The costs of macroprudential deleveraging in a low interest rate environment

Jack Chen*, Daria Finocchiaro†, Jesper Lindé‡, Karl Walentin§¶

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Abstract

We examine the short- and long-term effects of different borrower-based macroprudential (MPP) tools in an environment where both real and nominal interest rates are low. The analysis is conducted in a two-agent New Keynesian model that includes long-term debt, housing transaction costs and a zero lower bound constraint on policy rates. We find that the long-term macroeconomic costs, in terms of forgone consumption, of all the MPP tools we consider are moderate. Yet, the short-term output loss is more substantial following an LTV rather than an LTI tightening, especially in an environment where debt is high and monetary policy is close to the effective lower bound. Our findings stress that when designing macroprudential policies aimed at addressing household debt imbalances, it is important to take into account their interaction with monetary policy and the initial state of the economy, in terms of both debt level and closeness to the zero lower bound.

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*IMF
†Uppsala University and Sveriges Riksbank
‡IMF and CEPR
§Sveriges Riksbank
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Correspondence: Chen: jchen@imf.org; Finocchiaro: daria.finocchiaro@riksbank.se; Lindé: JLinde@imf.org; Walentin: karl.walentin@riksbank.se.

1 Introduction

A decade after the unfolding of the Global Financial Crisis, several countries in Northern Europe, Canada and Australia are experiencing soaring household debt and fast-inflating house prices as shown in Figure 1. While record-low interest rates keep the debt-service-to-income ratio at moderate levels presently, policy makers around the world have expressed concerns about households' vulnerability to normalized interest rates.[1] Different policies have been put forward to stem the perceived imbalances. While some institutions like the Bank for International Settlements (see e.g. BIS (2016) Box IV.B, pp. 76–77) have advocated leaning against the wind policies for central banks to moderate the risks of rising household indebtedness on a transient basis, there seems to be consensus that monetary policy cannot be the first line of defense to address very persistent upward pressure on housing prices and a desire among households to debt finance housing purchases.[2]

Amid this background, various macroprudential policies, e.g. caps on loan-to-value (LTV) debt-to-income (LTI) and debt-service-to-income (DSTI) ratios, and fiscal policies, for instance reduced (or removed) mortgage rate deductibility (MID) and higher property taxes, have been put forth as more long-term viable tools to reduce the demand for housing and debt, in a strive to reduce households' vulnerabilities to economic fluctuations.[3]

Our aim is to evaluate the effectiveness of different macroprudential policies to reduce household indebtedness. Specifically, we seek to quantify the short- and long-term output losses associated with different policies that reduce household debt equally in the long term. When quantifying the output costs of reducing households' indebtedness, two observations are key. First, as shown in Figure 1, aggregate debt-to-income ratios are highly elevated relative to historical values. Second, in many economies monetary policy is either at, or close to, the effective lower bound without much scope to stimulate the economy following sizeable macroprudential adjustments. These two considerations, which both plausibly are

[1] See Hoffmann et al. (forthcoming)

[2] See e.g. IMF (2015) and the references therein. Some research have even suggested that leaning against the wind policy may be counterproductive and increase indebtedness in the near-term, see e.g. Gelain et al. (2017)

[3] In the following, we call lower mortgage deductibility a macroprudential tool because the way we implement the policy avoids any re-distributional effects between borrowers and savers (borrowers fully pay for the mortgage interest rate deductions by lump-sum transfers). Our definition of macroprudential policy is consistent with the ECB, which defines it as any tool which prevents the excessive build-up of risks and smooths the financial cycle over time.

driven by a persistently low equilibrium real rate, must be properly taken into account in any analysis.

Because current economic conditions are extra-ordinary from a historical perspective, we believe that a purely empirical approach to address the question will be of limited value (a large degree of extrapolation would be necessary because few data points cover the situation we are currently facing). Therefore, we use a structural macroeconomic model to do the analysis. The macroeconomic model we consider – an augmented version of the Iacoviello and Neri (2010) two agent New Keynesian model with housing and collateral constraints – allows us to consider the joint initial position with elevated debt levels and monetary handcuffs. In our framework, three factors generate the sharp rise in house prices and loan-to-income ratio as observed in the data between early 1990s and the 2000s. First, we assume that an increased desire to save has reduced the equilibrium real rate from 3 to 0.5 percent. Such a fall is well in line the mortgage rate time series in Figure 1 as well as with point estimates from a voluminous and growing empirical literature which aims at measuring equilibrium real interest rates (see e.g., Sajedi and Thwaites (2016), Holston et al. (2017), Lisack et al. (2017), Del Negro et al. (2018) and Fries et al. (2018)). The reduction in the long-term real interest rate contributes to a sizeable decline in the user cost of housing, and thus drives up the relative price of houses. The rise in house prices implies a roughly proportional increase in debt and the debt-to-income ratio accordingly rises sharply in our model. Second, we introduce an explicit role for credit supply by allowing for a somewhat higher LTV ratio now relative to the past. This is consistent with the loosening in credit conditions as documented before the GFC.[4] However, the fall in the real rate and the increase in the LTV do not cause average indebtedness to rise quite as much, double, as in the data. In line with anecdotal evidence we therefore let a slight increase in home equity extraction account for the remainder of the increase.

An important feature of the low real rate (high debt) regime is a substantial increase in the long-run residential investment share of GDP (from 4 to 7 percent of GDP). When the

[4] In particular, supported by LTV statistics on new loans issued in Sweden 2000 and 2014, we assume an increase in LTV ratios from 0.75 to 0.85. While this increase in leverage contributes to the increased LTI ratio we see in the data, the bulk of the LTI increase is driven by the falling equilbrium real rate. We have also entertained the idea of other drivers of higher LTI ratios such as lower mortgage amortization standards but have not found any data which supports them.

relative price of housing – the user cost – declines, both borrowers and savers consume more housing. Interestingly, this increase in residential investment is consistent with the data for many of the countries included in Figure 1. For instance, in Sweden residential investment have risen from less than 2 percent after the housing crisis in the early 1990s to about 7 percent in 2017. Such an exposure to the volatile housing market is a crucial component of the transmission mechanism of macroeconomic disturbances in our framework and poses challenges for monetary and fiscal policy to stabilize the economy. Specifically, in a high debt environment the economy is more volatile not only because constrained debtors have a higher marginal propensity to consume but also because housing investment constitutes a bigger share of the economy.

Our main findings are as follows. First, we find that the long-term costs of all the macroprudential actions (tightening of LTV, LTI or DSTI ratios or lower mortgage deductibility) are very moderate, regardless of whether we consider a steady state with normal (say mid-1990s) or elevated debt levels (the current state). Second, the short-term effects depends critically on the initial debt level and the scope for the central bank to provide accommodation. When monetary policy is unconstrained and the initial debt level is low the short-term costs will be small. But in an environment with elevated debt levels and little scope for central banks to cut rates, macroprudential actions may be associated with a significant drop in output and consumption. Specifically, LTI or DSTI tightening are more efficient tools, i.e. have lower macroeconomic costs, than LTV tightening to curb household debt; the latter implies larger housing prices swings and a transitory negative feedback effect on debt capacity as prices are part of the collateral constraint. As a result, short-term effects on output and inflation are more than twice as large from LTV tightening. Finally, the increase in volatility due to higher exposure of housing markets in the high debt environment is further exacerbated when the economy is close to the effective lower bound and it is welfare detrimental Taken together, our findings stress that when designing macroprudential policies aimed at addressing current household debt imbalances, it is important to account for their contractionary effects and the interaction with monetary policy.

Our work is related to different strands of the growing literature on housing, monetary policy and its interaction with other stabilization policies. Starting with Iacoviello (2005), several papers have explored the linkages between housing, household credit conditions and the macroeconomy (see e.g. Iacoviello and Neri (2010) and Justiniano et al. (2015)). We build on Iacoviello and Neri (2010), i.e. a two-agent new Keynesian model with housing production and a collateral constraint, and expand their framework to incorporate long-term debt, housing transactions costs and a broader set of macroprudential instruments. Furthermore, we explicitly take into account the zero (or effective) lower bound constraint on monetary policy. These new features have a considerable impact on the monetary transmission mechanism and are therefore crucial for our work.

The new elements we introduce have been studied in isolation before, but to the best of our knowledge not jointly yet. For instance, Garriga et al. (2017) show how the presence of multi-period mortgage contracts can enhance the traditional interest-rate transmission mechanism of monetary policy. Differently from ours, their model abstract from other nominal rigidities to insulate the effect of the long-term nominal of aspect of mortgages. Gelain et al. (2017) study the effects of monetary policy in new Keynesian environments with long-term debt but abstract from the interaction between monetary and other stabilization policies. Their focus is on optimal monetary policy and they show that, compared to inflation targeting, debt-to-GDP stabilization calls for a more expansionary policy when debt to-GDP ratio is high.

In line with our results, Walentin (2014) finds that the impact of monetary policy is stronger when the level of debt is higher. Our findings mirror the empirical work in Calza et al. (2013), which shows that countries with more developed mortgage markets and high mortgage debt-to-GDP feature larger responses to monetary policy shocks. In their study, the possibility of mortgage equity release and the prevalence of adjustable rate mortgage (ARM henceforth) contracts turns to be crucial for the response of consumption. Similarly, using household data for the US and the UK Cloyne et al. (2018) show that mortgagors' consumption reacts more strongly than other households' consumption to monetary policy shocks. Flodén et al. (2018) find that highly indebted Swedish households cut their non-housing expenditures more than less indebted households following changes in the policy rate. In contrast, Alpanda and Zubairy (2018) argues that monetary policy is less effective when the debt gap is high. They rationalize their findings in a partial equilibrium model where highly indebted households cannot further increase borrowing in response to interest rate cuts. Richter et al. (2018) provide empirical evidence on the contractionary effects of LTV tightening, but do not differentiate between situations when monetary policy is constrained and when it is unconstrained (away from the ZLB). They find that a 10 percentage point tightening of the LTV induces a 1.1% reduction in output. This result is consistent with ours as it is in-between what we find for constrained and unconstrained monetary policy.

Our work also contributes to the growing literature on the interaction between monetary policy and macroprudential regulations (see e.g. De Paoli and Paustian (2017), Gelain and Ilbas (2017), Ferrero et al. (2018) and Lambertini et al. (2013)). Like us, Alpanda and Zubairy (2017) builds on Iacoviello (2005), but they do not take into account neither the supply side of housing nor the ZLB constraint on monetary policy. Their main finding is that monetary policy is too blunt a tool to stabilize households' debt compared to other more tailor-made housing-related policies. Finocchiaro et al. (2016) study the effects of different MPP tools in a set-up with housing and banks, but their focus is on the long-run costs of deleveraging. On the normative side, both De Paoli and Paustian (2017) and Ferrero et al. (2018) derive a welfare-based loss function in models featuring credit markets frictions. The latter shows that, during boom-bust episodes in housing markets macroprudential policy can help avoid zero lower bound episodes by alleviating debt leveraging. Similarly, Rubio and Yao (2018) study optimal LTV rules in low interest rate environments and show that the macroprudential authority needs to use its instrument more aggressively to stabilize financial cycles and that a direct response to output strengthens economic stability. Conversely, we focus on the positive side of this issue and measure the effectiveness of different policies to reduce households' indebtedness in an environment in which households' loan to income ratios are strongly elevated to begin with.

Finally, our results are consistent with the findings of Mendicino et al. (2018) for bank capital-based macroprudential measures. In their framework, when monetary policy hits the lower bound, it loses the ability of dampening the macroeconomic effects of a (bank) capital requirement increase. Conversely, we focus on borrower-based macroprudential measures and stress the importance of taking into account initial conditions, i.e. the level of debt, to properly assess the trade-offs associated with different tools.

The remaining part of the paper is organized as follows. Section 2 presents the model environment. Section 3 discusses our calibration choices to account for the increased indebtedness evident in the data. It also presents the long-term macroeconomic effects of the different MPP instruments we consider. Next, Section 4 presents the short-term effects of the MPP instruments when monetary policy is at the ZLB, comparing the effects in the "normal" regime with moderate debt levels with the low real rate regime with elevated debt levels. Section 5 and 6 compares the contractionary effects of the different MPP tools. Section 7 evaluates welfare under different LTV levels. Finally, Section 8 concludes.

2 The model

Consider a two-agent new Keynesian economy (TANK) with housing and long-term, collateralized household debt. The economy is populated by households and firms. Households consume both housing, h, and non-housing goods, c, and provide work in both sectors. They are divided in two groups with a combined mass of unity; patient households, subscript P, and impatient households, subscript I, which discount the future at different rates, $\beta_P > \beta_I$. On the production side, the non-housing sector combines capital and labor to produce a good that can be be used for consumption, production capital or as an intermediate input in the production of housing. The housing sector combines capital, labor, land and the intermediate good to produce new housing. Monetary policy is constrained by the zero lower bound. For ease of exposition, in what follows we describe the optimization problems faced by each agent in the economy and relegate to the appendix the complete set of first-order conditions and technical details.

