phi_a \left(nfa_t - \overline{nfa}\right) + \widetilde{\Phi}_t. \tag{13}$$

The optimality conditions with respect to labor and wages can be combined to derive a New-Keynesian wage Phillips curve (after log-linearization):

$$\widehat{\pi}_{wP,t} - \varsigma_w \widehat{\pi}_{t-1} = \beta_P E_t \left[\widehat{\pi}_{wP,t+1} - \varsigma_w \widehat{\pi}_t\right] - \frac{1}{\kappa_w}\left[\widehat{w}_{P,t} - \left(\vartheta \widehat{l}_{P,t} + \frac{1}{1-\zeta}\left(\widehat{c}_{P,t} - \zeta \widehat{c}_{P,t-1}\right)\right) - \widehat{\theta}_{w,t}\right], \tag{14}$$

where the nominal wage inflation, $\widehat{\pi}_{wP,t}$, and the real wage rate, $\widehat{w}_{P,t}$, for patient households are related as

$$\widehat{\pi}_{wP,t} - \widehat{\pi}_t = \widehat{w}_{P,t} - \widehat{w}_{P,t-1}. \tag{15}$$

Since households are wage-setters in the labor market, wages are marked-up relative to the marginal rate of substitution (MRS) between leisure and consumption. Wage stickiness, along with exogenous mark-up shocks, provides variation in the wedge between wages and MRS with a long-run correction to the steady-state mark-up.

3.1.2 Banks

There is a unit measure of banks indexed by i, which use deposits and their own capital to fund their lending to impatient households and entrepreneurs. Bank loans are modeled as perpetuities with exponentially decaying coupon payments as in Woodford (2001). In particular, each unit of bank loan $z \in \{I, E\}$ is valued at $P_{z,t}$ dollars in period t, and gives the bank the right to payments of $P_t \delta_z^{t+s}$ at period $t+s+1$ for all $s \geq 0$. In other words, in return for a unit of loan, a bank is entitled to receive P_t in period $t+1$, $P_t\delta_I$ in period $t+2$, $P_t\delta_I^2$ in period $t+3$ etc. for household loans, and similar coupon payments for entrepreneurial loans.

Note that a long-term bank loan extended last period would pay coupon payments of $P_{t-1}\delta_z^{t+s+1}$ at period $t+s+1$ for $s \geq 0$; hence, this loan would be priced in period t as $\delta_z P_{z,t}/\pi_t$. This allows us to write the banks' cash-flow in recursive form as:

$$\begin{aligned} &\frac{D_{B,t}}{P_t} + R_{d,t-1}\frac{D_{t-1}}{P_t} + (1+\Upsilon_{I,t})\frac{P_{I,t}}{P_t}b_{I,t} + (1+\Upsilon_{E,t})\frac{P_{E,t}}{P_t}b_{E,t} \\ &\quad \leq \frac{(P_{t-1}+\delta_I P_{I,t}/\pi_t)}{P_t}b_{I,t-1} + \frac{(P_{t-1}+\delta_E P_{E,t}/\pi_t)}{P_t}b_{E,t-1} + \frac{D_t}{P_t} - \text{adj. costs} \end{aligned} \tag{16}$$

where $D_{B,t}$ are dividends paid out to shareholders, $P_{I,t}b_{I,t}$ and $P_{E,t}b_{E,t}$ denote the nominal market value of the stock of long-term loans extended to impatient households and entrepreneurs respectively, and $\Upsilon_{I,t}$ and $\Upsilon_{E,t}$ denote monitoring costs incurred by banks when extending household and business loans (explained in more detail below). Banks also incur quadratic costs of adjustment for changing dividends, with level parameter κ_{dB}; this feature is similar to Jermann and Quadrini (2012), and captures evidence in the corporate finance literature regarding the smoothing of corporate dividend payouts.

The balance sheet position of bank i at the end-of-period t is given by

$$\frac{P_{I,t}}{P_t}b_{I,t}(i) + \frac{P_{E,t}}{P_t}b_{E,t}(i) = \frac{D_t(i)}{P_t} + \frac{A_t(i)}{P_t}, \tag{17}$$

where A_t denotes the net worth of the bank (i.e. bank capital). Letting $p_{z,t} = P_{z,t}/P_t$, and defining the gross yield on bank asset z as:

$$R_{z,t} = \frac{1}{p_{z,t}} + \delta_z, \tag{18}$$

we can write the bank's cash-flow condition:

$$\begin{aligned} &\frac{D_{B,t}(i)}{P_t} + R_{d,t-1}\frac{D_{t-1}(i)}{P_t} + \frac{1+\Upsilon_{I,t}}{R_{I,t}-\delta_I}b_{I,t}(i) + \frac{1+\Upsilon_{E,t}}{R_{E,t}-\delta_E}b_{E,t}(i) \\ &\quad \leq \frac{R_{I,t}b_{I,t-1}(i)}{(R_{I,t}-\delta_I)\pi_t} + \frac{R_{E,t}b_{E,t-1}(i)}{(R_{E,t}-\delta_E)\pi_t} + \frac{D_t(i)}{P_t} - \text{adj. costs.} \end{aligned} \tag{19}$$

Monitoring costs of banks, balance sheet channel and the adverse feedback loop Banks incur monitoring costs when extending household and business loans. Similar to the funding spread, the monitoring costs help generate credit spreads between the lending rates of banks and their funding rate as in Curdia and Woodford (2011). Monitoring costs of banks depend on the leverage position of borrowers; in particular, borrowers are be able get loans at cheaper rates if they have a larger equity stake in the asset purchased relative to the equity required by regulations:

$$1+\Upsilon_{I,t}=\chi_{I1}\left(\frac{\left(1-m_{I,t}\right)q_{h,t}h_{I,t}}{n_{I,t}}\right)^{\chi_{I2}}\widetilde{\varepsilon}_{I,t}, \tag{20}$$

$$1+\Upsilon_{E,t}=\chi_{E1}\left(\frac{\left(1-m_{E}\right)q_{k,t}k_{E,t}}{n_{E,t}}\right)^{\chi_{E2}}\widetilde{\varepsilon}_{E,t}, \tag{21}$$

where $h_{I,t}$ and $k_{E,t}$ denote housing and capital purchased by impatient households and entrepreneurs respectively. Similarly, $n_{I,t}$ and $n_{E,t}$ denote the real net worth of impatient households and entrepreneurs respectively, and are given by:

$$n_{I,t} = q_{h,t}h_{I,t}-p_{I,t}b_{I,t}, \tag{22}$$

$$n_{E,t} = q_{k,t}k_{E,t}-p_{E,t}b_{E,t}. \tag{23}$$

$m_{I,t}$ is the regulatory loan-to-value (LTV) ratio on mortgage loans, whereas m_E denotes the debt to asset ratio of entrepreneurs at the steady-state. χ_{I1} and χ_{E1} are level parameters, while χ_{I2} and χ_{E2} regulate the elasticity of the monitoring costs with respect to borrower leverage. $\widetilde{\varepsilon}_{I,t}$ and $\widetilde{\varepsilon}_{E,t}$ are exogenous shocks to monitoring costs which follow AR(1) processes. These shocks reflect changes in the perceived riskiness of loans, not captured by borrower leverage, similar to shocks to collateral quality in Boivin et al. (2010), and shocks to the variance of entrepreneurs' project returns in Christiano et al. (2010).

Note that the the model features an *adverse feedback loop* similar to Davis (2010). In particular, adverse shocks that increase monitoring costs of banks, $\Upsilon_{I,t}$ and $\Upsilon_{E,t}$, also reduce the level of bank capital directly since these costs reduce the amount of retained earnings that could be added to bank capital. The increase in lending rates also reduce the price of bank assets since

$$p_{z,t}=\frac{1}{R_{z,t}-\delta_z}. \tag{24}$$

This leads to a further deterioration in banks' capital position, raising banks' funding cost of banks, and adversely affecting bank lending.

Optimality conditions The objective of banks is to maximize the present value of dividend payouts:

$$\max E_t\sum_{\tau=t}^{\infty}\beta_B^{\tau-t}\frac{\lambda_{P,\tau}}{\lambda_{P,t}}\left[\upsilon_{B,\tau}\frac{D_{B,\tau}\left(i\right)}{P_\tau}\right], \tag{25}$$

where they discount future flows using the stochastic discount factor of shareholders (i.e. patient households), except that their time-discount factor, β_B, is slightly lower than that of patient households to ensure non-negative flows from patient households to banks at the steady-state (Iacoviello, 2013). $\upsilon_{B,t}$ is an exogenous AR(1) process capturing banks' preference changes with respect to paying dividends versus retaining earnings.[9]

The first order condition with respect to dividends yields

$$\left(\frac{d_{B,t}}{d_{B,t-1}}-1\right)\frac{d_{B,t}}{d_{B,t-1}}=E_t\left\{\left(\beta_B\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\frac{\lambda_{B,t+1}}{\lambda_{B,t}}\right)\left[\left(\frac{d_{B,t+1}}{d_{B,t}}-1\right)\left(\frac{d_{B,t+1}}{d_{B,t}}\right)^2\right]\right\}-\frac{1}{\kappa_{dB}}\left(1-\frac{\upsilon_{B,t}}{\lambda_{B,t}}\right), \tag{26}$$

where $d_{B,t}$ are real dividends, and the Lagrange multiplier on the cash-flow condition, $\lambda_{B,t}$, is equal to 1 at the steady-state and when dividend adjustment costs are 0. Banks choose to attract deposits up to the point where they equate the marginal gain to the expected discounted funding cost, which is given by:

$$1=E_t\left[\left(\beta_B\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\frac{\lambda_{B,t+1}}{\lambda_{B,t}}\right)\frac{R_{d,t}}{\pi_{t+1}}\right]. \tag{27}$$

The optimality conditions for household and business loans similarly equate the marginal cost of increasing lending with the expected discounted return on these loans:

$$\frac{1+\Upsilon_{I,t}}{R_{I,t}-\delta_I}=E_t\left[\left(\beta_B\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\frac{\lambda_{B,t+1}}{\lambda_{B,t}}\right)\frac{R_{I,t+1}}{R_{I,t+1}-\delta_I}\right], \tag{28}$$

$$\frac{1+\Upsilon_{E,t}}{R_{E,t}-\delta_E}=E_t\left[\left(\beta_B\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\frac{\lambda_{B,t+1}}{\lambda_{B,t}}\right)\frac{R_{E,t+1}}{R_{E,t+1}-\delta_E}\right]. \tag{29}$$

Log-linearizing these expressions, and combining with the first-order-condition with respect to deposits, we get

$$\widehat{R}_{z,t}=\left(1-\frac{\delta_z}{R_z}\right)\sum_{s=0}^{\infty}\left(\frac{\delta_z}{R_z}\right)^s E_t\left[\widehat{R}_{d,t+s}+\widehat{\Upsilon}_{z,t+1}\right],\ \text{for } z\in\{I,E\}, \tag{30}$$

which implies that the banks' lending rate depends not only on current, but also on expected future deposit rates and monitoring costs. We can further combine this with (12) to get

$$\widehat{R}_{z,t}=\left(1-\frac{\delta_z}{R_z}\right)\sum_{s=0}^{\infty}\left(\frac{\delta_z}{R_z}\right)^s E_t\left[\widehat{R}_{t+s}+\widehat{\varkappa}_{t+s}+\widehat{\Upsilon}_{d,t+s}+\widehat{\Upsilon}_{z,t+1}\right],\ \text{for } z\in\{I,E\}, \tag{31}$$

which implies that long-term rates faced by borrowers depend on (i) the interest rate on long-term gov. bonds (based on the expectations hypothesis), (ii) bank funding spread based on current and future bank leverage and investor appetite, and (iii) bank lending spread based on current and future borrower leverage.

[9] Note that in principle, we can have negative dividends which would capture new equity injections from shareholders. See Jermann and Quadrini (2012) and Alpanda (2013) for more on this issue.

3.1.3 Impatient households

The economy is also populated by a unit measure of infinitely-lived impatient households. Their utility function is identical to that of patient households, except that their time-discount factor is assumed to be less than banks to facilitate borrowing; hence, $\beta_I < \beta_B$. Labor services of impatient households are also heterogenous, and are aggregated into a homogeneous labor service by perfectly-competitive labor intermediaries using a Dixit-Stiglitz aggregator. The labor demand curve facing each impatient household is thus given by

$$l_{I,t}(i) = \left(\frac{W_{I,t}(i)}{W_{I,t}}\right)^{-\eta_{l,t}} l_{I,t}, \tag{32}$$

where $W_{I,t}$ and $l_{I,t}$ are the aggregate nominal wage rate and labor services for impatient households, respectively.

The impatient households' period budget constraint is given by

$$\begin{aligned} c_{I,t}(i) + q_{h,t}\left[h_{I,t}(i) - (1-\delta_h)\psi_{h,t}h_{I,t-1}(i)\right] + \frac{R_{I,t}b_{I,t-1}(i)}{(R_{I,t}-\delta_I)\pi_t} \\ \leq (1-\tau_{l,t})\frac{W_{I,t}(i)}{P_t}l_{I,t}(i) + \frac{b_{I,t}(i)}{R_{I,t}-\delta_{I,t}} + \frac{TR_{I,t}}{P_t} - \text{adj. costs}, \end{aligned} \tag{33}$$

where $TR_{I,t}$ denotes lump-sum transfers received from the government. Impatient households also face quadratic adjustment costs in the change in wages, and the level of their housing stock with level parameters κ_w and κ_{hI} respectively. The balance sheet position of impatient household i at the end-of-period t is given by

$$\frac{N_{I,t}(i)}{P_t} = q_{h,t}h_{I,t}(i) - p_{I,t}b_{I,t}(i). \tag{34}$$

where $N_{I,t}$ denotes their net worth in nominal terms.

The first-order conditions of the impatient households with respect to consumption, housing and wages are similar to those of patient households. The optimality condition for their borrowing is given by:

$$\frac{1}{R_{I,t}-\delta_I} = E_t\left[\left(\beta_I\frac{\lambda_{I,t+1}}{\lambda_{I,t}}\right)\frac{R_{I,t+1}}{(R_{I,t+1}-\delta_I)\pi_{t+1}}\right], \tag{35}$$

which equates the marginal gain of borrowing to the expected discounted interest cost.

3.1.4 Entrepreneurs

There is a unit measure of entrepreneurs in the economy indexed by i. Entrepreneurs purchase capital from capital producers, financing this purchase through bank loans and retained earnings.

Entrepreneur i's cash-flow condition at period t is given by

$$\frac{D_{E,t}(i)}{P_t} + q_{k,t}\left[k_{E,t}(i) - (1-\delta_k)\psi_{k,t}k_{E,t-1}(i)\right] + \frac{R_{E,t}b_{E,t-1}(i)}{(R_{E,t}-\delta_E)\pi_t}$$
$$\leq (1-\tau_{k,t})r_{kE,t}\psi_{k,t}k_{E,t-1}(i) + \tau_{k,t}\delta_k\psi_{k,t}k_{E,t-1}(i) + \frac{b_{E,t}(i)}{R_{E,t}-\delta_E} - \text{adj. costs}, \tag{36}$$

where $k_{E,t}$ denotes entrepreneurial capital, and $D_{E,t}$ is dividends paid out to shareholders. Entrepreneurs also face quadratic adjustment costs in the change in dividends and the level of their capital stock with level parameters κ_{dE} and κ_{kE} respectively. The balance sheet position of entrepreneur i at the end-of-period t is given by

$$\frac{N_{E,t}(i)}{P_t} = q_{k,t}k_{E,t}(i) - \frac{P_{E,t}}{P_t}b_{E,t}(i). \tag{37}$$

where $N_{E,t}$ denotes nominal entrepreneurial net worth accumulated over time using retained earnings.

The objective of the entrepreneur is to maximize the present value of dividend payouts:

$$\max E_t \sum_{\tau=t}^{\infty} \beta_E^{\tau-t}\frac{\lambda_{P,\tau}}{\lambda_{P,t}}\left[\upsilon_{E,\tau}\frac{D_{E,\tau}(i)}{P_\tau}\right], \tag{38}$$

where they discount future flows using the stochastic discount factor of shareholders (i.e. patient households), except the time-discount factor $\beta_E < \beta_B$ is slightly lower to ensure non-negative flows from banks to entrepreneurs at the steady-state (Iacoviello, 2013). $\upsilon_{E,t}$ is an exogenous AR(1) process capturing entrepreneurs' preference changes with respect to paying dividends versus retaining earnings. The first order condition with respect to dividends yields

$$\left(\frac{d_{E,t}}{d_{E,t-1}} - 1\right)\frac{d_{E,t}}{d_{E,t-1}} = E_t\left\{\left(\beta_E\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\frac{\lambda_{E,t+1}}{\lambda_{E,t}}\right)\left[\left(\frac{d_{E,t+1}}{d_{E,t}} - 1\right)\left(\frac{d_{E,t+1}}{d_{E,t}}\right)^2\right]\right\} - \frac{1}{\kappa_{dE}}\left(1 - \frac{\upsilon_{E,t}}{\lambda_{E,t}}\right), \tag{39}$$

where $d_{E,t}$ are real dividends, and the Lagrange multiplier on the cash-flow condition, $\lambda_{E,t}$, is equal to 1 at the steady-state and when dividend adjustment costs are 0.

The optimality condition with respect to capital (ignoring adjustment costs) equates the marginal cost of purchasing capital with the expected discounted marginal capital gains and rental returns:

$$q_{k,t} = E_t\left[\left(\beta_E\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\frac{\lambda_{E,t+1}}{\lambda_{E,t}}\right)\left[(1-\delta_k)q_{k,t+1} + (1-\tau_{k,t})r_{kE,t+1} + \tau_{k,t}\delta_k\right]\psi_{k,t+1}\varkappa_{k,t}\right]. \tag{40}$$

Entrepreneurs borrow up to the point where they equate the marginal gain from receiving a unit of loan to the expected discounted interest costs:

$$\frac{1}{R_{E,t}-\delta_E} = E_t\left[\left(\beta_E \frac{\lambda_{P,t+1}}{\lambda_{P,t}}\frac{\lambda_{E,t+1}}{\lambda_{E,t}}\right)\frac{R_{E,t+1}}{(R_{E,t+1}-\delta_E)\,\pi_{t+1}}\right]. \tag{41}$$

The two conditions above imply that, at the optimum, the demand for entrepreneurial capital increases up to the point where the expected returns from capital is equated to the cost of borrowing from banks.

3.2 Goods production

3.2.1 Final goods aggregators

There are five different types of final goods aggregators; for consumption goods, c_t, capital investment goods, $i_{k,t}$, housing investment goods, $i_{h,t}$, government expenditure goods, g_t, and export goods, $y_{x,t}$. In what follows, we describe the consumption goods aggregators, but the others are modeled in an analogous fashion.

Non-residential consumption final goods producers are perfectly competitive, and they produce consumption final goods, c_t, using domestic goods, $c_{d,t}$, and imported goods, $c_{m,t}$ as inputs:

$$c_t = \left[(1-\phi_c\phi_t)^{\frac{1}{\eta_c}}(c_{d,t})^{\frac{\eta_c-1}{\eta_c}} + (\phi_c\phi_t)^{\frac{1}{\eta_c}}(c_{m,t})^{\frac{\eta_c-1}{\eta_c}}\right]^{\frac{\eta_c}{\eta_c-1}}, \tag{42}$$

where ϕ_c denotes the share of imports in the consumption goods aggregator, and η_c is the elasticity of substitution between domestic and imported goods. To capture shocks to import demand, the share of imports for consumption final goods is assumed to be subject to exogenous variation following an AR(1) process:

$$\log\phi_t = \rho_\phi \log\phi_{t-1} + \varepsilon_{\phi,t}. \tag{43}$$

Since the final goods producers are perfectly competitive, they earn zero profits in equilibrium. For any level of output, their optimal demand for the domestic and imported goods are thus given by

$$c_{d,t} = \left(\frac{P_{d,t}}{P_t}\right)^{-\eta_c}(1-\phi_c\phi_t)\,c_t, \tag{44}$$

$$c_{m,t} = \left(\frac{P_{m,t}}{P_t}\right)^{-\eta_c}\phi_c\phi_t c_t, \tag{45}$$

where $P_{d,t}$ and $P_{m,t}$ are the prices of the domestic and imported goods respectively, while P_t is the price of the final consumption good. Note that, in equilibrium, the final consumption goods production is equal to purchases by patient and impatient households:

$$c_t = c_{P,t} + c_{I,t}. \tag{46}$$

3.2.2 Domestic Firms

There is a unit measure of monopolistically competitive domestic firms indexed by j. Their technology is described by the following production function:

$$y_{d,t}(j) = z_t \left\{ [u_{P,t}(j) \, k_{P,t-1}(j)]^{\mu_k} \, [u_{E,t}(j) \, k_{E,t-1}(j)]^{1-\mu_k} \right\}^{\alpha} \left[l_{P,t}(j)^{\mu_l} \, l_{I,t}(j)^{1-\mu_l} \right]^{1-\alpha} - f_d, \quad (47)$$

where α is the share of capital in overall production, and μ_k and μ_l denote the shares of patient households in capital and labor. $u_{P,t}$ and $u_{E,t}$ denote the utilization rates for each type of capital, and f_d is a fixed cost of production.[10] The aggregate productivity shock, z_t, follows an AR(1) process.

Domestic goods produced are heterogeneous across firms, and are aggregated into a homogenous domestic good by perfectly-competitive final goods producers using a standard Dixit-Stiglitz aggregator. The demand curve facing each firm is given by

$$y_{d,t}(j) = \left(\frac{P_{d,t}(j)}{P_{d,t}} \right)^{-\eta_{d,t}} y_{d,t}, \quad (48)$$

where $y_{d,t}$ is aggregate domestic output, and $\eta_{d,t}$ is a time-varying elasticity of substitution between the differentiated goods. We specify an exogenous AR(1) process on $\theta_{d,t} = \eta_{d,t}/(\eta_{d,t} - 1)$,

$$\log \theta_{d,t} = (1 - \rho_d) \log \theta_d + \rho_d \log \theta_{d,t-1} + \varepsilon_{d,t}, \quad (49)$$

where θ_d is the gross mark-up of price over marginal cost at the steady-state.

Firm j's profits at period t is given by

$$\begin{aligned} \frac{\Pi_{d,t}(j)}{P_t} = {} & \frac{P_{d,t}(j)}{P_t} y_{d,t}(j) - \frac{W_{P,t}}{P_t} l_{P,t}(j) - \frac{W_{I,t}}{P_t} l_{I,t}(j) - r_{kP,t} \psi_{k,t} k_{P,t-1}(j) - r_{kE,t} \psi_{k,t} k_{E,t-1}(j) \\ & - \frac{\kappa_{uP}}{1+\varpi} \left[u_{Pt}(j)^{1+\varpi} - 1 \right] k_{P,t-1}(j) - \frac{\kappa_{uE}}{1+\varpi} \left[u_{E,t}(j)^{1+\varpi} - 1 \right] k_{E,t-1}(j) - \text{adj. costs}, \end{aligned} \quad (50)$$

where κ_{uP} and κ_{uE} are level parameters, and ϖ is the elasticity parameter for the utilization cost specification. Similar to wage-stickiness, price-stickiness is introduced via quadratic adjustment costs with level parameter κ_d, and ς_d captures the extent to which price adjustments are indexed to past inflation.

A domestic firm's objective is to choose the quantity of inputs and output, and output price each period to maximize the present value of profits (using the patient households' stochastic discount factor) subject to the demand function they are facing with respect to their individual output from the aggregators. At the optimum, the relative demand for the two types of labor is related to relative

[10] The fixed cost parameter f_d is set equal to $\theta_d - 1$ times the steady-state level of output to ensure that pure economic profits are zero at the steady-state; hence, there is no incentive for firm entry and exit in the long-run.

wage rates as

$$\frac{l_{I,t}}{l_{P,t}} = \left(\frac{1-\mu_l}{\mu_l}\right)\frac{w_{P,t}}{w_{I,t}}, \tag{51}$$

where $w_{P,t}$ and $w_{I,t}$ are real wages deflated by the composite goods price, P_t . Similarly, the relative demand for the two types of capital is related to the relative rental rates of capital as

$$\frac{k_{E,t-1}}{k_{P,t-1}} = \left(\frac{1-\mu_k}{\mu_k}\right)\frac{r_{kP,t} + \frac{\kappa_{uP}}{1+\varpi}\left(u_{P,t}^{1+\varpi}-1\right)}{r_{kE,t} + \frac{\kappa_{uE}}{1+\varpi}\left(u_{E,t}^{1+\varpi}-1\right)}. \tag{52}$$

The optimality conditions for capital utilization similarly equates the marginal cost of increasing utilization at the margin with the revenue gain that arises from increased production.

The first-order condition for prices yields (after log-linearization) the following New Keynesian Phillips curve for domestic goods inflation:

$$\widehat{\pi}_{d,t} = \frac{\beta_P}{1+\beta_P\varsigma_d}E_t\widehat{\pi}_{d,t+1} + \frac{\varsigma_d}{1+\beta_P\varsigma_d}\widehat{\pi}_{d,t-1} + \frac{1}{(1+\beta_P\varsigma_d)\,\kappa_d}\left(\widehat{w}_{P,t} + \widehat{l}_{P,t} - \widehat{p}_{d,t} - \frac{1}{\theta_d}\widehat{y}_{d,t} + \widehat{\theta}_{d,t}\right). \tag{53}$$

Due to market power, domestic producers set the price of their goods at a mark-up relative to marginal cost. The adjustment costs in price-setting, as well as exogenous mark-up shocks, introduce variation in these mark-ups with a long-run adjustment to the steady-state constant mark-up. The nominal rigidities in price-setting imply that shocks that alter the marginal cost of production feed into domestic goods inflation slowly.

3.3 International trade

3.3.1 Importers

There is a unit measure of monopolistically competitive importers indexed by i. They import foreign goods from abroad, differentiate them and mark-up their price, and then sell these heterogenous goods to perfectly competitive import aggregators, who aggregate these into a homogenous import good using a standard Dixit-Stiglitz aggregator. The demand curve facing each importer is given by

$$y_{m,t}(j) = \left(\frac{P_{m,t}(j)}{P_{m,t}}\right)^{-\eta_{m,t}} y_{m,t}, \tag{54}$$

where $y_{m,t}$ is aggregate imports, and $\eta_{m,t}$ is a time-varying elasticity of substitution between the differentiated goods. We specify an exogenous AR(1) process on $\theta_{m,t} = \eta_{m,t}/(\eta_{m,t}-1)$,

$$\log\theta_{m,t} = (1-\rho_{\theta m})\log\theta_m + \rho_{\theta m}\log\theta_{m,t-1} + \varepsilon_{\theta m,t}, \tag{55}$$

where θ_m is the gross mark-up of the domestic price of imported good over its import price at the steady-state.