2.1 Households

2.1.1 Patient households

A representative patient household maximizes the following expected lifetime utility

$$E_0 \sum_{t=0}^{\infty} (\beta_P)^t z_t \left[\begin{array}{c} \Gamma_c ln(c_{P,t} - \epsilon c_{P,t-1}) + j_{P,t} ln(h_{P,t}) \\ -\frac{v_t}{1+\eta}(n_{c,P,t}^{1+\xi} + n_{h,P,t}^{1+\xi})^{\frac{1+\eta}{1+\xi}} \end{array} \right] \quad (1)$$

where c, h, n_c, and n_h are consumption, housing, and hours worked in the consumption and housing sectors, respectively. β denotes the discount factor, and the terms z and v capture shocks to intertemporal preferences and labor supply, respectively. j is a housing preference shock aiming to capture preference shifts towards or away from housing. In the specification of labor disutility, η is the inverse Frisch elasticity of labor supply while ξ is a measure of the labor immobility between sectors, such that $\xi > 0$ implies that households prefer to spread their working hours to both sectors (see Hovarth (2000)).[5]

Patient households are the savers in the economy; they accumulate capital and houses and lend long-term to impatient households. Their budget constraint can be described as follows

$$
\begin{aligned}
& c_{P,t} + \frac{i_{c,t}}{A_{k,t}} + i_{h,t} + k_{b,t} + q_t h_{P,t} + p_{l,t} l_t + \frac{L_{P,t}}{P_t} \\
= & \frac{w_{c,P,t} n_{c,P,t}}{X_{wc,t}} + \frac{w_{h,P,t} n_{h,P,t}}{X_{wh,t}} + (p_{l,t} + R_{l,t}) l_{t-1} + \frac{M_{P,t}}{P_t} \\
& + R_{c,t} z_{c,t} k_{c,t-1} R_{h,t} z_{h,t} k_{h,t-1} \\
& - \frac{a(z_{ct}) p_t^{ch} k_{c,t-1}}{A_{k,t}} - a(z_{ht}) p_t^{kh} k_{h,t-1} + p_{b,t} k_{b,t} \\
& - \phi_{P,t} + q_t (1 - \delta_h) h_{P,t-1} + Div_t
\end{aligned} \tag{2}
$$

where k_c, δ_{kc} and k_h, δ_{kh} denote capital and its depreciation rates in the non-housing and housing sector, respectively, k_b intermediate inputs, and l land.

A_k indicates investment-specific technology in the non-housing sector. X_{wc} and X_{wh} are wage markups accruing to labor unions, Div denotes profits from retail firms and lump-sum payments from labor unions corresponding to the wage markups, R_c, R_h and R_l are rental rates, z_c and z_h capital utilization rates, $a(z_c)$ and $a(z_h)$ utilization costs in terms of capital goods (see the Appendix for functional forms for the utilization costs). The term

$$
\phi_{f,t} \equiv \frac{\phi_h}{2} \left(\frac{h_t}{h_{t-1}} - 1 \right)^2 q_t h_{t-1} \qquad f = \{P, I\}
$$

aims at capturing transaction costs borne by households adjusting their housing stock. The

[5] The scaling factor $\Gamma_c = (1-\epsilon)/(1-\beta_\epsilon)$ ensures that the marginal utility of consumption is $1/c$ in the steady state.

law of motion of capital in the two sectors are described by

$$k_{ct} = (1 - \delta_{kc})\, k_{ct-1} + F\,(i_{ct}, i_{ct-1})$$
$$k_{ht} = (1 - \delta_{kh})\, k_{ht-1} + F\,(i_{ht}, i_{ht-1})\,,$$

where our choice of functional forms for the adjustment costs, $F\,(\cdot,\cdot)$, closely follows Christiano et al. (2005), as described in the Appendix.

We characterize long-term mortgage contracts as in Alpanda and Zubairy (2017). That is, each period savers receive mortgage payments, $\frac{M}{P}$, which are the sum of interest, r^M, and constant-principal, κ, payments[6],

$$\frac{M_t}{P_t} \equiv [r^M_{t-1} + \kappa]\frac{D_{t-1}}{P_t}. \tag{3}$$

The total stock of debt evolves according to

$$\frac{D_t}{P_t} = (1 - \kappa)\,\frac{D_{t-1}}{P_t} + \frac{L_t}{P_t}. \tag{4}$$

It is further assumed that new mortgage loans, L, carry a fixed interest rate, r^F, and a fraction of existing loans, Φ, are refinanced at this rate. As a result, the effective mortgage rate is a weighted average of present and past rates:

$$r^M_t = (1 - \Phi)\left(1 - \frac{L_t}{D_t}\right) r^M_{t-1} + \left[\frac{L_t}{D_t} + \Phi\left(1 - \frac{L_t}{D_t}\right)\right] r^F_t. \tag{5}$$

2.1.2 Impatient households

Impatient households' utility is similar to patient households. Most importantly, they discount the future at a higher rate, $\beta_I < \beta_P$, and assign a higher relative utility to housing $j_I > j_P$. Owing to the high impatience, they accumulate only the required net worth to finance the down payment on their home and borrow the rest from patient households, i.e. they are the borrowers in our economy. Their budget constraint is described by

$$\begin{aligned} c_{I,t} + q_t h_{I,t} + \frac{M_{I,t}}{P_t} &= \frac{w_{c,I,t} n_{c,I,t}}{X_{wc,t}} + \frac{w_{h,I,t} n_{h,I,t}}{X_{wh,t}} + q_t(1 - \delta_h) h_{I,t-1} \\ &\quad - \phi_{I,t} + \frac{L_{I,t}}{P_t} + (1 - \tau_t)\, r^M_{t-1}\frac{D_{I,t-1}}{P_t} + Div_{I,t} - T_t \end{aligned} \tag{6}$$

[6] See Garriga et al. (2017) and Gelain et al. (2017) for examples of time-varying amortization rates.

where τ captures the partial deductibility of interest payments and T are lump-sum taxes. In order to analyze the effects of the different macroprudential measures we will consider alternative specifications of the borrowing constraint. Specifically, household borrowing can be either limited by a collateral (LTV) constraint[7]

$$\frac{L_t}{P_t} \leq \theta_t^{LTV} q_t[h_{It} - (1-\delta_h)h_{I,t-1}] + \gamma \left[q_t(1-\delta_h)h_{I,t-1} - (1-\kappa)\frac{D_{t-1}}{P_t} \right], \tag{7}$$

or by the following loan-to-income (LTI) constraint

$$\frac{L_t}{P_t} \leq \theta_t^{LTI} \left[w_{c,I,t} n_{c,I,t} + w_{h,I,t} n_{h,I,t} \right] + \gamma \left[q_t(1-\delta_h)h_{I,t-1} - (1-\kappa)\frac{D_{t-1}}{P_t} \right], \tag{8}$$

or by the following debt-service-to-income (DSTI) constraint

$$\frac{L_t}{P_t} \leq \theta_t^{DSTI} \frac{w_{c,I,t} n_{c,I,t} + w_{h,I,t} n_{h,I,t}}{(1-\tau_t) r_t^F + \kappa} + \gamma \left[q_t(1-\delta_h)h_{I,t-1} - (1-\kappa)\frac{D_{t-1}}{P_t} \right]. \tag{9}$$

When the first restriction is in place, each period impatient households can borrow using a fraction θ of their housing investments as collateral; similarly, when the second or third constraint is present households' borrowing or debt service costs can not exceed a certain multiple of their income. In all three cases, borrowers are, in addition, allowed to extract a constant fraction γ of the available home equity every period. For small enough shocks around the steady state the constraints hold with equality.[8]

2.2 Firms and technology

2.2.1 Wholesale sector

There is a perfectly competitive wholesale sector where capital and labor are input to produce the non-housing good, Y_t, while new houses, IH_t are produced with capital, labor, land and an intermediate input. Firms maximize the following profit function:

$$\frac{Y_t}{X_t} + q_t IH_t - \left(\sum_{i=c,h} w_{it} n_{it} + \sum_{i=c,h} w_{it} n_{i,I,t} + R_{ct} z_{ct} k_{ct-1} + R_{ht} z_{ht} k_{ht-1} + R_{lt} + p_{bt} k_{bt} \right) \tag{10}$$

[7] This specification follows Alpanda and Zubairy (2017).

[8] Although there can be instances in which more than one constraint bind at the same time (see Greenwald (2018), Grodecka (2017) and Justiniano et al. (forthcoming)), in our framework we let borrowing restrictions bind only one at a time.

subject to the production technologies for goods and new houses, respectively:

$$Y_t = \left(A_{ct}\left(n_{c,P,t}^{\alpha}\left(n_{c,I,t}\right)^{1-\alpha}\right)\right)^{1-\mu_c}\left(z_{ct}k_{ct-1}\right)^{\mu_c} \tag{11}$$

$$IH_t = \left(A_{ht}\left(n_{h,P,t}^{\alpha}\left(n_{h,I,t}\right)^{1-\alpha}\right)\right)^{1-\mu_h-\mu_b-\mu_l}\left(z_{ht}k_{ht-1}\right)^{\mu_h} k_{bt}^{\mu_b} l_{t-1}^{\mu_l} \tag{12}$$

where A_{ct} and A_{ht} are the productivity levels in the non-housing and housing sectors, respectively and α is the labor income share of patient households. The production specification above implies complementarity across labor skills from the two types of households.

2.2.2 Retailers

To model price stickiness in the non-housing sector, we assume that monopolistically competitive retailers differentiate the homogenous good. These firms buy homogenous goods at the price P_t^w and sell them at the price $P_t = X_t P_t^w$, where X_t is the markup. Retailers face Calvo frictions in their price setting, i.e. each quarter they are allowed to chose a new price with a fixed probability $1-\theta_\pi$. It is further assumed that the remaining fraction, θ_π, of firms partially index their prices by a fraction ι_π to past inflation. The resulting Phillips curve is:

$$\log \pi_t - \iota_\pi \log \pi_{t-1} = \beta(E_t \log \pi_{t+1} - \iota_\pi \log \pi_t) - \kappa_p \log\left(\frac{X_t}{X}\right) + \log \varepsilon_{\pi,t} \tag{13}$$

where $\kappa_p \equiv (1-\beta\theta_\pi)(1-\theta_\pi)/\theta_\pi$ and log $\varepsilon_{\pi,t}$ is an *i.i.d.* cost-push shock (see e.g. Smets and Wouters (2007)).

Analogously to prices, nominal wages are sticky. The resulting four wage equations, one for each sector-household pair, are documented in the Appendix.

2.3 Monetary, fiscal and macroprudential policy

Monetary policy is constrained by the zero lower bound and follows the following Taylor rule

$$R_t = \max\left\{0, \hat{R}_t\right\} \tag{14}$$

with

$$\hat{R}_t = R_{t-1}^{\rho_R}\left(\pi_t^{r_\pi} Y_{GAP,t}^{r_Y} \Delta Y_t^{r_{\Delta Y}} \bar{r}\right)^{(1-\rho_R)} \exp\left(\varepsilon_{r,t}\right) \tag{15}$$

where $\hat{R}_t$ denotes the notional (shadow) interest rate, $\varepsilon_{r,t}$ is an i.i.d. monetary shock, Y_t^{GAP} measures the deviation of output from its flex-price-wage correspondent and $\bar{r}$ the steady state value for the real rate. As standard in this class of models in the absence of corrective subsidies, the steady state is inefficient in the flex price-wage equilibrium due to the distortions in the product and labor market. Nevertheless, the presence of the output gap in eq. (15) implies that monetary policy will recognize any policy change (e.g. macroprudential policy) that has an effect on potential output.

The government balances its budget period-by-period by financing the interest rate deductions with lump-sum taxes paid by impatient households

$$T_t = \tau_t r_{t-1}^M \frac{D_{t-1}}{P_t}$$

2.4 Market clearing

Market clearing for goods implies:

$$c_{Pt} + c_{It} + i_{ct}/A_{kt} + i_{ht} + k_{bt} = Y_t$$

Similarly, for houses:

$$h_{Pt} + h_{It} - (1 - \delta_h)(h_{Pt-1} + h_{It-1}) = IH_t$$

3 Long-run drivers of higher household indebtedness

In this section, we characterize the calibration of the model and motivate our choice of drivers behind the observed increased indebtedness over time. We also present the long-run impact of various MPP tools.

3.1 Calibration

What accounts for the large increase in household indebtedness that occurred from the 1990's to the 2010's, a doubling of the aggregate LTI in the case of Sweden? Figure 1 shows how real mortgage rates have fallen in recent decades in many economies. Del Negro et al. (2018), among others, argue that this low real rate represents a persistent new regime. Following this evidence, we assume a real interest rate in the 2010's 250bp lower than in the 1990's to be a key driver. In the model, such a fall in the real interest rate accounts for the main chunk of the indebtedness increase in the data. Motivated by the evidence in Figure 2, we additionally assume a higher maximum LTV. More specifically, we let the LTV increase by 10 percentage points, as in the data. Figure 3 shows the LTI and LTV distributions of new loans in Sweden 2015-2017. It indicates extreme bunching at 85% LTV while no analogous bunching is visible in the LTI dimension. We therefore choose the LTV constrained economy as our benchmark. However, the fall in the real rate and the increase in the LTV does not cause average indebtedness to rise quite as much as in the data. In line with anecdotal evidence we therefore let an increase in home equity withdrawal (HEW) as a fraction of available home equity soak up the residual in the doubling in indebtedness. This implies increasing the HEW share from 1.5% to 2.1% from the 1990's to the 2010's. Both these numbers are in the neighborhood of the empirical evidence for the US, 1.7%, reported by Greenspan and Kennedy (2007). Home equity withdrawal appear similar between U.S. and Sweden in terms of frequency and amounts according to Li and Zhang (2017).

Finally, we allow for a lower inflation rate in the current decade by lowering the steady inflation in the calibration of the 2010's.

Table 1 reports the parameters mentioned above that differ between the two regimes, while Table 2 reports the calibration of parameters that are unchanged between regimes.

[TABLE 1 HERE]

The calibration of the parameters that apply to both regimes is as follows. First, parameters affecting mainly the steady state, e.g. markups, factor shares and depreciation rates, are set to conventional values in the literature.

Second, parameters that affect only the dynamics are set to the estimated values in Iacoviello and Neri (2010) except investment adjustment cost estimates that we take from Walentin (2014), as no such parameters exist in Iacoviello and Neri (2010). There are some additional exceptions that we now describe. Motivated by the bulk of the empirical literature (see e.g. Christiano et al. (2005) and Smets and Wouters (2007)), we use higher consumption habit parameters (0.7) than estimated by Iacoviello and Neri (2010) (0.32 and 0.58) to ensure a more conventional monetary policy transmission mechanism. A voluminous literature have also documented lower sensitivity of prices to product and labor market changes observed since the onset of the financial crisis (see e.g. Del Negro et al. (2015) and Lindé et al. (2016)). We therefore consider a higher degree of stickiness in prices compared to Iacoviello and Neri. Since we want to consider a policy rule which recognizes changes to potential output, we include the model consistent output gap in the policy rule. We set its parameter to 0.25, consistent with the view that the output gap carries a large weight in a liquidity trap. Such a weight also often approximates optimal policy well in New Keynesian model environments, see e.g. the seminal work by Erceg et al. (2000) and the recent paper by Debortoli et al. (2018). We also use a stronger response of the policy rate to inflation than Iacoviello and Neri (2010). Finally, we set the share of savers, α, to two thirds, 0.67. This value is slightly higher than the prior used by Iacoviello and Neri, but below their posterior median (0.79). Our slightly larger share of borrowers, $(1-\alpha)$, than estimated by Iacoviello and Neri is inspired by the recent literature on wealthy hand-to-mouth consumers (see e.g. Kaplan et al. (2018)) and our desire to have a total debt to income ratio in line with the data. Our choice of α will still imply that the model underestimates the total debt to income ratio relative to the data (too many savers without any debt relative to constrained borrowers in the model), but the tension is somewhat moderated.

Third, we set the parameters related to the behavior of borrowers and savers as follows. The speed of amortization parameter is set to yield 46 years of amortization to be in line with Riksbank calculations on the aggregate amortization rate in recent years for Sweden[9] and the average interest rate fixation period is set to 1 year to match the average for Swedish mortgages. The steady state weight on housing in the utility function for patients, j_P, is set jointly with the corresponding weight for impatient households, j_I, to yield residential investment of 3% of GDP (4% of private sector absorption)[10] and to match LTI of borrowers of 433/2% in the 1990's. The target for LTI is based on the loan size-weighted LTI for new mortgage loans computed using data from Finansinpektionen (FI), i.e. the Swedish FSA, which amounts to 433% on average for 2015-2017, when the low level of the interest rate had

[9] Source: Sveriges Riksbank own calculation on Finansinpektionen data (FI mortgage survey) .

[10] The model has no government consumption, so before presenting any ratio involving GDP we adjust for this by multiplying by private sector absorption/GDP=3/4, i.e. accounting for a government consumption of 25%.

been established and aggregate LTI had doubled compared to the 1990's.[11]

Fourth, let us explain the parameters related to housing transactions and home equity withdrawal. The housing transaction cost parameter ϕ_h is set to match the peak non-housing consumption response to a monetary policy shock for the 1990's version of our model. The target is taken from Cloyne et al. (2018). Specifically, it is the average of the U.S. and U.K. peak response for non-durable consumption of borrowers, i.e. a 0.33% response to a 25 bp monetary policy shock (their Figures 7 and 8; our Figure 7).

Finally, we have chosen to work with a calibration without trend growth. The reason is that with infinitely lived households in models like ours that abstract from idiosyncratic risk and occasionally binding borrowing constraints for households, the only way to have i) bounded expected utility of households and ii) a real interest rate below the rate of growth of the economy is to let $\beta > 1$.We find this unappealing and prefer a setting without trend growth. It is beyond the scope of this paper to relax the simplifying assumptions mentioned above.

[TABLE 2 HERE]

3.2 Increased household indebtedness and its effects

Table 3 documents the steady state implications of the long-term increase in household indebtedness that occurred between the 1990's and the 2010's. Recall the three main drivers of this in our LTV constrained economy, as documented in Table 1: a fall in the real rate, an increase in the LTV ratio and an increase of the HEW share. Jointly, these three changes double the LTI of borrowers, from 217% to 433%.[12]

The computation of the LTI and DSTI constrained economies in the 1990's and the 2010's is more mechanic; we simply calibrate the LTI (DSTI) ratio parameter, θ_t^{LTI}, (θ_t^{DSTI}) to get the same LTI of borrowers as in the LTV constrained economy, while accounting for the

[11] Source: FI mortgage survey 2017

[12] Our comparison of the 1990's and the 2010's also captures the effects of the decrease in the inflation rate, but because of (nominal) MID this goes the opposite way - the decrease in the inflation rate reduces the incentive to take on debt, although only marginally.

change in the real rate and the change in the inflation rate. Our aim with this is to keep the LTI, DSTI and LTV constrained economies comparable.

Let us now comment on the long-term implications for the economy documented in Table 3. Comparing the 2010's to the 1990's, first, DSTI ratios of borrowers increase substantially less than the increase in debt (and LTI) while the pure interest payment over income (not including amortization) actually decrease slightly. The latter follows from the fall in the real interest rate in a setting, such as ours, where household preferences over housing and non-housing consumption is Cobb-Douglas (implying that in the long-run a fixed share of expenditures are allocated to housing) when there is also non-financial component in the user cost of housing, i.e. housing depreciation. We also note that the lower real rate has increased the share of GDP accounted for by both non-residential and residential investment. The increase in the latter is much stronger as the share almost doubles between the 1990's and the 2010's. As a result, in the 2010's the economy is much more exposed to fluctuations in housing markets.

Third, the doubling in the LTI ratio between 1990's and 2010's imply an increase in real house prices of more than a third.

[TABLE 3 HERE]

3.3 Long-term effects of MPP instruments

We now characterize the long-term effects of four debt-reducing policies: a tightening of the LTV constraint, a tightening of the LTI constraint, a tightening of the DSTI constraint and a MID removal from a starting point of 30%. Table 4 reports the results. The changes in LTV, LTI and DSTI parameters are calibrated to imply the same decline in the aggregate LTI in the long-run as obtained when removing MID in the high-debt, LTV-constrained economy, i.e. by 10.2%. This scaling is done separately for the low indebtedness and the high indebtedness regime. In the low indebtedness regime the LTV ratio is reduced from 0.75 to 0.65 and in the high indebtedness regime it is reduced from 0.85 to 0.77.[13].

[13] In the low debt environment, mortgage deductability is not completely removed, but instead reduced to 6.35%, thereby obaining a 10.2% reduction in aggregate LTI.

[TABLE 4 HERE]

The aggregate steady state effects of any of these four policies on output and consumption are almost negligible. Nevertheless, output falls in response to all debt-reducing policies under consideration even if the mechanisms behind these contractions is different. When a collateral constraint is binding (LTV and MID cases), reducing debt capacity has a small, positive effect on borrowers consumption. Housing investments and house prices strongly contract. The strong housing decrease of borrowers in response to a tighter LTV constraint is a result of the decreased usefulness of housing as collateral. In the case of removal of MID, debt-financed housing effectively (after tax) becomes more expensive and borrowers accordingly reduce their housing stock. In the long-run, borrowers instead devote a higher share of their income to non-housing consumption. The resulting fall in their marginal value of wealth induces borrowers to work less, thereby causing the observed contraction in output. On the contrary, when debt is tied to labor income, the fall in house prices and housing investment is more muted. In the high-debt economy, borrowers will reduce also their non-housing consumption in response to this debt-reducing policy. Nevertheless, their labor supply still decreases as work looses part of its "collateral" value. Specifically, when households are allowed to borrow a fraction of their labor income, the borrowing limit has a direct, positive, impact on their labor supply as impatient households work more to be able to borrow.[14] Note that the long-term aggregate effects on the economy of the debt reducing policies are roughly invariant, in percentage terms, to the debt level.

Finally, we note that LTI and DSTI tightening have nearly identical effects on all variables of study in the long run. This makes sense given our approach as for a given steady state LTI, the only difference between these two constraints is that DSTI takes into account the time-variation in the nominal interest rate.

[14] By inspecting their labor optimality condition

$$-u^I_{nc,t} = u^I_{c,t}\frac{w^I_{c,t}}{X^I_{wc,t}} + \lambda^{dti}_t m^{dti}_t w^I_{c,t}$$

it is clear that the debt limit, m^{dti}_t, has a direct effect on labor supply.

4 Short-run effects of LTV tightening

In this section, we explain how we generated a baseline in which the economy is driven to the zero lower bound (ZLB) and report the short-run effects of tightening of the LTV ratio. We compare the implied macroeconomic effects in a low vs. and high debt economy. The key finding is that the effects on the aggregate economy of a macroprudential tightening are substantially amplified in the high debt economy.

4.1 Simulations set-up

In what follows, we assume that the economy is driven to the ZLB by a mix of adverse shocks which lowers inflation below the central bank's targeted rate and drives down output below its potential level. By working in a linearized setting, we do not need to specify which particular shock have driven the economy to the ZLB.. The only thing that matters is the path of the notional, or shadow rate $\hat{R}_t$ in eq. (15), as the path of this variable determines the expected duration of the ZLB.[15] For simplicity, we assume that the macroprudential policy actions do not change the duration of the liquidity trap. Specifically in all scenarios, the economy is in a liquidity trap that is expected to last two years.

We implement the short-run experiments for debt reduction in the following way. The change in the LTV, LTI and DSTI parameters is modelled as an AR(1) with a coefficient arbitrarily close to unity. Noting that the LTV/LTI/DSTI constraint only applies to new mortgage loans while mortgage deductibility pertains to the entire stock of outstanding loans, we use an AR(2) for the latter to obtain a gradual reduction of MID and thereby achieve a similar time path for household debt. In particular, deductibility follows the following process with $\rho_{\tau,1} = 0.9$ and $\rho_{\tau,2} = 0.0000001$

$$\tau_t = (1 + \rho_{\tau,1} - \rho_{\tau,2})\, \tau_{t-1} - \rho_{\tau,1}\tau_{t-2} + \rho_{\tau,2}\tau + \varepsilon_{\tau,t}.$$

4.2 Tightening of LTV

Figure 4 reports the aggregate responses to a permanent reduction in the LTV ratio when monetary policy is constrained by the ZLB for 8 quarters, for a high and low debt economy,

[15] For proof, see e.g. Erceg and Lindé (2014).

respectively. The message of Figure 4 is twofold: i) The economy's transition in response to an LTV tightening implies large costs in terms of inflation and output when monetary policy is constrained, and ii) these costs are roughly three times as large in the high debt economy. In particular, GDP (inflation) will initially fall by more than 3 (1) percent in the high debt economy in response to an LTV tightening that reduces LTI by 10.2% in the long run. The corresponding numbers for the low debt economy is a 0.8 percent reduction in GDP and a 0.3 percent reduction in inflation.

To understand the drivers behind this large contraction we document the disaggregate effects of the cut in the LTV ratio in Figure 5. The LTV tightening has a direct effect on borrowers' debt capacity and therefore their demand. There is also an indirect contractionary effect on their debt capacity as house prices fall by more than 5 percent on impact (2.6 percent in the low debt economy). We note that all three major components of aggregate demand fall in response to the reduction in LTV. The fall is largest in residential investment, followed by aggregate (non-housing) consumption and non-residential investment.[16] The fall in aggregate consumption is due to the large initial contraction in borrowers consumption. We note that this reduction in borrowers' consumption is four times as large in the high debt regime. Quantitatively, the housing transaction costs are important for this response as they limit how much housing borrowers can sell to savers in the short run. This can be seen in the very gradual reduction of borrowers' housing. An additional reason for the gradual decline of the borrowers housing stock is that the tightened LTV only applies to new loans.

Two main forces are behind our finding that an LTV tightening is three times more contractionary in the high debt economy. First, tightening of LTV requires more monetary accommodation in a high debt economy. To show this, Figure 6 reports the aggregate responses to a permanent cut in the LTV ratio when monetary policy is unconstrained. Note that the appropriate policy rate response is three times as large in the high debt economy.[17].

[16]The strength in the decrease in residential investment might appear extreme. But properly accounting for the volatility of this variable moderates this impression. There are many occasions is the recent history when residential investment has fallen by more than 10 percent within a year, see Figure 1.

[17]We are not describing optimal monetary policy, but simply noting that the Taylor rule used seem appropriate in the sense that it trades off deviations in inflation against deviations in output in response to the LTV tightening.