Importers maximize the present value of profits (using the patient households' stochastic discount factor) subject to the demand function they are facing from the aggregators with respect to their own output. The importer's profits at period t are given by:

$$\frac{\Pi_{m,t}(j)}{P_t} = \frac{P_{m,t}(j)}{P_t} y_{m,t}(j) - \frac{e_t P_t^*}{P_t} y_{m,t}(j) - \text{adj. cost}, \tag{56}$$

where importers face quadratic price adjustment costs, which helps generate partial exchange rate pass-through to domestic prices. κ_w and ς_w are the price adjustment cost and indexation parameters respectively.

The first-order conditions of importers yields the following New Keynesian Phillips curve for import prices (after log-linearization):[11]

$$\widehat{\pi}_{m,t} = \frac{\beta_P}{1+\beta_P \varsigma_m} E_t \widehat{\pi}_{m,t+1} + \frac{\varsigma_m}{1+\beta_P \varsigma_m} \widehat{\pi}_{m,t-1} - \frac{1}{(1+\beta_P \varsigma_m)\kappa_m} \left(\widehat{p}_{m,t} - \widehat{rer}_t - \widehat{\theta}_{m,t} \right), \tag{57}$$

where $rer_t = e_t P_t^* / P_t$ is the real exchange rate. Due to market power, importers set the price of imported goods at a mark-up relative to the price at which they imported the goods. The adjustment costs in price-setting, as well as exogenous mark-up shocks, introduce variation in these mark-ups with a long-run adjustment to the steady-state constant mark-up. The nominal rigidities in the domestic price of imports also introduces partial exchange rate pass-through; variations in the nominal exchange rate alters the cost of importers, but these are not reflected fully on domestic import-goods prices immediately.

3.3.2 Exporters

Export firms are modeled analogous to importers, but are located in foreign countries. They purchase the domestic goods for P_t in Canadian dollars, but sell it abroad for $P_{m,t}^*(j)$ in terms of the foreign currency. The demand curve facing each monopolistically competitive exporter is given by

$$y_{x,t}(j) = \left(\frac{P_{m,t}^*(j)}{P_{m,t}^*} \right)^{-\eta_{x,t}} y_{x,t}, \tag{58}$$

where $y_{x,t}$ is aggregate exports, and $\eta_{x,t}$ is a time-varying elasticity of substitution between the differentiated goods. We specify an exogenous AR(1) process on $\theta_{x,t} = \eta_{x,t}/(\eta_{x,t}-1)$,

$$\log \theta_{x,t} = (1-\rho_x)\log \theta_x + \rho_x \log \theta_{x,t-1} + \varepsilon_{x,t}, \tag{59}$$

where θ_x is the gross mark-up of export prices over the domestic goods price at the steady-state.

The exporter's real profit at period t in terms of the foreign currency is given by:

$$\frac{\Pi_{x,t}(j)}{P_t^*} = \frac{P_{m,t}^*(j)}{P_t^*} y_{x,t}(j) - \frac{P_{x,t}/e_t}{P_t^*} y_{x,t}(j) - \text{adj. costs}, \tag{60}$$

[11] Note that we assume the existence of subsidies that correct the inefficiencies created by price mark-ups on importers and exporters. This allows us to set relative prices equal to 1 at the steady-state.

where κ_x and ς_x are the level and indexation parameters respectively for the quadratic price adjustment costs. Similar to the importers' problem, the optimality conditions of exporters yield (after log-linearization) a New Keynesian Phillips curve for export prices:

$$\widehat{\pi}^*_{m,t} = \frac{\beta_P}{1+\beta_P\varsigma_x} E_t\widehat{\pi}^*_{m,t+1} + \frac{\varsigma_x}{1+\beta_P\varsigma_x}\widehat{\pi}^*_{m,t-1} - \frac{1}{(1+\beta_P\varsigma_x)\,\kappa_x}\left(\widehat{p}^*_{m,t} + \widehat{rer}_t - \widehat{p}_{x,t} - \widehat{\theta}_{x,t}\right), \tag{61}$$

where $p^*_{m,t} = P^*_{m,t}/P^*_t$ is the relative price of exports in the foreign country. Similar to importers, exporters charge a mark-up over the domestic price when they export the good abroad, but this mark-up varies over time due to price adjustment costs and the presence of exogenous mark-up shocks. Variations in the domestic price are only slowly reflected in export prices due to the presence of nominal rigidities.

Foreign demand for domestic economy's exports are modeled in reduced form as

$$y_{x,t} = y^{\zeta^*}_{x,t-1}\left[\phi^*\left(p^*_{m,t}\right)^{-\eta^*} y^*_t\right]^{1-\zeta^*}\widetilde{\varepsilon}_{x,t}, \tag{62}$$

where exports depend on past exports, the relative price of exports, and foreign output. ζ^* determines the persistence of exports, and captures the habit formation of foreigners for domestic goods. y^*_t is the foreign output level, η^* determines the elasticity of exports with respect to the relative price, and ϕ^* is a level parameter. $\widetilde{\varepsilon}_{x,t}$ is an exogenous export demand shock given by an AR(1) process. Note that the balance of payments identity in the model is given by

$$\frac{e_t B^*_t}{\varkappa_t \Phi_t R^*_t P_t} - \frac{e_t B^*_{t-1}}{P_t} = \frac{P_{x,t}}{P_t} y_{x,t} - \frac{e_t P^*_t}{P_t} y_{m,t}. \tag{63}$$

3.4 Capital and housing producers

3.4.1 Capital producers

Capital producers are perfectly competitive. After goods production takes place, these firms purchase the undepreciated part of the installed capital from patient households and entrepreneurs at a relative price of $q_{k,t}$, and the new capital investment goods from final goods firms at a relative price of $p_{ik,t}$, and produce the capital stock to be carried over to the next period. This production is subject to adjustment costs in the change in investment, and is described by the following law-of-motion for capital:

$$k_t = (1-\delta_k)\,\psi_{k,t} k_{t-1} + z_{k,t} i_{k,t} - \frac{\kappa_k}{2}\left(\frac{i_{k,t}}{i_{k,t-1}} - 1\right)^2 z_{k,t} i_{k,t}, \tag{64}$$

where $k_t = k_{P,t} + k_{E,t}$, δ_k is the depreciation rate of capital, and κ_k is the adjustment cost parameter. $z_{k,t}$ captures investment-specific technological change which is assumed to be exogenous and follows an AR(1) process.

After capital production, the end-of-period installed capital stock is sold back to patient households and entrepreneurs at the installed capital price of $q_{k,t}$. The capital producers' objective is thus to maximize

$$E_t \sum_{\tau=t}^{\infty} \beta_P^{\tau-t} \frac{\lambda_{P,\tau}}{\lambda_{P,t}} \left[q_{k,\tau} k_\tau - q_{k,\tau} (1-\delta_k) \psi_\tau k_{\tau-1} - \frac{P_{ik,\tau}}{P_t} i_{k,\tau} \right], \tag{65}$$

subject to the law-of-motion of capital, where future profits are again discounted using the patient households' stochastic discount factor. The first-order-condition (after log-linearization) of capital producers yields a q-equation of investment:

$$\widehat{i}_{k,t} = \frac{\beta_P}{1+\beta_P} E_t \widehat{i}_{k,t+1} + \frac{1}{1+\beta_P} \widehat{i}_{k,t-1} + \frac{1}{(1+\beta_P)\kappa_k} \left(\widehat{q}_{k,t} + \widehat{z}_{k,t} - \widehat{p}_{ik,t} \right). \tag{66}$$

3.4.2 Housing producers

Housing producers are modeled analogous to capital producers. The law-of-motion for housing is given by:

$$h_t = (1-\delta_h) \psi_{h,t} h_{t-1} + z_{h,t} i_{h,t} - \frac{\kappa_h}{2} \left(\frac{i_{h,t}}{i_{h,t-1}} - 1 \right)^2 z_{h,t} i_{h,t}, \tag{67}$$

where $h_t = h_{P,t} + h_{I,t}$, δ_h is the depreciation rate of housing, and κ_h is the adjustment cost parameter. $z_{h,t}$ captures investment-specific technological change in housing which is assumed to be exogenous and follows an AR(1) process. Similar to capital producers, the first-order-condition of housing producers yields a q-equation for housing investment demand:

$$\widehat{i}_{h,t} = \frac{\beta_P}{1+\beta_P} E_t \widehat{i}_{h,t+1} + \frac{1}{1+\beta_P} \widehat{i}_{h,t-1} + \frac{1}{(1+\beta_P)\kappa_h} \left(\widehat{q}_{h,t} + \widehat{z}_{h,t} - \widehat{p}_{ih,t} \right). \tag{68}$$

3.5 Monetary, fiscal and macroprudential policy

The Central Bank targets the nominal interest rate using a Taylor rule

$$\log R_t = \rho \log R_{t-1} + (1-\rho) \left[\log R + a_\pi \log \frac{\pi_t}{\pi} + a_y \log \frac{y_t}{y} \right] + \widetilde{\varepsilon}_{r,t}, \tag{69}$$

where R is the steady-state value of the (gross) nominal policy rate, ρ determines the extent of interest rate smoothing, and the parameters a_π and a_y determine the importance of inflation and output gap in the Taylor rule. $\widetilde{\varepsilon}_{r,t}$ is the monetary policy shock which follows an AR(1) process.

The government's budget constraint is given by

$$\begin{aligned} g_t + tr_{P,t} + tr_{I,t} + \frac{B_{t-1}(i)}{P_t} \\ = \tau_{l,t} (w_{P,t} l_{P,t} + w_{I,t} l_{I,t}) + \tau_{k,t} (r_{kP,t} k_{P,t-1} + r_{kE,t} k_{E,t-1}) \psi_{k,t} + \frac{B_t(i)}{R_t P_t}, \end{aligned} \tag{70}$$

where final government expenditure, g_t, follows an exogenous AR(1) process given by

$$\log g_t = (1-\rho_g) \log g + \rho_g \log g_{t-1} + \varepsilon_{g,t}. \tag{71}$$

Transfer payments to households are given by:

$$tr_{i,t} = \Xi_i y_d \left(\frac{y_t}{y}\right)^{-\varrho_y} \widetilde{\varepsilon}_{tr,t} - \varrho_b b^g_{t-1}, \text{ for } i = P, I,$$

where Ξ_P and Ξ_I are level parameters, ϱ_y is the automatic stabilizer component of transfers, and ϱ_b determines the response of transfers to government debt.[12] Note that with our specification, an increase in tax revenue would be used to retire government debt, and slowly increase transfers to each type of household.

To capture possibly countercyclical macroprudential policy, we allow regulatory bank capital and LTV ratios to respond to total and household credit gaps, respectively:

$$\gamma_t = \gamma + \alpha_\gamma \left(\frac{b_t}{y_t} - \frac{b}{y}\right) + \widetilde{\varepsilon}_{\gamma,t}, \tag{72}$$

$$m_{I,t} = m_I - \alpha_m \left(\frac{p_{I,t} b_{I,t}}{y_t} - \frac{p_I b_I}{y}\right) + \widetilde{\varepsilon}_{m,t}, \tag{73}$$

where the market value of total bank credit is given by $b_t = p_{I,t} b_{I,t} + p_{E,t} b_{E,t}$, and α_γ and α_m measure the sensitivity of each countercyclical policy to the corresponsing credit gap.

3.6 Market clearing conditions

The intermediate domestic goods are used in the final goods production for consumption, capital investment, housing investment, government expenditure, and exports:[13]

$$c_{d,t} + i_{kd,t} + i_{hd,t} + g_{d,t} + y_{xd,t} = y_{d,t}. \tag{74}$$

Similarly, the intermediate imported goods are used by final goods producers as:

$$c_{m,t} + i_{km,t} + i_{hm,t} + g_{m,t} + y_{xm,t} = y_{m,t}. \tag{75}$$

The model's equilibrium is defined as prices and allocations such that households maximize discounted present value of utility, banks and entrepreneurs maximize discounted present value of dividends, and all firms maximize discounted present value of profits subject to their constraints, and all markets clear.

4 Calibration

We calibrate the parameters that pin down the model's steady-state ratios in order to match data targets obtained using averages from the Canadian National Income Accounts and Financial Flow

[12] Note that either taxes, government expenditure or transfers need to adjust with the level of government debt, so that the government cannot run a Ponzi scheme. We choose to make the adjustment through transfers based on the results of Leeper et al. (2010).

[13] Note that utilization costs and financial costs are modeled as transfer payments to patient households.

Accounts since the start of the inflation–targeting period in Canada (1991q1-20012q4).[14] For the parameters that mainly determine dynamics, we pick values from related literature and models currently used at the Bank. Table 1 summarizes the list of parameter values, and Table 2 lists the implied steady-state ratios in the model.

The trend inflation factor, π, is set to 1.005 corresponding to a 2% annual inflation target. The time-discount factor of patient and impatient households, β_P and β_I, are set to match an annualized 3% real risk-free interest rate, and a total spread on household loans of 240 basis points, the latter based on data for the effective household borrowing rate. Similarly, the discount rates for banks and entrepreneurs, β_B and β_E, are set to match a 14 basis points funding spread for banks, and a 200 basis points total spread on entrepreneurial loans, based on data for the 3-month banker's acceptance rate and the effective business borrowing rate.