Second, monetary policy is more potent in a high debt environment. This has the unpleasant implication that a ZLB is a particularly binding constraint in such an environment. To show this, Figure 7 reports the aggregate effects of a hike in the policy rate with 25 basis points for both high and low debt economies with a binding LTV constraint. The figure documents that the inflation response to a monetary shock is only mildly amplified in the high debt regime. Output instead responds much stronger (by roughly 50%) to monetary policy shocks in the high debt regime. The reason that output responds stronger in that regime is the stronger contribution from residential investment as well as borrowers' consumption. The reason that we report the main demand components in terms of GDP contribution is to make responses comparable between indebtedness regimes; as documented in Table 3 both forms of investment constitute a substantially larger share of GDP in the high debt regime.

5 Short run effects of different MPP tools

In this section we show that the effects of different MPP tools can differ substantially in the short run. When the economy is highly exposed to housing markets and monetary policy does not have room for intervention, the macroeconomic costs of an LTI or an DSTI tightening are substantially lower than from an LTV tightening. Figure 8 reports the aggregate responses to a permanent cut in the LTV, LTI or DSTI ratio when monetary policy is constrained by the ZLB for 8 quarters and indebtedness is high. As mentioned previously, the size of the shocks are chosen to have equivalent long-term LTI implications for all tools. As can be seen in Figure 8, the output response is more than twice as strong in the case of a tightening LTV constraint. The reason for the stronger output contraction yielded by a tightening of the LTV constraint is the negative feedback effects that occur through house prices in the presence of an LTV constraint. Figure 9 is useful in understanding these dynamics. Differently from the LTI and DSTI constraints, in an LTV constrained economy a fall in house prices (triggered by e.g. a debt-reducing policy change) reduce the borrowing capacity of households. This reduced borrowing capacity feeds back to borrowers' demand for both housing and non-housing consumption. The result of this is that an LTV tightening results in substantial "over-shooting" in terms of the reduction in all demand components for the first two years of tightened LTV. This mechanism is not new in the literature. It is simply another incarnation of the business cycle amplification outlined by Kiyotaki and Moore (1997) and Iacoviello (2005). It can be easily illustrated in a simplified version of our model where the total amount of houses is fixed, $\bar{H}$, utility is linear and the demand for housing of savers is inelastic $h^P = \bar{h}$.[18] In that world, a collateral constraint would have a direct impact on housing prices

$$q_t \left(1 - \mu_t \theta_t^{LTV}\right) = U_h \left(\bar{H} - \bar{h}\right) + \beta^I q_{t+1}$$

Specifically, given the constant shadow rent, movements in housing prices reflect only the tightness of the constraint through its shadow value, μ and the regulatory MPP limit, θ. An MPP tightening has a direct negative impact on prices which further exacerbates the initial contraction in the debt limit. In contrast, when households are allowed to borrow only a fraction of their labor income, housing prices will be unaffected by macroprudential actions

$$q_t = U_h \left(\bar{H} - \bar{h}\right) + \beta^I q_{t+1}$$

6 Short run effects of an MID removal

In this section we show that if LTV constraints are binding in a liquidity trap, MID removal can entail significant macroeconomic costs even when interest rate are low.

Figures 10 and 11 report the results of these experiments. The MID removal puts downward pressure on house prices as it increases the effective (after tax) user cost of debt-financed housing. The house price fall occurs almost immediately, regardless of how gradually MID is removed because of the forward-looking nature of asset prices. The reason that the macroeconomy contracts strongly is that the fall in house prices reduces borrowing capacity because of the LTV constraint. Quantitatively the macroeconomic contraction is almost as strong as for an LTV tightening.

The main take-away from this section is that MID removal will reduce house prices in the short run and because of the LTV constraint this will result in a substantial macroeconomic contraction.

[18] This last assumption aims at capturing some form of segmentation in housing markets and implies that houses are priced by borrowers.

7 Welfare implications of reducing debt limits

[Remains to be written.]

8 Conclusions

[Remains to be written.]

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Appendix A Further Model Details

In this appendix, we provide a complete description of the model and present the first order conditions.

A.1 First order conditions

This appendix reports all first-order conditions. The superscript prime refers to impatient households.

$$\begin{aligned}
& c_t + \frac{i_{ct}}{a_{k,t}} + \imath_{ht} + q_t h_t + l_t \\
& = w_{ct} n_{ct} + w_{ht} n_{ht} + R_{ct} z_{ct} k_{ct-1} + R_{ht} z_{ht} k_{h,t-1} \\
& + \left(r_{t-1}^M + \kappa\right) \frac{d_{t-1}}{\pi_t} + \mu_l q_t I H_t \\
& + q_t \left(1 - \delta_h\right) h_{t-1} - \frac{\phi_h}{2} \left(\frac{h_t}{h_{t-1}} - 1\right)^2 q_t h_{t-1} \\
& + \left(1 - \frac{1}{X_t}\right) Y_t - a\left(z_{ct}\right) p_t^{kc} \frac{k_{c,t-1}}{a_{k,t}} - a\left(z_{ht}\right) p_t^{kh} k_{ht-1} - T_t
\end{aligned} \tag{A.1}$$

$$Div_t = \left(1 - \frac{1}{X_t}\right) Y_t$$

$$\begin{aligned}
& u_{c,t} q_t \left[1 + \Phi^h \left(\frac{h_t}{h_{t-1}} - 1\right)\right] \\
& = a_{z,t} a_{j,t} j \left[\frac{1 - \epsilon^h}{(1 - \beta \epsilon^h)}\right] \left[\frac{1}{h_t - \epsilon^h h_{t-1}} - \frac{\beta \epsilon^h}{h_{t+1} - \epsilon^h h_t}\right] \\
& + u_{c,t+1} \beta q_{t+1} (1 - \delta) \\
& + \left[\frac{\Phi^h}{2} u_{c,t+1} \beta q_{t+1} \left(\left(\frac{h_{t+1}}{h_t}\right)^2 - 1\right)\right]
\end{aligned} \tag{A.2}$$

$$u_{h,t} = \varsigma_t j_t \left[\frac{1 - \epsilon^h}{(1 - \beta \epsilon^h)}\right] \left[\frac{1}{h_t - \epsilon^h h_{t-1}} - \frac{\beta \epsilon^h}{h_{t+1} - \epsilon^h h_t}\right]$$

$$u_{ct} = \beta u_{ct+1} R_t / \pi_{t+1} \tag{A.3}$$

$$\lambda_t^{dP} + r_t^M \lambda_t^{rP} = \frac{\beta}{\pi_{t+1}} \Big[u_{ct+1}(r_t^M + \kappa) + (1-\kappa) \Big(\lambda_{t+1}^{dP} + \lambda_{t+1}^{rP} [(1-\Phi) r_t^M + \Phi r_{t+1}^F] \Big) \Big] \tag{A.4}$$

$$p_t^{kc} u_{ct} = \beta u_{ct+1} \left[R_{ct+1} z_{ct+1} + p_{t+1}^{kc} \left(1 - \delta_{kc} - \frac{a\left(z_{ct+1}\right)}{a_{k,t+1}} \right) \right] \tag{A.5}$$

$$u_{c,t} = \frac{\beta u_{c,t+1} \left(R_{ht+1} z_{ht+1} + p_{t+1}^{kh} \left\{ 1 - \delta_{kh} - a(z_{ht+1}) \right\} \right)}{p_t^{kh}} \tag{A.6}$$

$$1 = p_t^{kc} a_{k,t} \left[1 - S_{c,t} - S'_{c,t} \frac{\Gamma_{AK} i_{ct}}{i_{ct-1}} \right] + \beta \frac{u_{c,t+1}}{u_{c,t}} p_{t+1}^{kc} a_{k,t} S'_{c,t} \left(\frac{i_{ct+1}}{i_{ct}} \right)^2 \tag{A.7}$$

$$1 = p_t^{kh} \left[1 - S_{h,t} - S'_{h,t} \frac{i_{ht}}{i_{ht-1}} \right] + \beta \frac{u_{c,t+1}}{u_{c,t}} p_{t+1}^{kh} S'_{h,t} \left(\frac{i_{ht+1}}{i_{ht}} \right)^2 \tag{A.8}$$

$$a_t a_{z,t} (n_{c,t}^{1+\xi} + n_{h,t}^{1+\xi})^{\frac{\eta-\xi}{1+\xi}} n_{c,t}^{\xi} = u_{ct} \frac{w_{ct}}{X_{wct}} \tag{A.9}$$

$$a_t a_{z,t} (n_{c,t}^{1+\xi} + n_{h,t}^{1+\xi})^{\frac{\eta-\xi}{1+\xi}} n_{h,t}^{\xi} = u_{ct} \frac{w_{ht}}{X_{wht}} \tag{A.10}$$

$$d_t = \frac{(1-\kappa)}{\pi_t} d_{t-1} + l_t \tag{A.11}$$

$$r_t^M d_t = (1-\Phi)(1-\kappa) d_{t-1} \frac{r_{t-1}^M}{\pi_t} + \left[l_t + \Phi(1-\kappa) \frac{d_{t-1}}{\pi_t} \right] r_t^F \tag{A.12}$$

$$u_{ct} = \lambda_t^{dP} + \lambda_t^{rP} r_t^F \tag{A.13}$$

$$\lambda_t^{rP} = \frac{\beta}{\pi_{t+1}} \Big(u_{ct+1} + (1-\Phi)(1-\kappa) \lambda_{t+1}^{rP} \Big) \tag{A.14}$$

$$transfer'_t = T'_t = \frac{r^M_{t-1}\tau_{t-1}d_{t-1}}{\pi_t} \tag{A.15}$$

$$T_t = 0 \tag{A.16}$$

$$S'_{ct} = \frac{1}{2}\sqrt{S''_c}\left\{\exp\left[\sqrt{S''_c}\left(\frac{i_{ct}}{i_{ct-1}} - 1\right)\right] - \exp\left[-\sqrt{S''_c}\left(\frac{i_{ct}}{i_{ct-1}} - 1\right)\right]\right\}$$

$$S'_{ht} = \frac{1}{2}\sqrt{S''_h}\left\{\exp\left[\sqrt{S''_h}\left(\frac{i_{ht}}{i_{ht-1}} - 1\right)\right] - \exp\left[-\sqrt{S''_h}\left(\frac{i_{ht}}{i_{ht-1}} - 1\right)\right]\right\}$$

$$\begin{aligned} &c'_t + q_t h'_t + [r^M_{t-1} + \kappa]\frac{d_{t-1}}{1\pi_t} + \left[\frac{\Phi^{h'}}{2}\left(\frac{h'_t}{h'_{t-1}} - 1\right)^2 q_t h'_{t-1}\right] \\ &= w'_{c,t}n'_{c,t} + w'_{h,t}n'_{h,t} + q_t(1-\delta_h)\frac{h'_{t-1}}{1} + l_t + \tau_t r^M_{t-1}\frac{d_{t-1}}{1\pi_t} - T'_t \end{aligned} \tag{A.17}$$

$$\begin{aligned} u'_{c,t}q_t\left[1 + \Phi^{h'}\left(\frac{h'_t}{h'_{t-1}} - 1\right)\right] &= a_{z,t}a'_{j,t}(j') \\ &\left[\frac{1-\epsilon^h}{(1-\beta'^h)}\right]\left[\frac{1}{h'_t - \epsilon^h h'_{t-1}} - \frac{\beta'\epsilon^h}{h'_{t+1} - \epsilon^h h'_t}\right] \\ &+ u'_{c,t+1}\beta' q_{t+1}1(1-\delta) \\ &+ \left[\frac{\Phi^{h'}}{2}u'_{c,t+1}\beta' q_{t+1}\left((\frac{h'_{t+1}}{h'_t})^2 - 1\right)\right] \\ &+ \lambda^{ltv}_t m^{ltv}_t q_t - \lambda^{ltv}_{t+1}\beta' q_{t+1}(1-\delta_h)(m^{ltv}_{t+1} - \gamma) \end{aligned} \tag{A.18}$$

$$l_t = m^{ltv}_t q_t[h'_t - (1-\delta_h)h'_{t-1}] + \gamma[q_t(1-\delta_h)h'_{t-1} - (1-\kappa)\frac{d_{t-1}}{\pi_t}] \tag{A.19}$$

$$\begin{aligned} \lambda'^{dp}_t + \lambda'^{rP}_t r^M_t = \frac{\beta'}{\pi_{t+1}}\Big\{ & u'_{c,t+1}(r^M_t(1-\tau_{t+1}) + \kappa) + \lambda^{ltv}_{t+1}\gamma(1-\kappa) + (1-\kappa)\Big[\lambda'^{dp}_{t+1} \\ & + \lambda'^{rP}_{t+1}\Big((1-\Phi)r^M_t + \Phi r^F_{t+1}\Big)\Big]\Big\} \end{aligned} \tag{A.20}$$

$$a_t a_{z,t}(n_{c,t}^{\prime 1+\xi'} + n_{h,t}^{\prime 1+\xi'})^{\frac{\eta-\xi'}{1+\xi'}} n_{c,t}^{\prime \xi'} = u'_{c,t} \frac{w'_{ct}}{X'_{wct}} \tag{A.21}$$

$$a_t a_{z,t}(n_{c,t}^{\prime 1+\xi'} + n_{h,t}^{\prime 1+\xi'})^{\frac{\eta-\xi'}{1+\xi'}} n_{h,t}^{\prime \xi'} = u'_{c,t} \frac{w'_{ht}}{X'_{wht}} \tag{A.22}$$

$$u'_{c,t} - \lambda_t^{ltv} - \lambda_t^{\prime dP} - \lambda_t^{\prime rP} r_t^F = 0 \tag{A.23}$$

$$\lambda_t^{\prime rP} = \frac{\beta'}{\pi_{t+1}} \left(u'_{c,t+1}(1-\tau_{t+1}) + (1-\Phi)(1-\kappa)\lambda_{t+1}^{\prime rP} \right) \tag{A.24}$$

$$Y_t = a_{c,t}^{1-\mu_c} \left(n_{c,t}^{\alpha} n_{c,t}^{\prime 1-\alpha} \right)^{1-\mu_c} \left(z_{c,t} k_{c,t-1} \right)^{\mu_c} \tag{A.25}$$

$$IH_t = \left(a_{h,t}(n_{h,t}^{\alpha} n_{h,t}^{\prime 1-\alpha}) \right)^{1-\mu_h-\mu_b-\mu_l} (z_{h,t} k_{h,t-1})^{\mu_h} (\mu_b q_t IH_t)^{\mu_b} \tag{A.26}$$

$$(1-\mu_c)\alpha \frac{Y_t}{X_t n_{ct}} = w_{ct} \tag{A.27}$$

$$(1-\mu_c)(1-\alpha) \frac{Y_t}{X_t n'_{ct}} = w'_{ct} \tag{A.28}$$

$$(1-\mu_h-\mu_b-\mu_l)\alpha \frac{q_t IH_t}{n_{h,t}} = w_{ht} \tag{A.29}$$

$$(1-\mu_h-\mu_b-\mu_l)(1-\alpha) \frac{q_t IH_t}{n'_{h,t}} = w'_{ht} \tag{A.30}$$

$$\frac{\mu_c}{X_t} \frac{Y_t}{k_{ct-1}} = R_{ct} z_{ct} \tag{A.31}$$

$$\mu_h \frac{q_t IH_t}{k_{ht-1}} = R_{ht} z_{ht} \tag{A.32}$$

$$
\begin{aligned}
log(\pi_t - \pi^*) - \iota_\pi log(\pi_{t-1} - \pi^*) = \beta\Bigg(& log(\pi_{t+1} - \pi^*) - \iota_\pi log(\pi_t - \pi^*)\Bigg) \\
& - \frac{(1-\theta_\pi)(1-\beta\theta_\pi)}{\theta_\pi} log\Bigg(\frac{X_t}{X^{ss}}\Bigg) + log(\epsilon_{p,t}) \qquad \text{(A.33)}
\end{aligned}
$$

$$
\begin{aligned}
R_t = R_{t-1}^{r_R}(\pi_t/\pi^{ss})^{(1-r_R)r_\pi} & \Bigg(\frac{Y_t}{Y_t^{flex}}/\frac{Y_{t-1}}{Y_{t-1}^{flex}}\Bigg)^{(1-r_R)r_Y} \\
& \Bigg(log(\frac{1}{\beta}) + \pi^{ss}\Bigg)^{1-r_R}\frac{\epsilon_{mp,t}}{a_s} \qquad \text{(A.34)}
\end{aligned}
$$

$$
h_t + h'_t = (1-\delta)(h_{t-1}/1) + (1-\delta)(h'_{t-1}/1) + IH_t \qquad \text{(A.35)}
$$

$$
u_{ct} = a_{z,t}\frac{1-\epsilon}{1(1-\beta\epsilon)}\left(\frac{1}{c_t - \epsilon c_{t-1}} - \frac{\beta\epsilon}{c_{t+1} - \epsilon c_t}\right) \qquad \text{(A.36)}
$$

$$
u'_{ct} = a_{z,t}\frac{1-\epsilon'}{1(1-\beta'\epsilon')}\left(\frac{1}{c'_t - \epsilon' c'_{t-1}} - \frac{\beta\epsilon'}{c'_{t+1} - \epsilon' c'_t}\right) \qquad \text{(A.37)}
$$

$$
\begin{aligned}
ln(w_{ct}) = \frac{1}{1+\beta 1} ln(w_{c,t-1}) + (\frac{1}{1+\beta 1})(ln(w_{c,t-1}) + ln\pi_{t+1} - ln\pi^{ss}) \\
- \frac{(1+\beta 1\iota_{wc})}{1+\beta 1}(\pi_t - \pi^{ss}) + \frac{\iota_{wc}}{1+\beta 1}(ln\pi_{t-1} - ln\pi^{ss}) \\
- \frac{\frac{(1-\theta_{wc})(1-\beta 1\theta_{wc})}{\theta_{wc}}}{(1+\beta 1)} ln\frac{X_{wc,t}}{X_w^{ss}} \qquad \text{(A.38)}
\end{aligned}
$$

$$
\begin{aligned}
ln(w'_{ct}) = & \frac{1}{1+\beta'} ln(w'_{c,t-1}) + (\frac{1}{1+\beta'})(ln(w'_{c,t-1}) + ln\pi_{t+1} - ln\pi^{ss}) \\
& - \frac{(1+\beta'\iota_{wc})}{1+\beta'}(\pi_t - \pi^{ss}) + \frac{\iota_{wc}}{1+\beta'}(ln\pi_{t-1} - ln\pi^{ss}) \\
& - \frac{\frac{(1-\theta_{wc})(1-\beta' 1\theta_{wc})}{\theta_{wc}}}{(1+\beta')} ln\frac{X'_{wc,t}}{X_w^{ss}} \qquad \text{(A.39)}
\end{aligned}
$$

$$
\begin{aligned}
ln(w_{ht}) = & \frac{1}{1+\beta} ln(w_{h,t-1}) + (\frac{1}{1+\beta})(ln(w_{h,t-1}) + ln\pi_{t+1} - ln\pi^{ss}) \\
& - \frac{(1+\beta\iota_{wh})}{1+\beta}(\pi_t - \pi^{ss}) + \frac{\iota_{wh}}{1+\beta 1}(ln\pi_{t-1} - ln\pi^{ss}) \\
& - \frac{\frac{(1-\theta_{wh})(1-\beta\theta_{wh})}{\theta_{wh}}}{(1+\beta)} ln\frac{X_{wh,t}}{X_w^{ss}}
\end{aligned} \tag{A.40}
$$

$$
\begin{aligned}
ln(w'_{ht}) = & \frac{1}{1+\beta'} ln(w'_{h,t-1}) + (\frac{1}{1+\beta'})(ln(w'_{h,t-1}) + ln\pi_{t+1} - ln\pi^{ss}) \\
& - \frac{(1+\beta'\iota_{wh})}{1+\beta'}(\pi_t - \pi^{ss}) + \frac{\iota_{wh}}{1+\beta'}(ln\pi_{t-1} - ln\pi^{ss}) \\
& - \frac{\frac{(1-\theta_{wh})(1-\beta'\theta_{wh})}{\theta_{wh}}}{(1+\beta' 1)} ln\frac{X'_{wh,t}}{X_w^{ss}}
\end{aligned} \tag{A.41}
$$

$$
\frac{\frac{R_{ct}}{p_t^{kc}}}{(1/\beta) - (1-\delta_{kc})} = \frac{\zeta_{kc}}{1-\zeta_{kc}} z_{kc,t} + (1 - \frac{\zeta_{kc}}{1-\zeta_{kc}}) \tag{A.42}
$$

$$
\frac{\frac{R_{ht}}{p_t^{kh}}}{(1/\beta) - (1-\delta_{kh})} = \frac{\zeta_{kc}}{1-\zeta_{kc}} z_{kh,t} + (1 - \frac{\zeta_{kc}}{1-\zeta_{kc}}) \tag{A.43}
$$

$$
k_{ct} = (1-\delta_{kc})\, k_{ct-1} + (1 - S_{c,t})\, i_{ct} \tag{A.44}
$$

$$
k_{ht} = (1-\delta_{kh})\, k_{ht-1} + (1 - S_{h,t})\, i_{ht} \tag{A.45}
$$

$$
data - Y_t = c_t + c'_t + k_{ct} - (1-\delta_{kc}) k_{c,t-1} + k_{h,t} - (1-\delta_{kh}) \Bigg(k_{h,t-1} + q_t IH_t \Bigg)
$$

$$
\begin{aligned}
a(z_{ct+1}) = & \left(\frac{1}{\beta} - (1-\delta_{kc}) \right) \\
& - \left(0.5 \frac{\zeta_{kc}}{1-\zeta_{kc}} z_{ct}^2 + (1 - \frac{\zeta_{kc}}{1-\zeta_{kc}}) z_{ct} + (0.5 \frac{\zeta_{kc}}{1-\zeta_{kc}} - 1) \right)
\end{aligned} \tag{A.46}
$$

$$a(z_{ht+1}) = \left(\frac{1}{\beta} - (1-\delta_{kh})\right)$$
$$-\left(0.5\frac{\zeta_{kc}}{1-\zeta_{kc}} z_{kht}^2 + (1 - \frac{\zeta_{kc}}{1-\zeta_{kc}}) z_{kht} + (0.5\frac{\zeta_{kc}}{1-\zeta_{kc}} - 1)\right) \tag{A.47}$$

$$S_{ct} = \frac{1}{2}\left\{ \begin{array}{c} \exp\left[\sqrt{S_c''}\left(\frac{i_{ct}}{i_{ct-1}} - 1\right)\right] \\ + \exp\left[-\sqrt{S_c''}\left(\frac{\Gamma_{AK} i_{ct}}{i_{ct-1}} - 1\right)\right] - 2 \end{array} \right\} \tag{A.48}$$

$$S_{ht} = \frac{1}{2}\left\{ \begin{array}{c} \exp\left[\sqrt{S_h{}''}\left(\frac{1 i_{ht}}{i_{ht-1}} - 1\right)\right] \\ + \exp\left[-\sqrt{S_h{}''}\left(\frac{1 i_{ht}}{i_{ht-1}} - 1\right)\right] - 2 \end{array} \right\} \tag{A.49}$$

A.2 Shocks

The stochastic process for the exogenous shocks in the model are described below. All innovations are denoted by the letter ε, with a subscript specifying the type. The standard deviations of these innovations are denoted by σ with the corresponding subscript. The preference shocks are AR(1) processes:

$$\log z_t = \rho_z \log z_{t-1} + \varepsilon_{z,t}$$
$$\log j_{c,t} = \rho_j \log j_{c,t} + (1-\rho_j) \log j_c + \varepsilon_{j,c,t} \quad , c = \{P, I\}$$
$$\log v_t = \rho_v \log v_{t-1} + \varepsilon_{v,t}$$

Shocks to the LTV, LTI and DSTI requirements, θ, are very persistent AR(1) processes as described in the main text. Interest rate deductibility (τ) follows an AR(2) process also described in the main text. As mentioned above, the cost-push shock, $\varepsilon_{\pi,t}$, and the monetary policy shock, $\varepsilon_{r,t}$, are i.i.d. Technology shocks are described in more detailed in the subsection below.

A.2.1 Technology shocks

We allow for three productivity processes: consumption goods, housing, and non-housing investment-specific productivity. The three processes are:

$$\log a_{ct} = \rho_{AC} \log a_{ct-1} + \varepsilon_{ct}$$

$$\log a_{ht} = \rho_{AH} \log a_{ht-1} + \varepsilon_{ht}$$

$$\log a_{kt} = \rho_{AK} \log a_{kt-1} + \varepsilon_{kt}$$

A.3 Definition of investment adjustment cost function and utilization cost

The investment adjustment costs can be expressed as:

$$F\left(i_t, i_{t-1}\right) = \left(1 - \tilde{S}\left(\frac{i_t}{i_{t-1}}\right)\right) i_t \quad s = \{K, H\}$$

where

$$\tilde{S}\left(x\right) = \frac{1}{2}\left\{\exp\left[\sqrt{S_s''}\left(x - \Gamma_s\right)\right] + \exp\left[-\sqrt{S_s''}\left(x - \Gamma_s\right)\right] - 2\right\} \quad s = \{SK, SH\}$$

The capital utilization cost function is (with the same parameter ζ for both sectors)

$$a(z_{st}) = R_s\left(\frac{1}{2}\frac{\zeta}{1-\zeta}z_{st}^2 + (1 - \frac{\zeta}{1-\zeta})z_{st} + (\frac{1}{2}\frac{\zeta}{1-\zeta} - 1)\right) \quad s = \{c, h\}$$

A.4 Wage equations

The wage equations for each sector-household pair is:

$$\omega_{c,P,t} - \iota_{wc} \log \pi_{t-1} = \beta_P(E_t\omega_{c,P,t+1} - \iota_{wc} \log \pi_t) - \varepsilon_{w,P,c} \log\left(\frac{X_{wct}}{X_{wc}}\right)$$

$$\omega_{c,I,t} - \iota_{wc} \log \pi_{t-1} = \beta_I(E_t\omega_{c,I,t+1} - \iota_{wc} \log \pi_t) - \varepsilon_{w,I,c} \log\left(\frac{X_{wct}}{X_{wc}}\right)$$

$$\omega_{h,P,t} - \iota_{wh} \log \pi_{t-1} = \beta_P(E_t\omega_{h,P,t+1} - \iota_{wh} \log \pi_t) - \varepsilon_{w,P,c} \log\left(\frac{X_{wht}}{X_{wh}}\right)$$

$$\omega_{h,I,t} - \iota_{wh} \log \pi_{t-1} = \beta_I(E_t\omega_{h,I,t+1} - \iota_{wh} \log \pi_t) - \varepsilon_{w,I,c} \log\left(\frac{X_{wht}}{X_{wh}}\right)$$

where ω_{it} denotes log nominal wage inflation, i.e. $\omega_{it} = w_{it} - w_{it-1} + \pi_t$. $\varepsilon_{wc}, \varepsilon_{wh}$ are defined below.