The inverse of labor supply elasticity, ϑ, is set to 5 to ensure a Frisch elasticity of labor supply of 0.2 as in Smets and Wouters (2007). Similarly, the habit parameter for consumption, ζ, is set to 0.94 as in ToTEM II. The level parameters for housing in the utility function, ξ_{hP} and ξ_{hI}, are calibrated to ensure that total housing value is 1.5 times annual GDP, and impatient households own about 32% of total housing. At the steady-state of the model, households altogether have 70% equity in total housing, and the ratio of quarterly consumption to housing is around 0.1, consistent with the Financial Flow Accounts data and Basant Roi and Mendes (2007). The level parameters for labor supply, ξ_{lP} and ξ_{lI}, are calibrated to ensure that labor supply is equal to 1 at the steady-state for both types of households.

According to Canadian Financial Flow and National Accounts data, residential and business investment relative to output are about 6.5% and 12.2%, while housing-to-GDP and capital-to-GDP ratios are about 1.5 and 2.0 on an annualized basis. Based on these, we calibrate the quarterly depreciation rates for housing and capital stocks, δ_h and δ_k, to 1.08% and 1.53%, respectively. The share of capital in domestic production, α, is set to 0.3 implying an income share of labor equal to 70%. We set the capital share of patient households, μ_k, to 0.43 to match a 75% equity share in total capital, while entrepreneurs' equity share in their own capital, $1 - m_E$, is 50%.[15] We set the wage share of patient households, μ_l, to 0.68, and the transfer to output ratio for impatient households, Ξ_I, is calibrated to ensure that the share of impatient households in total wage income and total consumption are both 32%, similar to their share in total housing.

The share of imported goods in final goods production, ϕ_c, ϕ_{ik}, ϕ_{ih}, ϕ_g and ϕ_x, are set to 0.3, 0.18, 0, 0.08 and 0.33 respectively similar to values used in ToTEM II. The implied aggregate import-to-GDP ratio is 32%. The elasticity of substitution between domestic and foreign goods, η_c, η_{ik}, η_{ih}, η_g and η_x, are all set to 0.5 also following ToTEM II. The elasticity of the exchange rate to

[14] Note that inflation-targeting was adopted in Canada in February 1991.

[15] Note that debt-to-asset ratio of non-financial corporations is around 0.5 in the Financial Flow Accounts of Canada when we consider only the liability side of the balance sheet. If we subtract financial assets from debt, then the net debt-to-asset ratio is close to 0, and recently negative. We therefore target a total debt-to-asset ratio of 0.25 for capital owners. Also note that the steady-state loan-to-value ratio for business loans, m_E, is set to 0.5 as in Bernanke et al. (1999), reflecting a debt-to-equity ratio of 1 for borrowing firms.

the net foreign asset position, Φ_a, is set to 0.003, while the backward-looking component, Φ_e, is set to 0.25 in the benchmark calibration, between the values used in ToTEM I and ToTEM II. For the export demand specification, the persistence parameter, ζ^*, is set to 0.8, while the elasticity with respect to the relative price, η^*, is set to 1.5, following corresponding figures in ToTEM II. The level parameter for exports, ϕ^*, is set to 0.32 to ensure that there is balanced trade at the steady-state of the model.

The price and wage mark-up parameters, θ_w, θ_d, θ_m, and θ_x, are all set to 1.25 to reflect 25% mark-up. The price and wage adjustment cost parameters, κ_w, κ_d, κ_m, and κ_x, are set to 333, 84, 84, and 2 respectively based on the slopes of Philips curves in ToTEM II, while the indexation parameters, ς_w, ς_d, ς_m, and ς_x, are set to 0.5. The inverse of the elasticity of the utilization rate to the rental rate of capital, ϖ, is set to 5 similar to ToTEM, while the level parameters in the utilization cost specification, κ_{uP} and κ_{uE}, are calibrated to ensure that the utilization rate of each type of capital is equal to 1 at the steady-state. The investment adjustment costs, κ_k and κ_h, are set to 12 implying that the elasticity of investment demand to Tobin's q is around 0.04, similar to values in ToTEM.[16]

For the financial parameters, the coupon rates for the long-term bank loans, δ_I and δ_E, are set to 0.97 and 0.92 reflecting average loan lives of 20 and 10 quarters respectively. The elasticity of monitoring costs with respect to bank's leverage, χ_{d2}, is calibrated to ensure that 1 percentage point increase in bank capital requirements reduces output by about 0.3 per cent, consistent with the MAG report of the Basel Committee on Banking Supervision. Similarly, the elasticity of monitoring costs with respect to impatient households' leverage, χ_{I2}, is calibrated to ensure that reducing LTV from 0.95 to 0.9 would result in a 1.1% decline in household debt in the first year, consistent with the estimates from HRAM, Bank of Canada's micro-data based household finance model. The monitoring cost elasticity for business loans, χ_{E2}, is set to 0.01 to ensure that 1 p.p. increase in capital requirements lead to a 25 basis points increase in the spread faced by entrepreneurs, largely consistent with the MAG report of the Basel Committee on Banking Supervision.[17]

For the policy parameters, the steady-state LTV ratio, m_I, is set to 0.95, which is the maximum LTV allowed for first-time home buyers in Canada since 2009.[18] The bank capital requirement ratio, γ, is set to 0.1, and the risk-weights that apply to capital requirements, ω_I and ω_E, are set to 0.5 and 1 for household and business loans respectively, consistent with Basel III regulations. In the

[16] The adjustment cost for the housing and capital stocks, κ_{hI}, κ_{kP} and κ_{kE}, are set to 0 in the benchmark calibration, while κ_{hP} is set to 50 reflecting slower adjustment in housing for savers in the economy to better match housing quantity dynamics from the data. The dividend adjustment cost parameters for banks and entrepreneurs, κ_{dB} and κ_{dE}, are both set to 50 to mimic slow adjustment of dividends observed in the data.

[17] Note that the level parameters in the monitoring cost specifications, χ_{d1}, χ_{I1}, and χ_{E1}, are calibrated such that they are consistent with the steady-state funding and lending spreads reported previously. Also note that the elasticity parameter in the portfolio preference term of investors, $\varrho_{\varkappa}$, is set to 0 in the benchmark calibration.

[18] Note that three fourths of all CMHC originations for first-time home-buyers have LTVs at the regulatory maximum. The average LTV for first-time homebuyers is around 0.934, slightly lower than the regulatory maximum, while survey evidence suggests that around 40% of borrowers also borrow part of their downpayments, which are not reflected in these numbers. Also note that 75% of CMHC mortgage originations for first-time homebuyers had LTVs close to 0.95, the regulatory maximum, since 2009. 20% of mortgages had LTVs close to 0.9, and only about 5% had lower LTVs.

benchmark calibration, we set the countercyclicality parameters for macroprudential policy, α_γ and α_m, to 0. The smoothing parameter in the monetary policy rule, ρ, is set to 0.75, the long-run response coefficients for inflation, a_π, is set to 2.5 similar to ToTEM, while the output response coefficient in the Taylor rule is set to 0 in the benchmark calibration. The government's share in output, g/y, is 0.23, while labor and capital income tax rates, τ_l and τ_k, are set to 0.3 and 0.55 respectively, the latter calibrated using the data targets for capital-output and investment-output ratios and the model-implied rental rates of capital.

The persistence parameters for the macroprudential policy shocks are set arbitrarily close to 1 (i.e. these are permanent shocks), while the persistence parameter for the monetary policy shock is set to 0.15. For the capital quality and exuberance shocks, as well as the preference and risk-appetite shocks, the persistence parameters are set to 0.5. For all the rest of the shocks, the persistence parameters are set to 0.9.

5 Results

In this section, we use impulse responses to examine the effects of macroprudential regulations and monetary policy, as well as key financial shocks, on model variables.

5.1 The effects of macroprudential regulations and monetary policy

In Figure 3, we consider a permanent tightening in the regulatory LTV ratio, $m_{I,t}$, by 5 percentage points (from 95% to 90%). The increase in required housing equity leads to an increase in current and expected monitoring costs of banks, $\Upsilon_{I,t}$. This in turn leads to an increase in the lending rate faced by impatient households, $R_{I,t}$, inducing them to reduce their borrowing, $b_{I,t}$, and their demand for housing and consumption, $h_{I,t}$ and $c_{I,t}$, respectively. The decline in housing demand translates into a reduction in overall residential investment, $i_{h,t}$, and a decline in housing prices, $q_{h,t}$. The reduction in demand for consumption and residential investment goods also lead to a reduction in business investment, $i_{k,t}$, along with a decline in capital prices, $q_{k,t}$, as businesses find themselves with excess capital. Thus, the overall impact of the LTV policy on the economy is to reduce aggregate output, y_t; which is accompanied by a decline in inflation, π_t, as the derived demand for labor declines and wages fall.[19] The fall in inflation prompts the Central Bank to reduce the policy rate, R_t. This prompts patient households to increase their consumption expenditures, $c_{P,t}$, but aggregate consumption, c_t, declines nevertheless. Also, the decline in housing and capital prices induce patient households to increase their purchases of housing and capital, $h_{P,t}$ and $k_{P,t}$, but not as much to change the overall direction of residential and business investment. These general equilibrium effects on patient households' consumption and housing demand help contain the adverse effects of the LTV change on the economy. Another moderating factor is the resulting capital outflows, which lead to a depreciation in the real exchange rate, rer_t, and an increase in

[19] Note that the small increase in inflation at impact is due to the depreciation in the real exchange rate, and is very short-lived.

exports, $y_{x,t}$. On the other hand, the decline in asset prices lead to a reduction in price of long-term assets held by banks and increase their monitoring costs, leading to a decline in bank capital, a_t. This raises banks' funding rate, $R_{d,t}$, despite the decline in the policy rate, which translate into higher lending rates in the economy, and help exacerbate the adverse effects of the LTV policy change.

In Figure 4, we consider a permanent increase in the regulatory bank capital requirement ratio, γ_t, by 1 percentage point (from 10% to 11%). The increase in regulatory bank capital leads to an increase in the spread faced by banks, $\Upsilon_{d,t}$, given that they have insufficient net worth at impact. This leads to an increase in the funding rate, $R_{d,t}$, which is partially passed through to the borrowing rates faced by impatient households and entrepreneurs, $R_{I,t}$ and $R_{E,t}$, respectively. As a result, the amount of bank loans, $b_{I,t}$ and $b_{E,t}$, decline, and borrowers are forced to reduce their holdings of housing and capital, $h_{I,t}$ and $k_{E,t}$, as well as their consumption, $c_{I,t}$. This leads to a decline in demand for investment goods, $i_{k,t}$ and $i_{h,t}$, and to a reduction in asset prices, $q_{h,t}$ and $q_{k,t}$. As in the case of the LTV policy, the overall impact of the capital regulatary policy is to decrease overall output, y_t, along with a decline in wages and inflation, π_t. Again, the purchases of consumption, housing and capital by patient households due to falling asset prices and decline in the policy rate, along with depreciation in the real exchange rate in the short-run, dampen the adverse effects of the regulatory change in bank capital requirements. On the other hand, the fall in asset prices lead to a reduction in price of long-term assets held by banks and an increase in monitoring costs incurred by banks, which complicates their efforts to recapitalize. This keeps banks' funding rate, $R_{d,t}$, higher than it would otherwise be, and amplifies the adverse effects of the regulatory change.

Figure 5 plots the impulse responses of model variables to a 100 basis point (annualized) shock to the policy rate, $\widetilde{\varepsilon}_{r,t}$.[20] Note that the long-term rates faced by households, $R_{I,t}$, and entrepreneurs, $R_{E,t}$, increase by only a fraction of the change in the policy rate since the policy rate is expected to slowly decline from its peak. Facing higher rates, both impatient households and entrepreneurs reduce their borrowing, $b_{I,t}$ and $b_{E,t}$, and their purchases of housing and capital, $h_{I,t}$ and $k_{E,t}$, respectively. Impatient households also reduce their consumption expenditures, $c_{I,t}$. As before, these effects lead to a reduction in overall residential and business investment activity, $i_{h,t}$ and $i_{k,t}$, along with a reduction in aggregate output, y_t, and inflation, π_t. Also as before, the fall in asset prices, $q_{h,t}$ and $q_{k,t}$, lead to an increase in the monitoring cost of banks, amplifying the adverse effects of the monetary shock. Note however that some of the factors that helped moderate the effects of macroprudential policy now work in the opposite direction, and exacerbate the situation instead. In particular, the increase in the policy rate leads to a reduction in the consumption demand of patient households, $c_{P,t}$, to a real appreciation of currency leading to a fall in exports, $y_{x,t}$.

[20] Note that inflation is reduced as a result of the decrease in demand and the appreciation of currency, which results in the policy rate to increase slightly less than the monetary policy shock of 100 basis points at impact.

5.1.1 Comparing the effects of macroprudential and monetary policies on household debt

The impulse responses described above suggest that all three tools (i.e. regulatory LTV, capital requirements, and monetary policy) can be utilized to reduce household debt, but their respective costs in terms of the reduction in output are quite different (see Table 3). In particular, a 5 p.p. tightening in regulatory LTV decreases household debt by 1.1% in the first year of the policy change, and reduces it by another 6.5% at the peak during the transition path. The peak output impact at the peak is about 0.5%. In contrast, a 1% increase in capital requirements reduces household debt by about 1.8%, while reducing output by about 0.27% at the peak. Thus, reducing household debt by the same amount as LTV would require about a 4 p.p. increase in capital requirements, but this would lead to a 1% decline in output, about double the adverse impact implied by the LTV change. Alternatively, an increase of about 2 p.p. in bank capital would have the same impact on output as a 5 p.p. reduction in LTV, but its impact on household debt would be about a half at the peak.[21] Similarly, 100 bps. temporary increase in the policy rate reduces household debt by about 1.8% at the peak as well, but this comes at an output cost of about 0.5%, offering an even worse tradeoff than capital requirements in terms of reducing household debt.

In summary, among the three policies, regulatory LTV is identified as the most effective policy for reducing household indebtedness with the least output cost, followed by capital requirements and monetary policy, respectively. LTV policy is a targeted tool with respect to household debt, directly affecting the source of the issue, i.e. the borrowing of impatient households. The effects of LTV do spillover to other parts of the economy as the decline in consumption and housing demand of impatient households affect entrepreneurs directly, and their demand for capital. The decline in asset prices also affect banks' capital position and their funding costs. Nevertheless, the overall impact of the LTV policy is more contained within the residential sector, and is partly offset by the increased demand for consumption and housing by patient households, and the increased export demand due to real depreciation. This is in contrast to bank capital regulations, which also affect the business sector directly; in particular, this policy has a direct impact on the borrowing costs of entrepreneurs, leading to a faster decline in entrepreneurial loans, business investment, and the price of capital. As such, capital regulations provide a broader tool in reducing household debt, relative to regulatory LTV policy. Finally, monetary policy provides the broadest tool in this respect, as it also adversely impacts patient households' consumption demand, as well as foreign demand for domestic goods, while also reducing household debt.

[21] Also note that among the two macroprudential policies considered here, only LTV policy has a permanent impact on the level of household debt in the long-run. In particular, with a 5 p.p. permanent reduction in LTV, household debt is permanently lower by 4.8% at the terminal steady-state relative to its value at the initial steady-state. Although capital regulations are also permanent changes, their impact on household debt is temporary since in the long-run the banks' cost of debt versus equity are equalized given the temporary nature of dividend adjustment costs. Thus, at the terminal steady-state, banks increase their bank capital and reduce the level of funding through deposits, while keeping the size of their balance sheet, and the level of their lending, the same as in the initial steady-state.

5.2 The effects of asset quality, exuberance and risk-appetite shocks

Figure 6 plots the effects of a decline in the quality of capital, $\psi_{k,t}$, which is similar to the shock considered in Gertler and Karadi (2011). The decline in the quality of capital leads to a sharp decline in the price of capital, $q_{k,t}$. This increases the leverage of entrepreneurs raising the monitoring costs of banks, which leads to an increase in the lending rate faced by entrepreneurs, $R_{E,t}$. Banks' funding costs, $R_{d,t}$, also increase which results in the adverse effects of the capital quality shock spilling onto the housing sector as well. The overall decline in demand leads to a decline in inflation, π_t, prompting the policy rate, R_t, to be reduced. On the other hand, capital outflows lead to a depreciation of the real exchange rate, rer_t, which increases exports, $y_{x,t}$, and helps tame the adverse effects of the shock.

Figure 7 plots the effects of an increase in exuberance for housing, $\varkappa_{h,t}$. The increase in expected returns from housing leads to an increase in the current price of housing, $q_{h,t}$. This reduces the leverage of impatient households lowering the monitoring costs of banks, which leads to a decline in lending rate faced by impatient households, $R_{I,t}$. Similar to the capital quality shock, banks' funding costs are reduced, benefiting the non-housing sector as well as the housing sector. The shock leads to an overall increase in residential investment, $i_{h,t}$, and consumption, c_t, increasing overall output, y_t, and inflation, π_t. The increase in the policy rate, R_t, and the appreciation in the exchange rate, rer_t, help moderate the positive effects of the shock on the economy.

Figure 8 plots the impulse responses from a shock to the risk-appetite of patient households, $\varkappa_t$, which is the risk premium shock considered in Smets and Wouters (2007). This shock prompts agents to want to switch their portfolios towards short-term government bonds and foreign bonds, and away from their holdings of bank deposits and capital. The increase in discounting for patient households also leads them to decline their consumption demand, $c_{P,t}$. Asset prices, $q_{h,t}$ and $q_{k,t}$, decline while the funding and lending rates of banks, $R_{d,t}$, $R_{I,t}$, $R_{E,t}$, increase, lowering borrowers' demand for housing and capital purchases, $h_{I,t}$ and $k_{E,t}$. Overall output, y_t, falls, along with the fall in inflation, π_t. The decrease in housing price prompts patient households to purchase more housing, despite the increase in their effective discounting for future gains from housing. This, along with the decline in the policy rate, R_t, and the depreciation in the real exchange rate, moderate the adverse effects of the shock.

6 Conclusion

In this paper, we build a medium-scale small-open-economy DSGE model with nominal, real and financial frictions. In terms of modeling financial frictions, we aimed to keep the model tractable and flexible, while capturing the main themes emphasized in the literature on real-financial linkages. In this paper, we primarily study the effects of financial shocks, and consider the effectiveness of macroprudential and monetary policies in reducing household debt. We find that, for reducing household indebtedness, targeted policies such as LTV regulations are the most effective and least costly, followed by bank capital regulations and monetary policy respectively.

In future work, we plan to extend our current framework to also consider the following financial features: (i) bank financing for firms' payroll obligations and purchases of intermediate goods to capture the working capital channel, (ii) bank financing for working capital needs of importers and exporters to capture direct effects of financial frictions on trade, (iii) bank funding directly from abroad, and banks holding foreign assets to study the effects of exchange rate risk on bank capital, (iv) banks holding safe assets to satisfy liquidity requirements imposed by regulation or the market, (v) long-term government debt and the effects of unconventional monetary policy, (vi) insured retail deposits as an alternative and stable source of funding for financial intermediaries, (vii) financial assets held by corporations and corporate tax policy, (viii) rental housing alongside owner-occupied housing, and housing-related tax policy.

References

[1] Adolfson, M., S. Laseen, J. Linde, and M. Villani (2008). "Evaluating an Estimated New Keynesian Small Open Economy Model," *Journal of Economic Dynamics and Control*, 32, 2690-2721.

[2] Adrian, T. and H. S. Shin (2010). "Liquidity and Leverage," *Journal of Financial Intermediation*, 19, 418-437.

[3] Aikman, D., and M. Paustian (2006). "Bank capital, asset prices and monetary policy," Bank of England Working Paper No. 305.

[4] Allen, J., H. E. Damar, and D. Martinez-Miear (2012). "Consumer Bankruptcy and Information," Bank of Canada Working Paper 2012-18.

[5] Alpanda, S. (2013). "Identifying the Role of Risk Shocks in the Business Cycle Using Stock Price Data," *Economic Inquiry*, 51, 304-335.

[6] Alpanda, S., and J. Dorich (2013). "Quantitative Easing and the Financial Accelerator in a DSGE Model," mimeo, Bank of Canada.

[7] Alpanda, S., and A. Peralta-Alva (2010). "Oil Crisis, Energy-Saving Technological Change, and the Stock Market Crash of 1973-74," *Review of Economic Dynamics*, 13, 824-842.

[8] Alpanda, S., and S. Zubairy (2013). "Housing and Tax Policy," Bank of Canada Working Paper 2013-33.

[9] Amdur, D. (2010). "A Business Cycle Model of Aggregate Debt and Equity Flows," mimeo, Muhlenberg College.

[10] An, S., and F. Schorfheide (2007). "Bayesian Analysis of DSGE Models," *Econometric Reviews*, 26, 211-219.

[11] Aoki, K., J. Proudman, and G. Vlieghe (2004). "House prices, consumption, and monetary policy: a financial accelerator approach," *Journal of Financial Intermediation*, 13, 414-435.

[12] 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 2007-4.

[13] Benhabib, J., R. Rogerson, and R. Wright (1991). "Homework in Macroeconomics: Household Production and Aggregate Fluctuations," *Journal of Political Economy*, 99, 1166-1187.

[14] Bernanke, B. S., and M. Gertler (1999). "Monetary Policy and Asset Price Volatility," *Federal Reserve Bank of Kansas City Economic Review*, fourth quarter 1999, 17-41.

[15] Bernanke, B. S., M. Gertler, and S. Gilchrist (1999). "The Financial Accelerator in a Quantitative Business Cycle Framework." in *Handbook of Macroeconomics Volume 1C*, ed. by J. B. Taylor and M. Woodford, 1341-93. Amsterdam: Elsevier Science, North-Holland.

[16] Basel Committee on Banking Supervision (2011). "The Transmission Channels between the Financial and Real Sectors: A Critical Survey of the Literature," BCBS Working Paper No. 18.

[17] Beaton, K., and B. Desroches (2011). "Financial Spillovers Across Countries: The Case of Canada and the United States," Bank of Canada Discussion Paper 2011-1.

[18] Bianchi, J., and E. G. Mendoza (2010). "Overborrowing, Financial Crises and 'Macro-prudential' Taxes," NBER Working Paper 16091.

[19] Blanchard, O. J., and C. M. Kahn (1980). "The Solution of Linear Difference Models under Rational Expectations," *Econometrica*, 48, 1305–1311.

[20] Boivin, J., T. Lane, and C. Meh (2010). "Should Monetary Policy Be Used to Counteract Financial Imbalances?" Bank of Canada Review, Summer 2010, 23-36.

[21] Brunnermeier, M. K., and L. H. Pedersen (2008). "Market Liquidity and Funding Liquidity," *Review of Financial Studies*, 22, 2201-2238.

[22] Calvo, G. (1983): "Staggered Prices in a Utility Maximizing Framework," *Journal of Monetary Economics*, 12, 383-398.

[23] Carlstrom, C. T., and T. S. Fuerst (1997). "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review*, 87, 893-910.

[24] Carriga, C., R. Manuelli, and A. Peralta-Alva (2012). "A Model of Price Swings in the Housing Market", Federal Reserve Bank of St. Louis Working Paper 2012-022A.

[25] Cesa-Bianchi, A. and A. Rebucci (2013). "Does Easing Monetary Policy Increase Financial Instability?" Inter-American Development Bank Working Paper Series No. 387.

[26] Chari, V. V., L. J. Christiano, and P. J. Kehoe (2007). " Business Cycle Accounting," *Econometrica*, 75, 781-836.

[27] Chari, V. V., and P. J. Kehoe (2009). "Bailouts, Time Inconsistency and Optimal Regulation," Federal Reserve Bank of Minneapolis Research Department Staff Report.

[28] Chatterjee, S., and B. Eyigungor (2011). "A Quantitative Analysis of the US Housing and Mortgage Markets and the Foreclosure Crisis," Federal Reserve Bank of Philadelphia Working Paper 11-26.

[29] Chen, D. X., H. E. Damar, H. Soubra, and Y. Terajima (2012). "Canadian Bank Balance-Sheet Management: Breakdown by Types of Canadian Financial Institutions," Bank of Canada Discussion Paper 2012-7.

[30] Chen, H., V. Curdia, and A. Ferrero (2012). "The Macroeconomic Effects of Large-Scale Asset Purchase Programmes," *Economic Journal*, 122, F289-F315.

[31] Chen, N. K. (2001). "Bank net worth, asset prices and economic activity," *Journal of Monetary Economics*, 48, 415-436.

[32] Christensen, I., P. Corrigan, C. Mendicino, and S. Nishiyama (2009). "Consumption, Housing, and the Canadian Business Cycle," Bank of Canada Working Paper 2009-26.

[33] Christensen, I., and A. Dib (2008). "The Financial Accelerator in an Estimated New Keynesian Model," *Review of Economic Dynamics*, 11, 155-178.

[34] Christensen, I., and C. Meh (2011). "Countercyclical loan-to-value ratios and monetary policy", Bank of Canada Working Paper 2011-32.

[35] Christensen, I., C. Meh, and K. Moran (2011). "Bank Leverage Regulation and Macroeconomic Dynamics", mimeo, Bank of Canada.

[36] Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005). "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 113, 1-45.

[37] Christiano, L. J., R. Motto, and M. Rostagno (2010). "Financial Factors in Economics Fluctuations," European Central Bank Working Paper Series No. 1192 / May 2010.

[38] Cociuba, S., M. Shukayev, and A. Ueberfeldt (2012). "Financial intermediation, risk-taking and monetary policy," Bank of Canada Working Paper 2011-31.

[39] Cooley, T. F., and E. C. Prescott. (1995). "Economic Growth and Business Cycles," in T. F. Cooley (ed.), *Frontiers of Business Cycle Research*, Princeton University Press, 1-38.

[40] Curdia, V., and M. Woodford. (2011). "The Central Bank Balance Sheet as an Instrument of Monetary Policy," *Journal of Monetary Economics*, 58, 54-79.

[41] Davis, J. S. (2010). "The adverse feedback loop and the effects of risk in both the real and financial sectors", Federal Reserve Bank of Dallas Working Paper 66.

[42] Davis, M. A., and J. Heathcote (2005). "Housing and the Business Cycle," *International Economic Review*, 46, 751-784.

[43] Dell'Ariccia, G., D. Igan, L. Laeven, and H. Tong, with B. Bakker, and J. Vandenbussche (2012). "Policies for Macrofinancial Stability: How to Deal with Credit Booms," IMF working paper.