A.5 Definitions of various parameters

$$
\begin{aligned}
\varepsilon_{\pi} &= (1-\theta_{\pi})(1-\beta_P\theta_{\pi})/\theta_{\pi} \\
\varepsilon_{wPc} &= (1-\theta_{wc})(1-\beta_P\theta_{wc})/\theta_{wc} \\
\varepsilon_{wIc} &= (1-\theta_{wc})(1-\beta_I\theta_{wc})/\theta_{wc} \\
\varepsilon_{wPh} &= (1-\theta_{wh})(1-\beta_P\theta_{wh})/\theta_{wh} \\
\varepsilon_{wIh} &= (1-\theta_{wh})(1-\beta_I\theta_{wh})/\theta_{wh}
\end{aligned}
$$

A.6 Additional Results

In this appendix, we present some additional results referred to in the main text. [TBW]

A.7 Tables and Figures

Table 1: Parameters that drive the change in indebtedness.

Parameter	Moment	1990's		2010's	
		Value	Target	Value	Target
β_P	Real rate	0.9925	3%	0.99875	0.5%
$\bar{\pi}$	Inflation rate	0.005	2%	0.00375	1.5%
θ	LTV	0.75	75%	0.85	85%
γ	HEW fraction	0.015	-	0.02095	LTI=433%

Table 2: Calibrated structural parameters.

Description	Symbol	Value
Capital share in the goods production function	μ_c	0.35
Capital share in the housing production function	μ_h	0.10
Land share in the housing production function	μ_l	0.10
Intermediate share in the housing production function	μ_o	0.10
Gross markup in price and wages	X, X_{wh}, X_{wc}	1.15
Housing depreciation	δ_h	0.005
Capital depreciation, non-housing sector	δ_{kc}	0.025
Capital depreciation, housing sector	δ_{kh}	0.03
Taylor rule coefficient on inflation	r_π	2.00
Taylor rule coefficient on output gap	r_{Δ_y}	0.50
Taylor rule coefficient on output	r_y	0.25
Taylor rule smoothing	ρ_R	0.75
Calvo price rigidity	θ_π	0.9200
Calvo wage rigidity, non-housing sector	θ_{wc}	0.7920
Calvo wage rigidity, housing sector	θ_{wh}	0.9118
Price indexation	ι_π	0.6911
Wage indexation, non-housing sector	$\iota_{wc},$	0.08301
Wage indexation, housing sector	ι_{wh}	0.41186
Share of patient hhs	α	0.67
Consumption habit	$\varepsilon_P, \varepsilon_I$	0.70
Capital utilization cost	ζ	0.70
Investment adjustment costs non-housing sector	S''_c	5.316
Investment adjustment costs, housing sector	S''_h	7.485
Inverse Frisch elasticity, patient hhs	η_P	0.5238
Inverse Frisch elasticity, impatient hhs	η_I	0.5060
Sectorial labor mobility, patient hhs	ξ_P	0.6833
Sectorial labor mobility, impatient hhs	ξ_I	0.9654
Amortization rate on hhs loans	κ	0.0075
Share refinancing	Φ	0.3
Housing preference weight, patient hhs	j_P	0.1235
Housing preference weight, impatient hhs	j_I	0.2316
Housing transaction costs	ϕ_h	10

.

Table 3: Long-run equilibrium in low debt vs. high debt economy (in percent)

	1990's			2010's		
	LTV	LTI	DSTI	LTV	LTI	DSTI
LTI borrowers	217	217	217	433	433	433
DSTI (after tax) borrowers	14.2	14.2	14.2	19.1	19.1	19.1
Interest (after tax)/income of borrowers	7.67	7.67	7.66	6.08	6.08	6.07
Non-residential investment /GDP	17.1	17.2	17.2	20.9	20.9	21.0
Residential investment /GDP	3.0	2.6	2.6	5.2	4.4	4.4
House prices (%Δ from 1990's to 2010')				36.5	34.4	34.4

Table 4: State state effects of debt-reducing policies in the two indebtedness regimes (percent change).

	1990's				2010's			
	LTV		LTI	DSTI	LTV		LTI	DSTI
	LTV	MID	LTI	DSTI	LTV	MID	LTI	DSTI
Aggregate LTI	-10.2	-10.2	-10.2	-10.2	-10.2	-10.2	-10.2	-10.2
Output	-0.23	-0.27	-0.34	-0.34	-0.32	-0.37	-0.56	-0.56
Consumption	-0.11	-0.12	-0.33	-0.34	-0.07	-0.08	-0.56	-0.56
Non-residential investment	-0.17	-0.20	-0.34	-0.34	-0.20	-0.24	-0.56	-0.56
Residential investment	-2.72	-3.48	-0.37	-0.37	-3.05	-3.56	-0.58	-0.58
House prices	-1.06	-1.37	-0.04	-0.05	-1.21	-1.41	-0.07	-0.07
DSTI (after tax) of borrowers	-10.2	6.24	-10.2	-10.2	-10.2	2.09	-10.2	-10.2
Interest/income (after tax) of borrowers	-10.2	20.2	-10.2	-10.2	-10.2	28.32	-10.2	-10.2
Consumption of borrowers	1.07	1.20	0.37	0.38	0.98	1.11	-0.33	-0.33
Housing of borrowers	-7.03	-9.21	0.42	0.42	-7.94	-9.30	-0.27	-0.27
Hours worked of borrowers	-1.05	-1.23	-1.31	-1.31	-1.11	-1.27	-1.79	-1.79
Income of borrowers	-0.26	-0.32	-0.34	–0.34	-0.38	-0.44	-0.56	-0.56

Note: In the high debt environment, mortgage interest deductability (MID) is completely removed. In the low debt environment, MID is reduced to 6.35% to obtain the same reduction in LTI.

Figure 1: International Evidence

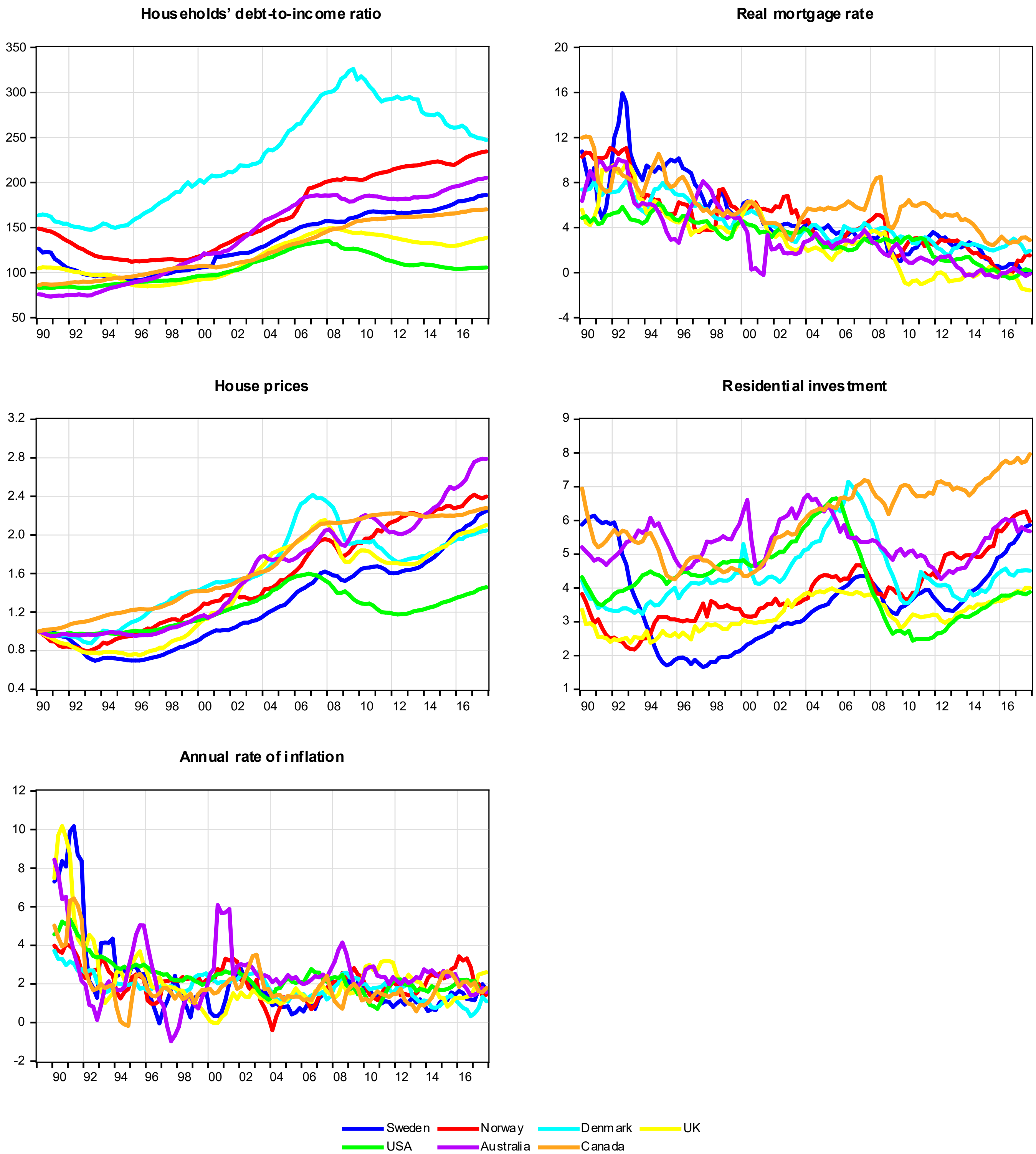

Figure 2: LTV in Sweden

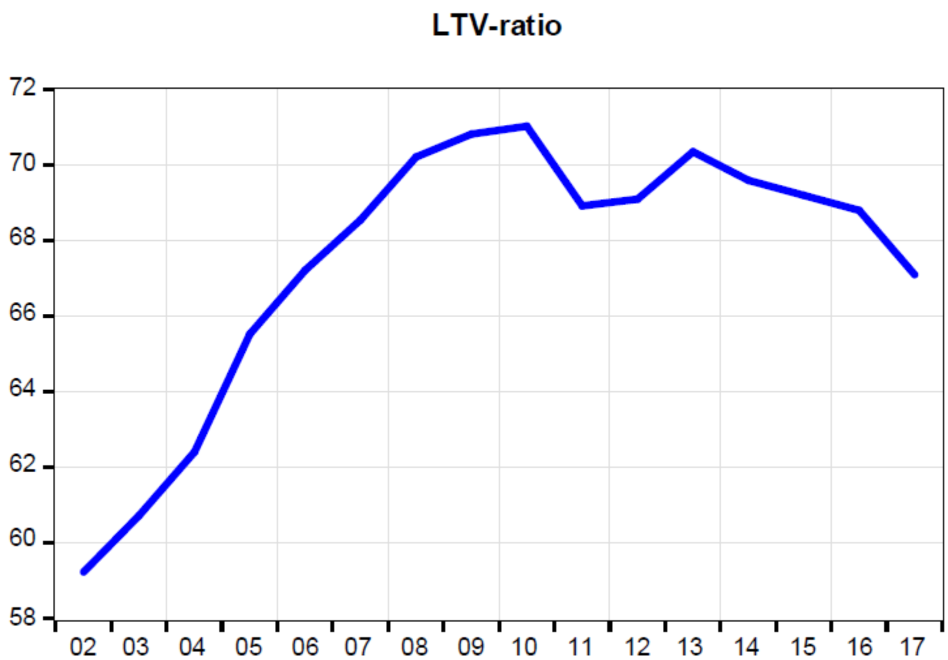

Figure 3: LTI and LTV in Sweden. Source: Swedish FSA Mortgage Survey, average 2015-2017