[44] De Nicolo, G., G. Favara, and L. Ratnovski (2012). "Externalities and Macroprudential Policy," IMF Staff Discussion Note.

[45] Diamond, D. W., and R. G. Rajan (2005). "Liquidity Shortages and Banking Crises," *Journal of Finance*, 60, 615-647.

[46] Dib, A. (2010a). "Banks, credit market frictions, and business cycles," Bank of Canada Working Paper 2010-24.

[47] Dib, A. (2010b). "Capital requirement and financial frictions in banking: macroeconomic implications", Bank of Canada Working Paper 2010-26.

[48] Djoudad, R. (2012). "A Framework to Assess Vulnerabilities Arising from Household Indebtedness Using Microdata," Bank of Canada Discussion Paper 2012-3.

[49] Dorich, J., M. Johnston, R. Mendes, S. Murchison, and Y. Zhang (2013). "ToTEM II: An Updated Version of the Bank of Canada's Quarterly Projection Model," Bank of Canada Technical Report 100.

[50] Farhi E., and J. Tirole (2012). "Collective Moral Hazard, Maturity Mismatch, and Systemic Bailouts," *American Economic Review*, 102, 60-93.

[51] Faruqui, U., and S. Torchani (2012). "How Important are Liquidity Constraints for Canadian Households? Evidence from Micro-Data," Bank of Canada Discussion Paper 2012-9.

[52] Fernández-Villaverde, J., and J. F. Rubio-Ramirez (2004). "Comparing Dynamic Equilibrium Economies to Data: A Bayesian Approach," *Journal of Econometrics*, 123, 153-187.

[53] Galati, G., and R. Moessner (2010). "Macroprudential Policy - a literature review," BIS Working Papers No. 337.

[54] Gali, J., and T. Monacelli (2005). "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, 72, 707-734.

[55] Gauthier, C., T. Gravelle, X. Liu, and M. Souissi (2011). "What Matters in Determining Capital Surcharges for Systemically Important Financial Institutions?" Bank of Canada Discussion Paper 2011-9.

[56] Gerali, Neri, Sessa and Signoretti (2010). "Credit and banking in a DSGE model of the Euro area", *Journal of Money Credit and Banking*, 42, 107-141.

[57] Gertler, M., S. Gilchrist, and F. M. Natalucci (2007). "External Constraints on Monetary Policy and the Financial Accelerator," *Journal of Money, Credit and Banking*, 39, 295-330.

[58] Gertler, M., and P. Karadi (2011). "A Model of Unconventional Monetary Policy," *Journal of Monetary Economics*, 58, 17-34.

[59] Gertler, M. and N. Kiyotaki, and A. Queralto (2012). "Financial Crises, Bank Risk Exposure and Government Financial Policy," *Journal of Monetary Economics*, 59, S17-S34.

[60] Gertler, M. and N. Kiyotaki (2010). "Financial Intermediation and Credit Policy in Business Cycle Analysis," Handbook of Monetary Economics, vol. 3, 547-599.

[61] Gilchrist, S., A. Ortiz, and E. Zakrajšek (2009). "Credit Risk and the Macroeconomy: Evidence from an Estimated DSGE Model," mimeo, Boston University.

[62] Granziera, E., and S. Kozicki (2012). "House Price Dynamics: Fundamentals and Expectations," Bank of Canada Working Paper 2012-12.

[63] Greenwood, J, and Z. Hercowitz (1991). "The Allocation of Capital and Time over the Business Cycle," *Journal of Political Economy*, 99, 1188-1214.

[64] Greenwood, J., and B. Jovanovic (1999). "The Information-Technology Revolution and the Stock Market," *American Economic Review, Papers and Proceedings*, 89, 116-122.

[65] Holmstrom, B. and J. Tirole (1997). "Financial intermediation, loanable funds and the real sector," *Quarterly Journal of Economics*, 112, 663-691.

[66] Iacoviello, M. (2005). "House Prices, Borrowing Constraints, and Monetary Policy in Business Cycles," *American Economic Review*, 95, 739-764.

[67] Iacoviello, M., and S. Neri (2010). "Housing Market Spillovers: Evidence from an Estimated DSGE Model," *American Economic Journal: Macroeconomics*, 2, 125-164.

[68] Iacoviello, M. (2013). "Financial Business Cycles," mimeo, Federal Reserve Board.

[69] Jermann, U. J., and V. Quadrini (2012). "Macroeconomic Effects of Financial Shocks," *American Economic Review*, 102, 238-271. [erratum: AER, 102, 1186].

[70] Justiniano, A., G. E. Primiceri, and A. Tambalotti (2011). "Investment Shocks and Business Cycles," *Review of Economic Dynamics*, 14, 101-121.

[71] Kareken J. H., and N. Wallace (1978). "Deposit Insurance and Bank Regulation: A Partial-Equilibrium Exposition," *Journal of Business*, 51, 413-438.

[72] Kartashova, K., and B. Tomlin (2013). "House Prices, Consumption and the Role of Non-Mortgage Debt," Bank of Canada Working Paper 2013-2.

[73] Kiyotaki, N., and J. Moore (1997). "Credit Cycles," *Journal of Political Economy*, 105, 211-48.

[74] Kiyotaki, N., and J. Moore (2012). "Liquidity, Business Cycles, and Monetary Policy," NBER Working Paper 17934.

[75] Krainer, J., S. LeRoy, and M. O (2009). "Mortgage Default and Mortgage Valuation," Federal Reserve Bank of San Francisco Working Paper 2009-20.

[76] McGrattan, E. R., and E. C. Prescott (2005). "Taxes, Regulations, and the Value of U.S. and U.K. Corporations," *Review of Economic Studies*, 72, 767-796.

[77] Meh, C., and K. Moran (2010). "The Role of Bank Capital in the Propagation of Shocks," *Journal of Economic Dynamics and Control*, 34, 555-576.

[78] Rajan, R. G. (2006). "Has Finance Made the World Riskier?," *European Financial Management*, 12, 499-533.

[79] Rotemberg, J. J. (1982). "Monopolistic Price Adjustment and Aggregate Output," *Review of Economic Studies*, 49, 517-31.

[80] Schmitt-Grohe, S. and M. Uribe (2003). "Closing Small Open Economy Models," *Journal of International Economics*, 61, 163-185.

[81] Shiller, R. (2000). "Irrational Exuberance," Princeton University Press (second edition 2005).

[82] Smets, F., and R. Wouters (2007). "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, 97, 586-606.

[83] Van den Heuvel, S. J. (2008). "The welfare cost of bank capital requirements," *Journal of Monetary Economics*, 55, 298-320.

[84] Woodford, M. (2001). "Fiscal Requirements for Price Stability," *Journal of Money, Credit and Banking*, 33, 669-728.

[85] Woodford, M. (2012). "Inflation Targeting and Financial Stability," NBER Working Paper 17967.

Table 1. Parameters		
	Symbol	Value
Discount factor	β_P, β_B, β_I, β_E	0.993, 0.992 0.987, 0.988
Inverse labor supply elasticity	ϑ	5
Habit in consumption	ζ	0.94
Level for housing in utility	ξ_{hP}, ξ_{hI}	3.1, 4.1
Level for labor in utility	ξ_{lP}, ξ_{lI}	11.2, 11.2
Depreciation rate	δ_h, δ_k	0.011, 0.015
Capital share in production	α	0.3
Patient HH share in K and L	μ_k, μ_l	0.43, 0.68
Import share in final goods	ϕ_c, ϕ_{ik}, ϕ_{ih}, ϕ_g, ϕ_x	0.3, 0.18, 0, 0.08, 0.33
EOS - domestic and foreign goods	η_c, η_{ik}, η_{ih}, η_g, η_x	0.5, 0.5, 0.5, 0.5, 0.5
Export demand (habit, elast., share)	ζ^*, η^*, ϕ^*	0.8, 1.5, 0.32
Wage and price and mark-up	θ_w, θ_d, θ_m, θ_x	1.25
Wage and price stickiness	κ_w, κ_d, κ_m, κ_x	333, 84, 84, 2
Wage and price indexation	ς_w, ς_d, ς_m, ς_x	0.5, 0.5, 0.5, 0.5
Utilization cost – elasticity	ϖ	5
Investment adj. cost	κ_h, κ_k	12, 12
Stock adj. cost	κ_{hP}, κ_{hI}, κ_{kP}, κ_{kE}	50, 0, 0, 0
Coupon rates on long-term loans	δ_I, δ_E	0.97, 0.92
Dividend adj. costs	κ_{dB}, κ_{dE}	50, 50
Monitoring cost elasticity	χ_{d2}, χ_{I2}, χ_{E2}	0.0075, 0.002, 0.01
Portfolio preference term	$\varrho_{\varkappa}$	0
Regulatory LTV and capital ratio	m_I, γ	0.95, 0.1
Taylor rule	ρ, a_π, a_y	0.75, 2.5, 0

Table 2. Model steady-state ratios		
	Symbol	Model
Consumption / GDP	c/y	0.583
Business investment /GDP	i_k/y	0.122
Residential investment /GDP	i_h/y	0.065
Government exp. / GDP	g/y	0.230
Exports / GDP (= Imports / GDP)	$y_x/y = y_m/y$	0.320
Capital stock / GDP (qrt.)	k/y	8.0
Housing stock / GDP (qrt.)	h/y	6.0
Wage share in total income	$1-\alpha$	0.7
Wage share of impatient hh.	$1-\mu_l$	0.32
Consumption share of impatient hh.	c_I/c	0.32
Housing share of impatient hh.	h_I/h	0.32
Capital share of entrepreneurs	k_E/k	0.5
Business debt / total capital	$p_E b_E/k$	0.25
for entrepreneurs only	$p_E b_E/k_E$	0.5
Mortgage debt / total housing	$p_I b_I/h$	0.3
for impatient hh. only	$p_I b_I/h_I$	0.95
Bank capital ratio	$a/\left(\omega_I p_I b_I + \omega_E p_E b_E\right)$	0.1

Table 3. Comparing peak effects of macroprudential and monetary policies (in p.p.)			
	5 p.p. $\downarrow$ in LTV	1 p.p. $\uparrow$ in cap. req.	100 bps. $\uparrow$ in policy rate
Output	-0.5	-0.3	-0.5
Consumption	-0.5	-0.1	-0.2
Business inv.	-0.8	-1.4	-1.4
Residential inv.	-6.9	-2.0	-2.4
Inflation	-0.08	-0.03	-0.14
House price	-4.4	-1.3	-2.4
Household debt	-7.6	-1.8	-1.8

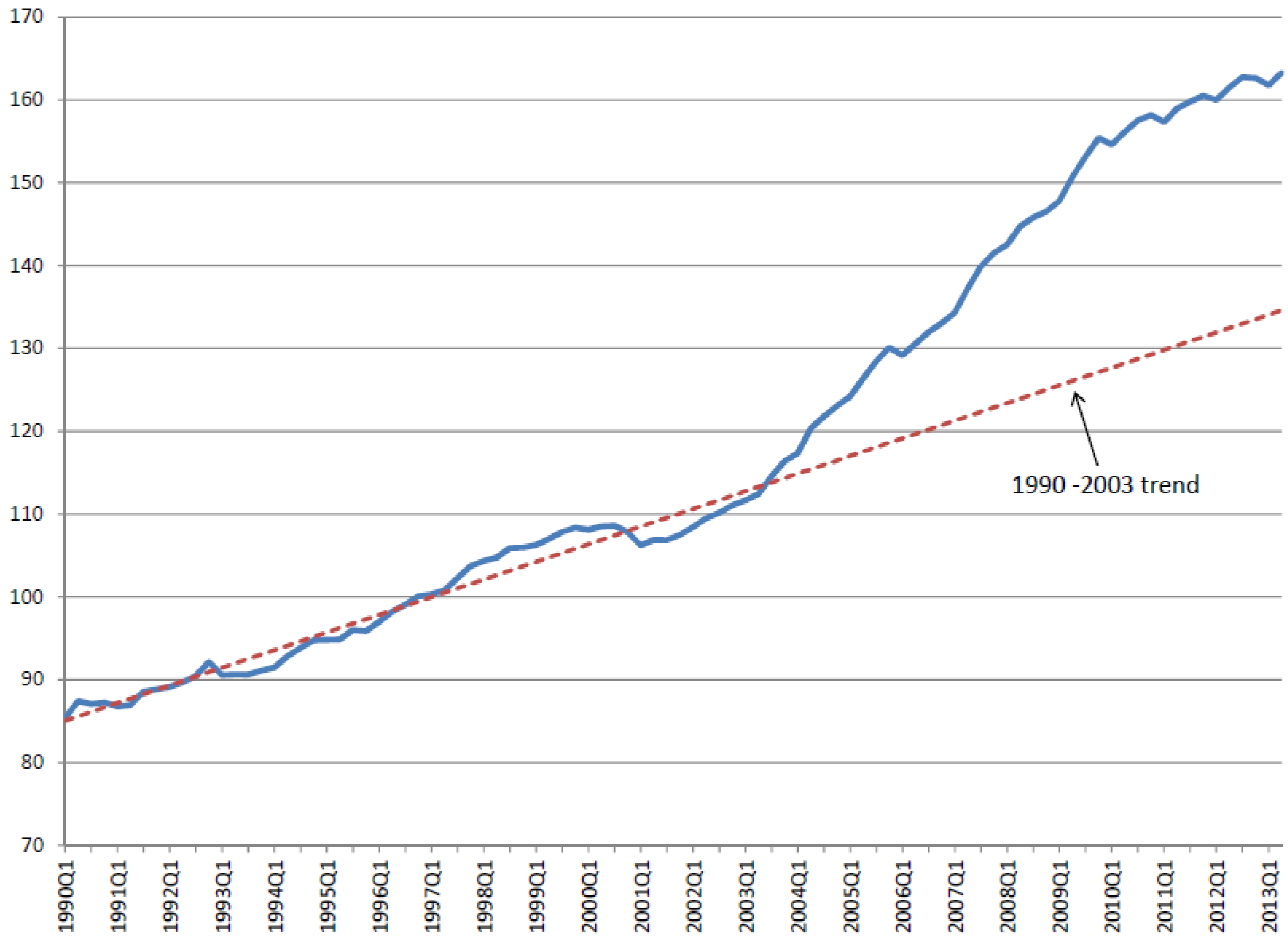

Figure 1: Household debt (as percent of disposable income) in Canada

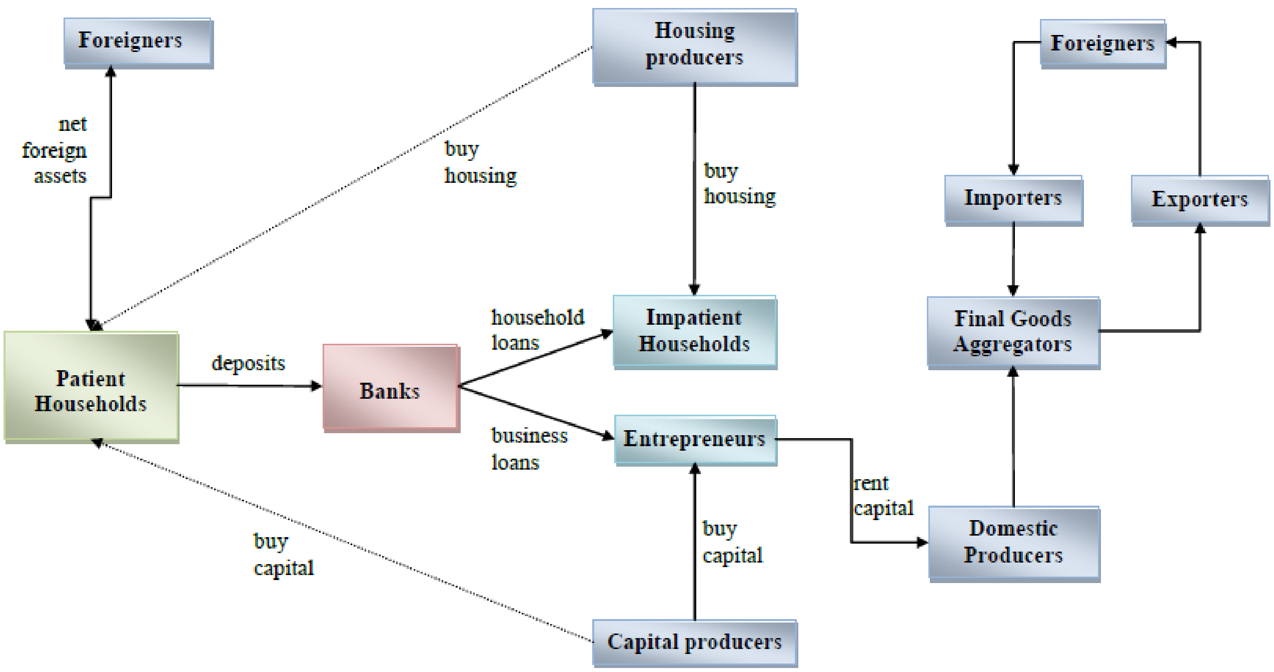

Figure 2: Model agents and key flows of funds, inputs and goods

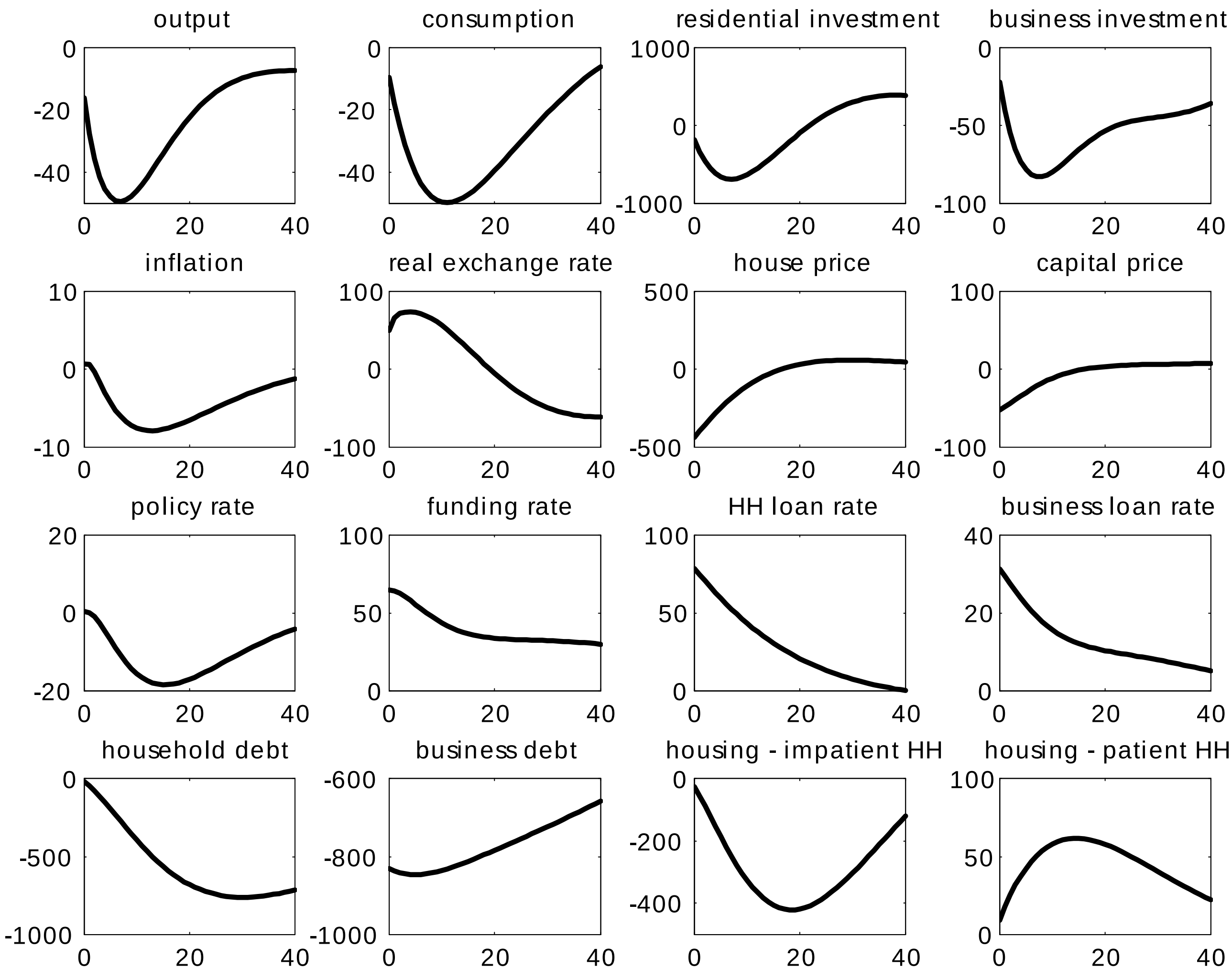

Figure 3: Effects of 5 p.p. decrease in regulatory LTV ratio (in bps.)

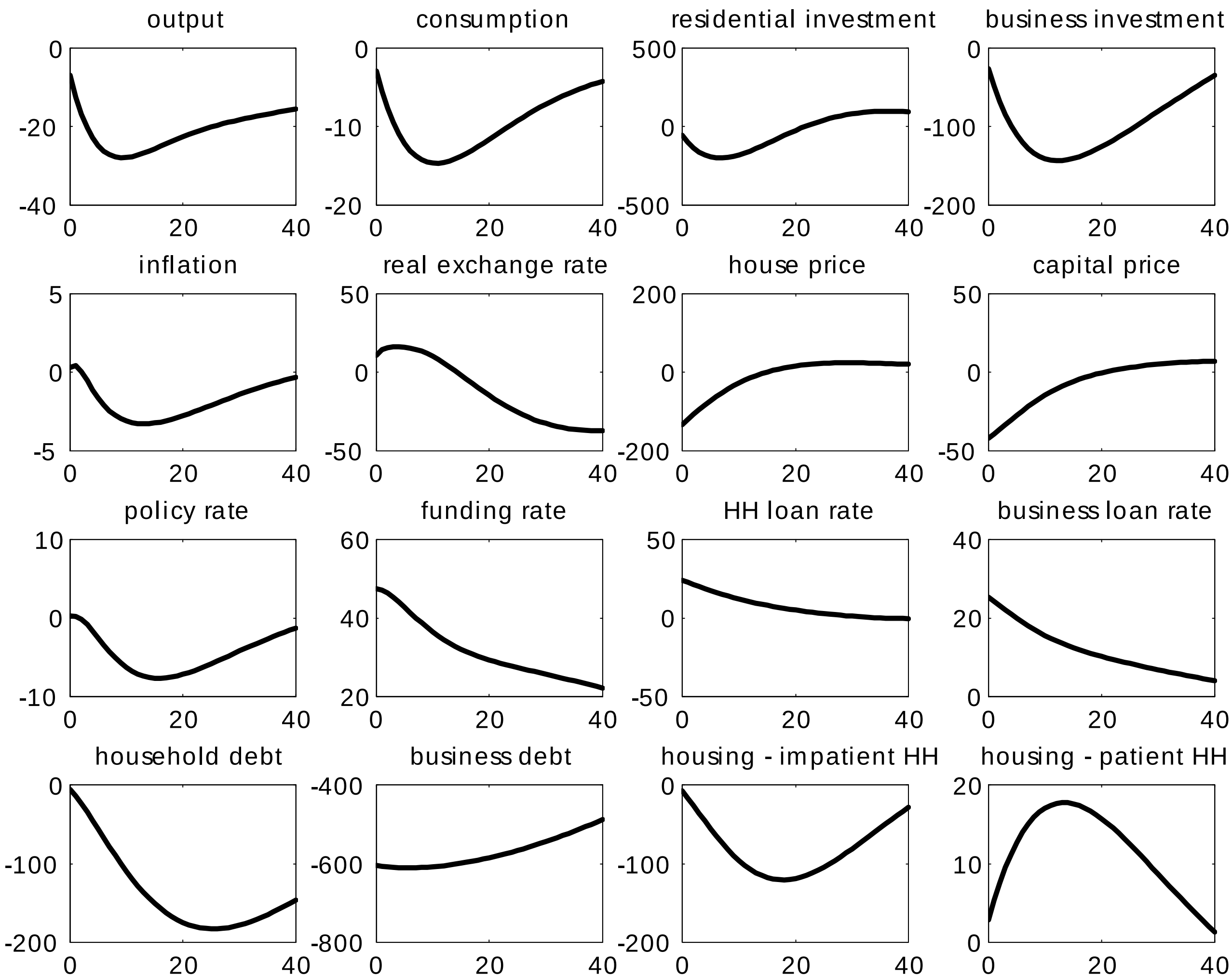

Figure 4: Effects of 1 p.p. increase in the capital requirement ratio (in bps.)

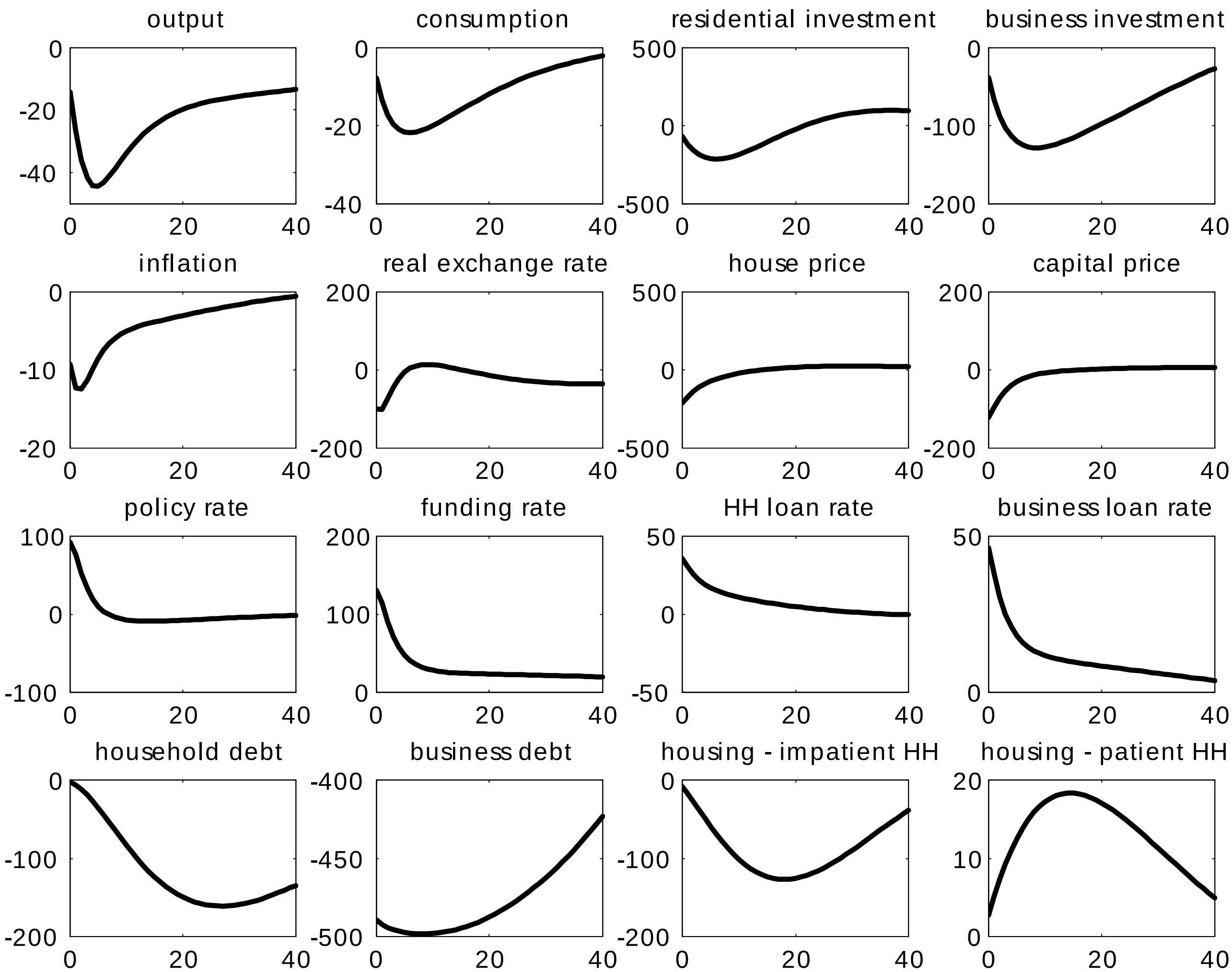

Figure 5: Effects of 100 bps. (annualized) shock to the policy rate (in bps.)