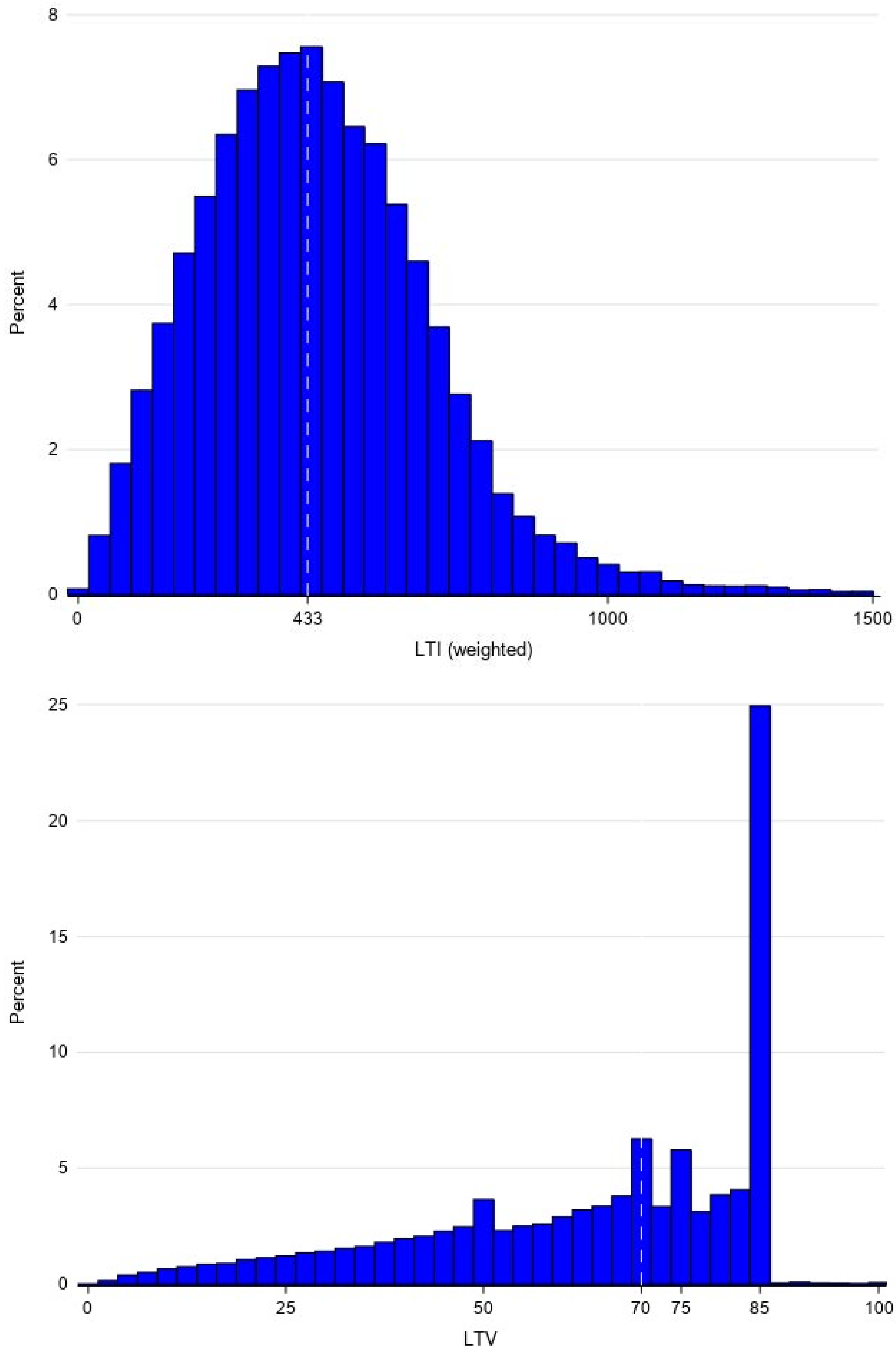

Figure 4: Aggregate Effects of LTV tightening in a liquidity trap under alternative household leverage assumptions

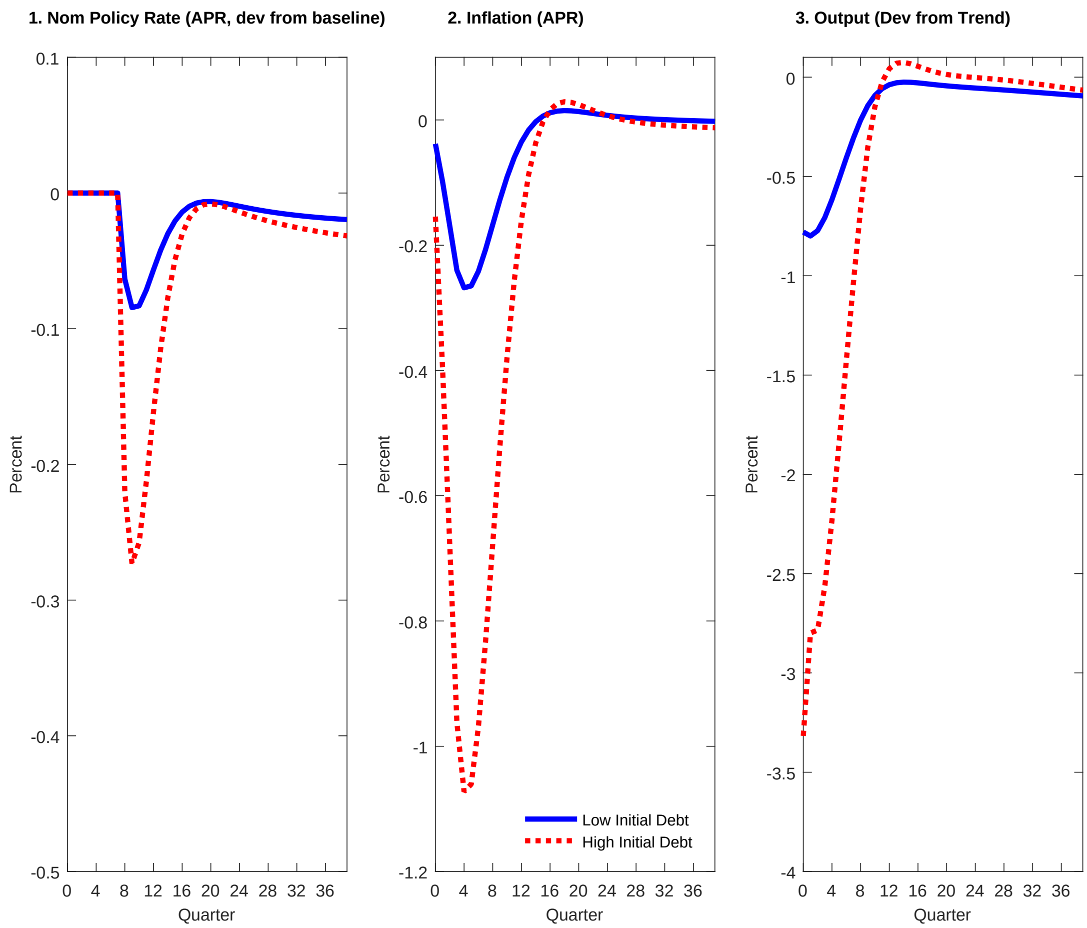

Figure 5: Disaggregate effects of permament LTV tightening in a liquidity trap under alternative household leverage assumptions

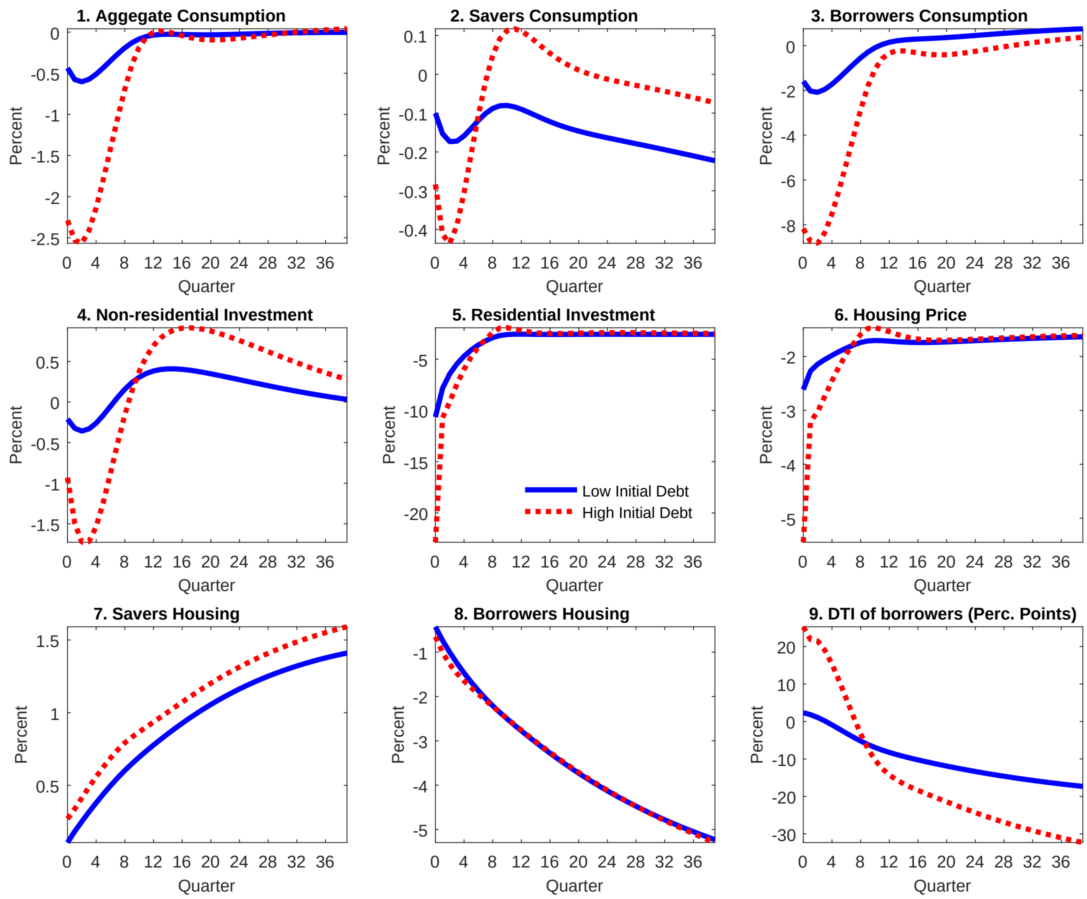

Figure 6: Aggregate effects of LTV tightening under alternative household leverage assumptions when monetary policy is unconstrained

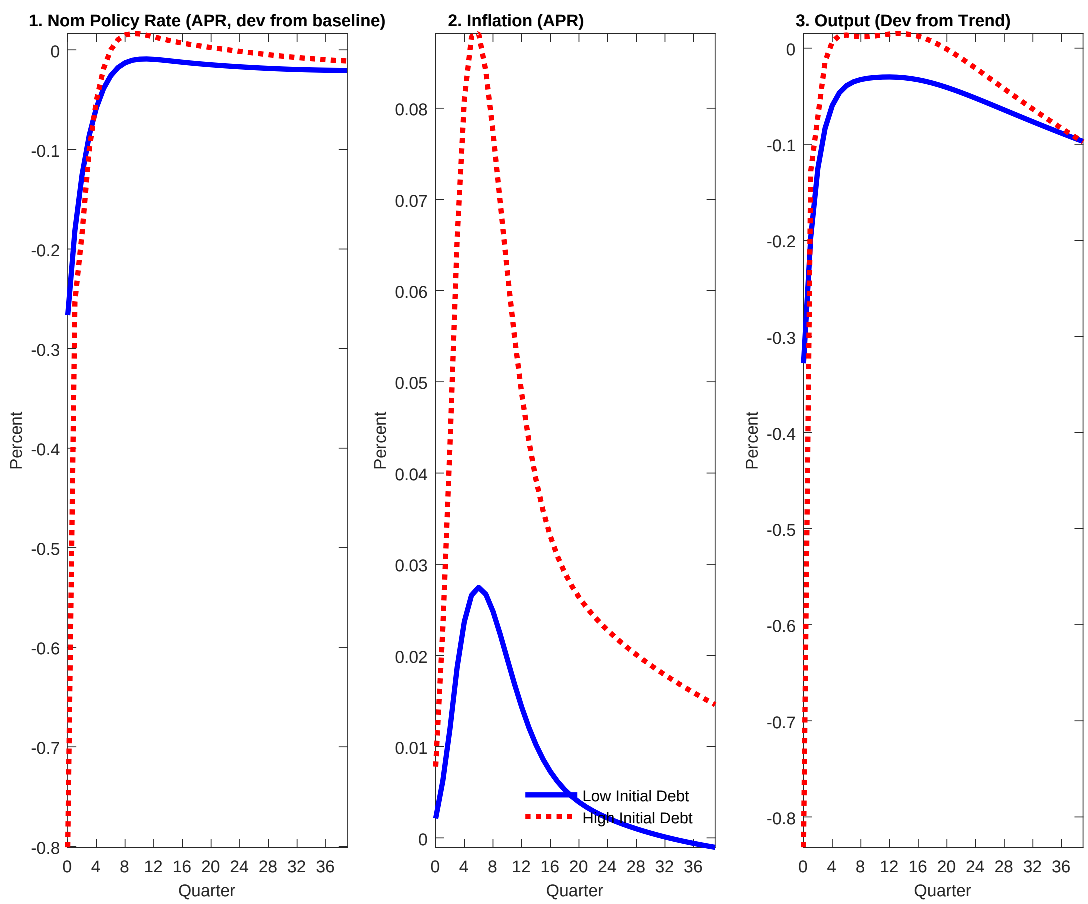

Figure 7: Effects of a contractionary Monetary Policy Shock under alternative household leverage assumptions in the LTV model

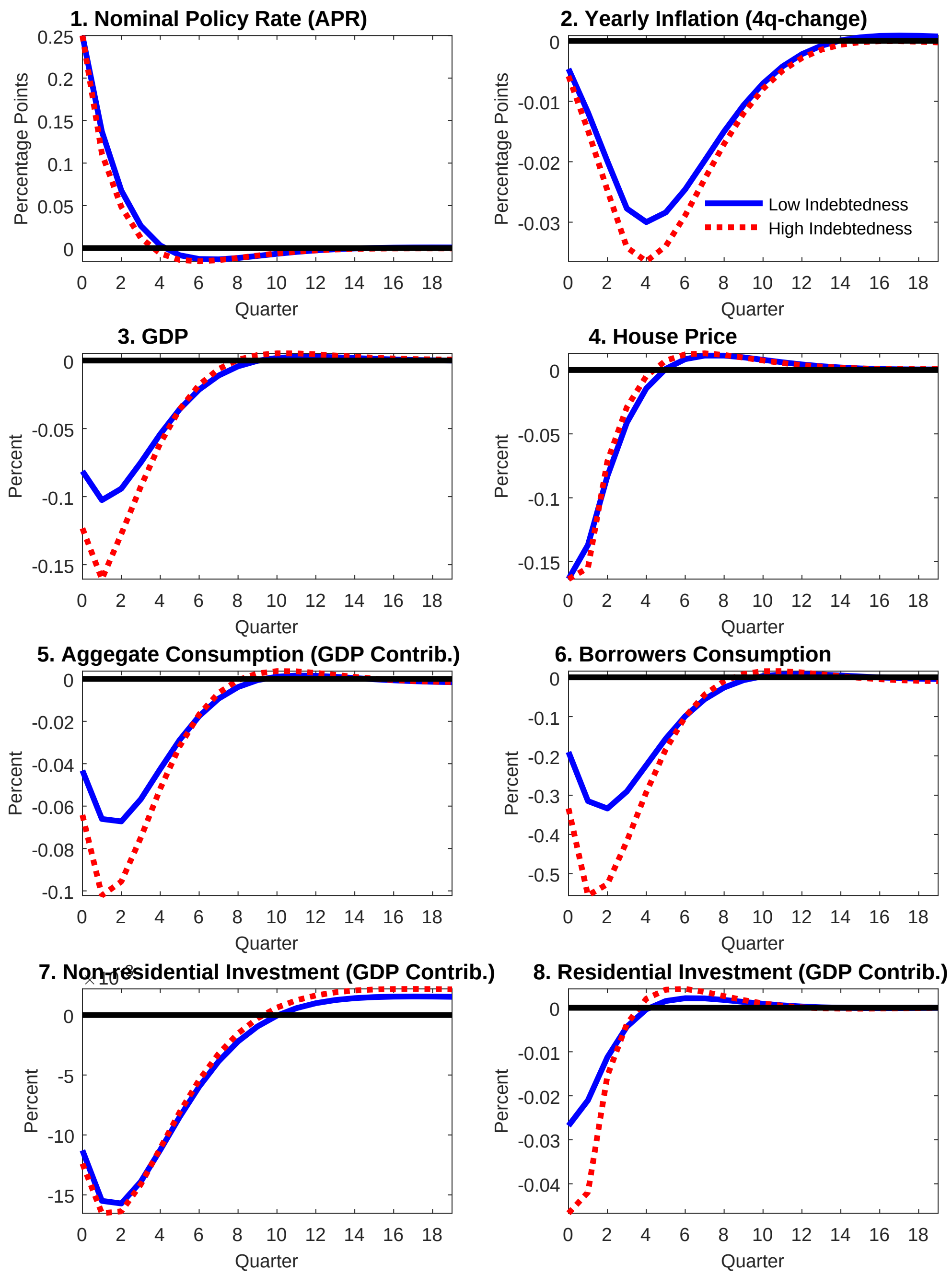

Figure 8: Aggregate Effects of LTV, LTI and DSTI tightening in a liquidity trap under high indebtedness

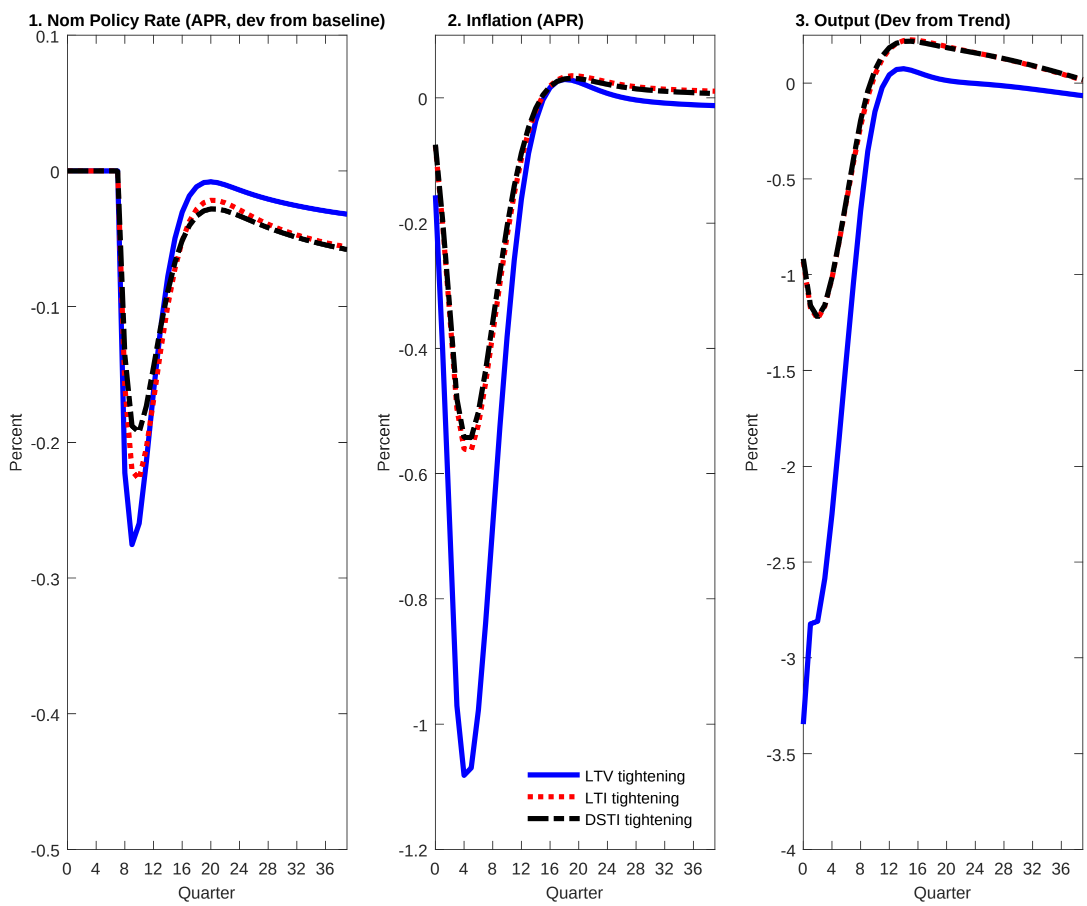

Figure 9: Disaggregate effects of LTV, LTI and DSTI tightening in a liquidity trap under high indebtedness

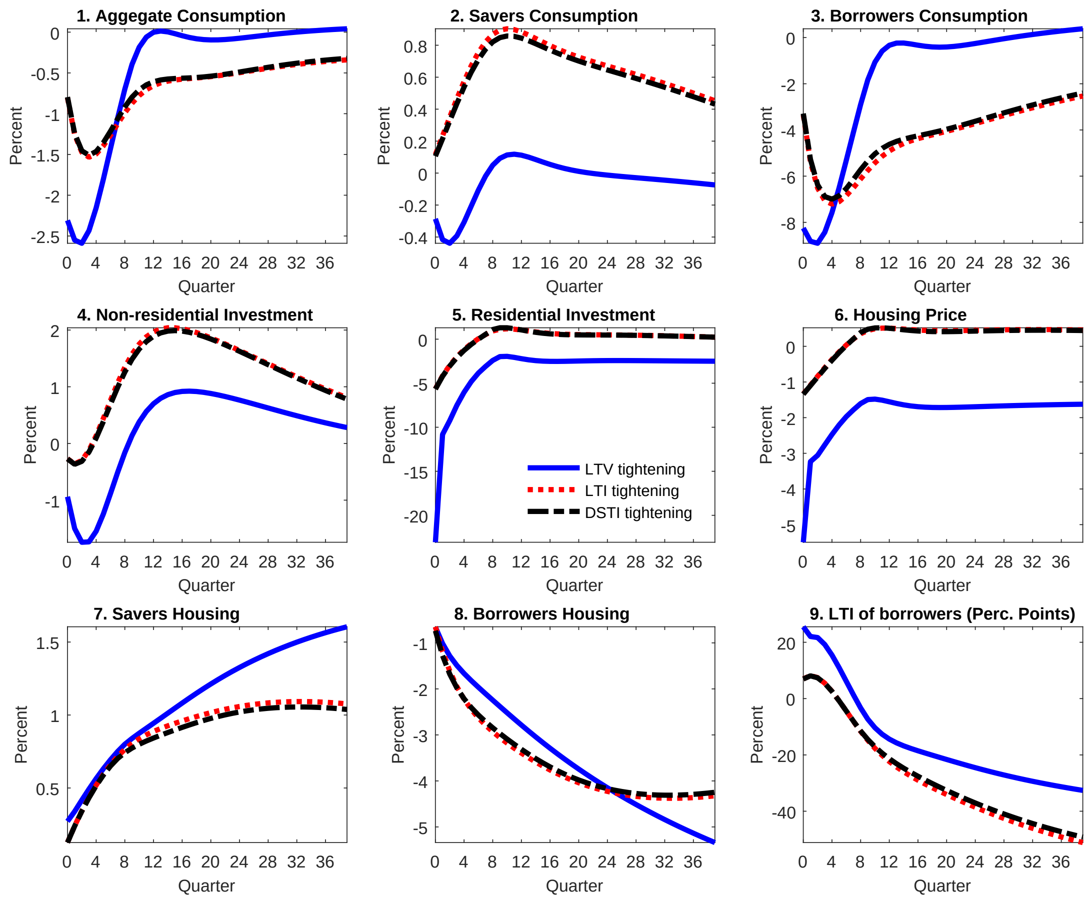

Figure 10: Aggregate Effects of a MID removal in a liquidity trap under high indebtedness

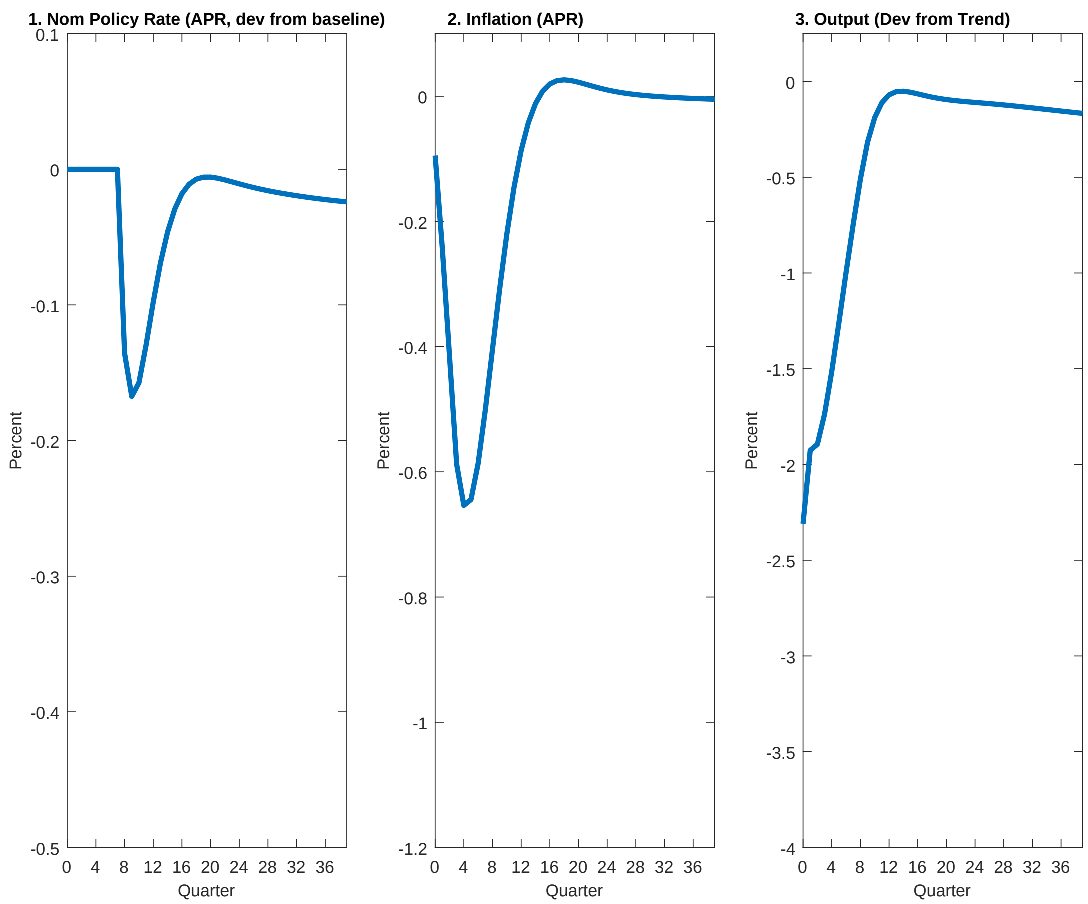

Figure 11: Disaggregate effects of a MID removal in a liquidity trap under high indebtedness