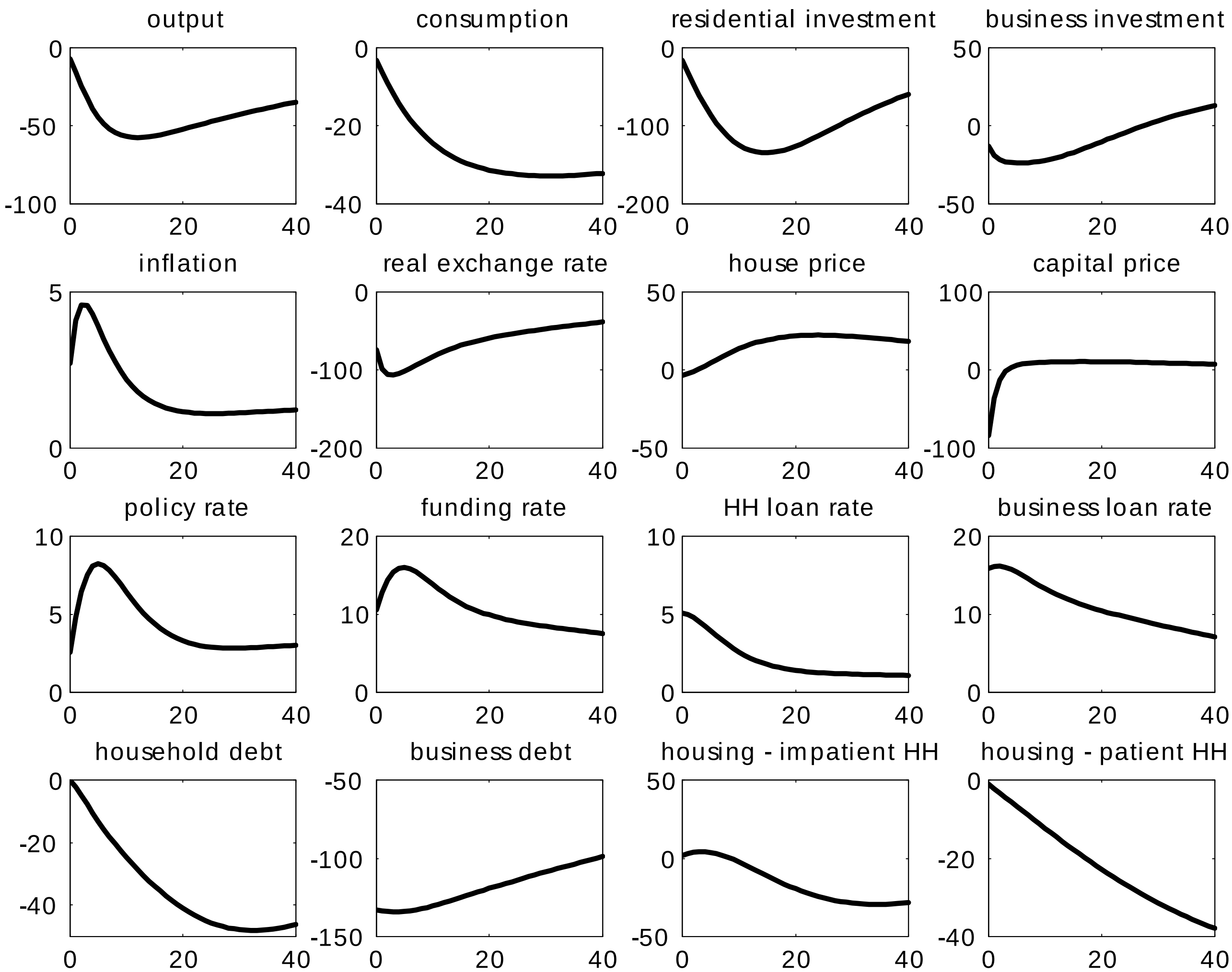

Figure 6: Effects of 1% decline in capital quality (in bps.)

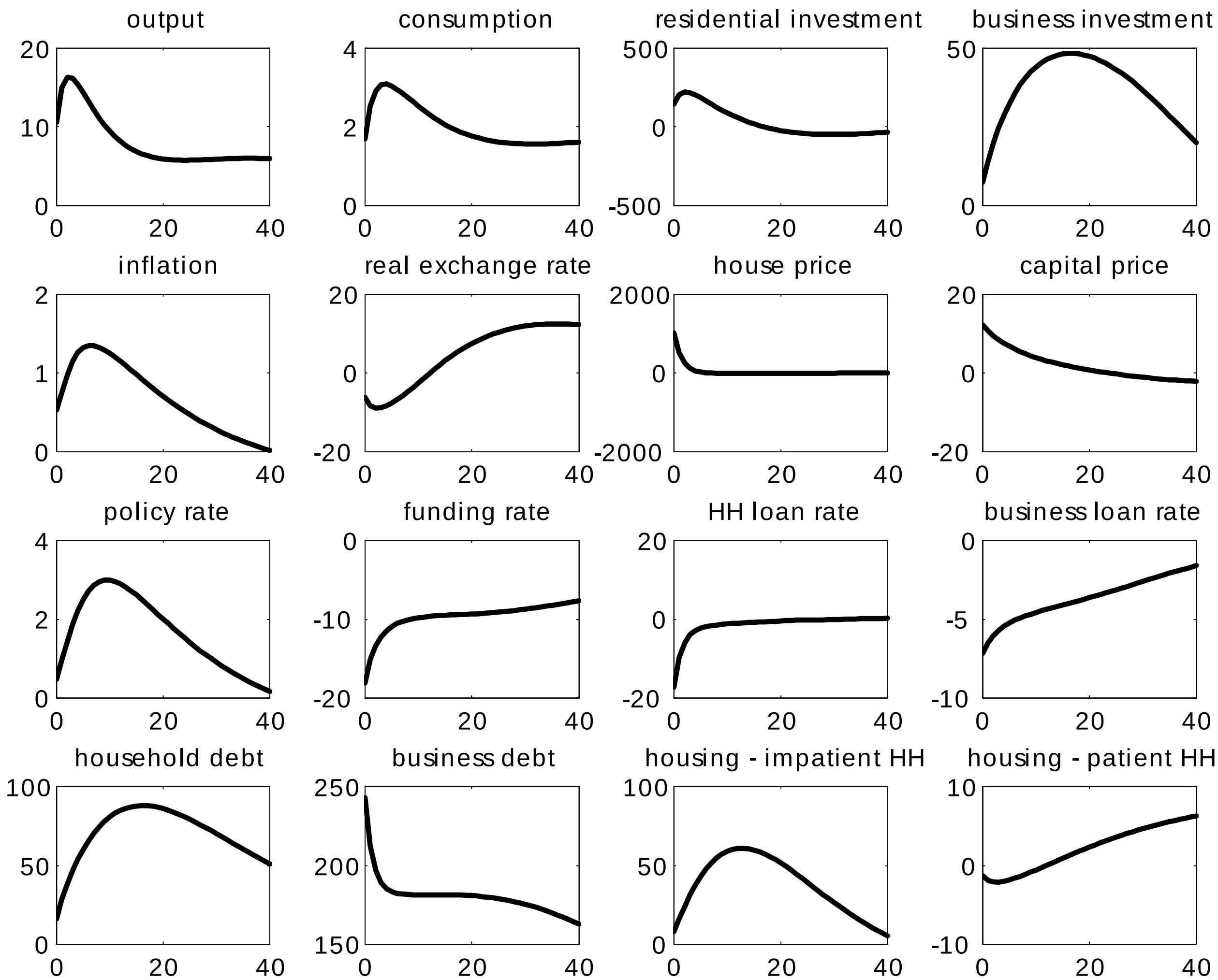

Figure 7: Effects of 5% shock to exuberance in the housing sector (in bps.)

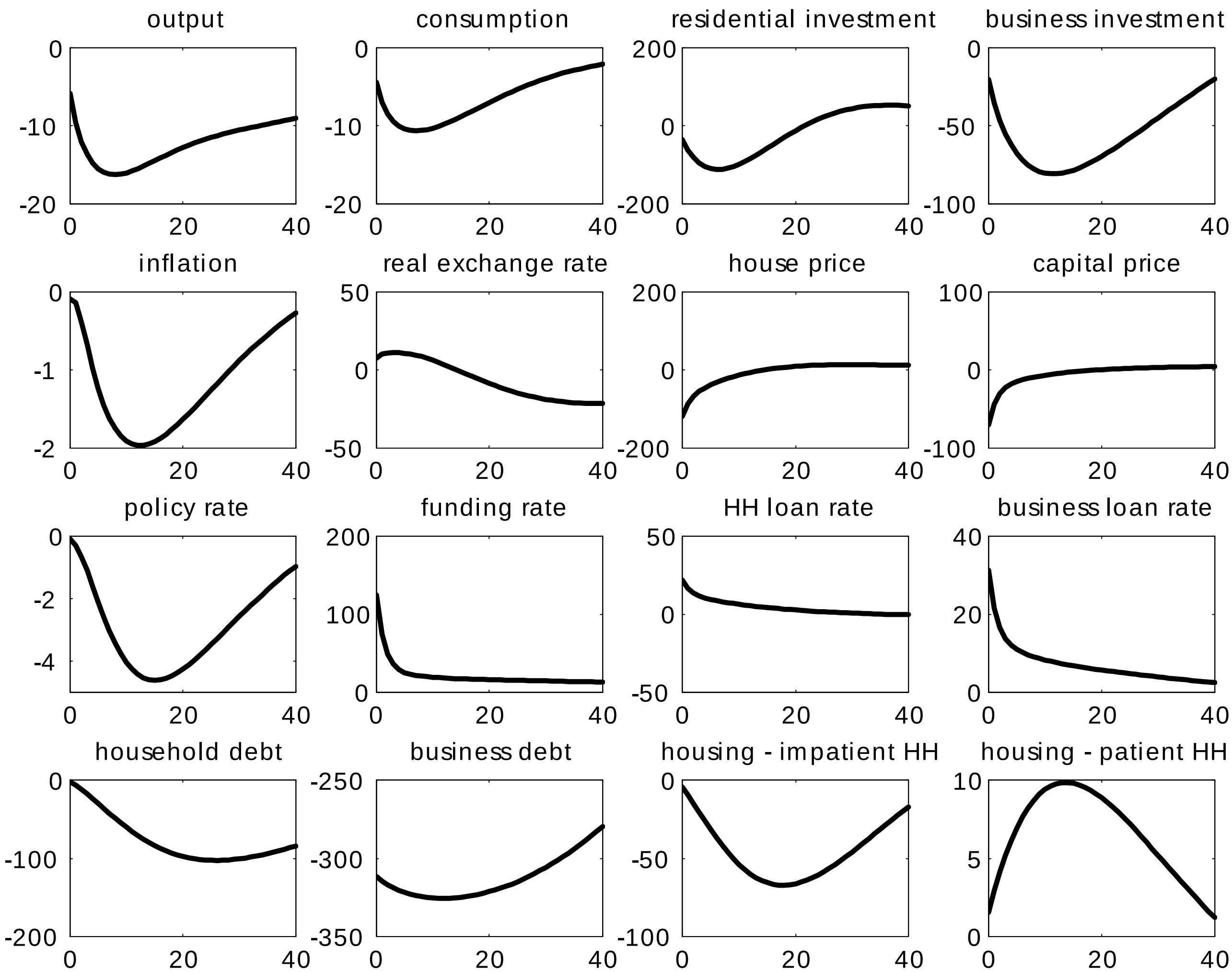

Figure 8: Effects of 1% shock to risk appetite of patient households (in bps.)