The Aggregate Demand Channel of Loan-to-Value Shocks*

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Premilinary and Incomplete

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Link to Latest Version

Abstract

This paper explores the aggregate and distributional effects of loan-to-value (LTV) tightening using a Heterogeneous-Agent New Keynesian (HANK) model. Households in the model face income risk, housing decisions, and collateral constraints. The tightening of the LTV affects the economy through aggregate demand effects. General equilibrium channels amplify the impact of stricter LTV limits, disproportionately affecting borrowers with high LTV limits. Monetary policy accommodation mitigates these effects, reducing the costs of stricter LTV regulations.

JEL classification: D31, E21, G01, G21.

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Ever since the global financial crisis, understanding the implications of household leverage has attracted considerable interest (see e.g. Mian et al., 2013). Academics and policymakers around the world have advocated for the use of macroprudential measures, such as loan-to-value limits, especially in highly leveraged housing markets (see e.g. Farhi and Werning, 2016; Korinek and Simsek, 2016). Yet, many questions remain unanswered. What are the redistributive effects of restricting households' ability to borrow? What channels are at play? What key factors determine the strength of the transmission?

Addressing these questions is challenging because it requires taking into account both household heterogeneity and general equilibrium effects. Changes in LTV directly impact some households more than others, depending on their financial situation and homeownership status. The direct effects of LTV changes are generally more strongly concentrated at the lower end of the housing market (see e.g. Fuster and Zafar, 2021; Van Bekkum et al., 2024). However, other factors could also influence the response of households to changes in LTVs. House prices (Acharya et al., 2022) and the macroeconomy as a whole (Richter et al., 2019) are also significantly affected by LTV changes, suggesting a role for indirect general equilibrium channels activated by changes in the LTV.

Our contribution to this debate is to offer a general equilibrium approach. We address the above questions using a Heterogeneous-Agent New Keynesian ("HANK") model (see e.g. Kaplan et al., 2018) augmented with a homeownership decision and loan-to-value limits. We show that a LTV tightening triggers substantial aggregate demand effects, with falling house prices and labor income contributing significantly to the decline in aggregate consumption. Moreover, general equilibrium channels exacerbate the unequal burden across households. Aggregate demand effects enable monetary policy accommodation to play a crucial role in limiting the costs of tighter LTV regulation and reducing its uneven burden across households.

In our model, households face uninsurable income risk. They consume non-durable goods and save by investing in liquid bonds. Households also consume housing services either through rental properties or homeownership. They can finance their housing purchase by taking out mortgages that are subject to a loan-to-value constraint. Mortgages are long-term nominal liabilities with minimum periodic amortization payments and variable interest rates. The housing market is segmented and housing is in fixed in supply.

We calibrate the model to match key moments in the Spanish data and then use it as a laboratory to study the effects of a LTV tightening. Our results highlight a number of important insights that deepen our understanding of the aggregate and distributional effects of macroprudential policy.

First, a tightening of the LTV limits affects the economy through aggregate demand effects. The LTV ratio defines the maximum loan size relative to the value of a house, thereby affecting households' borrowing capacity. A persistent reduction in the LTV limit leads to tighter borrowing conditions, which in turn result into a broader economic downturn characterized by a decline in house prices, a reduction in consumption, and a fall in labor income. Monetary policy responds to the fall in inflation by lowering the policy rate. Results are in line with Richter et al. (2019).

Second, general equilibrium effects account for the bulk of the decline in aggregate consumption. Our general equilibrium model enables us to examine the role of both direct and indirect transmission channels. While direct effects are particularly relevant for the impact on mortgages, broader general equilibrium effects further amplify the decline in aggregate consumption, through falling house prices and labor income. General equilibrium channels account for about 60 percent of the fall in aggregate consumption in cumulative terms.

Third, LTV tightening has distributional effects via falling house prices. While the decline in labor income negatively affects all households, falling house prices exacerbate the financial accelerator effects associated with the existence of housing collateral, with negative consequences for borrowers. The fall in house prices is particularly detrimental to homeowners with high LTVs, as it restricts their ability to borrow against their homes, thereby constraining their consumption. In contrast, renters benefit from the fall in house prices.

Overall, a tightening of LTV limits displays heterogeneous effects on households. Those who rent or own their homes with low LTV ratios - i.e. with less debt relative to the value of their homes - are less affected than those with high LTV ratios, who experience the largest welfare losses.

Finally, as a LTV tightening affects the economy through aggregate demand effects, the degree of monetary policy accommodation is a key factor affecting the strength of the transmission to the aggregate economy and the distributional implications. In particular, a stronger policy rate response to inflation limits the financial amplification effect through the house price channel, with distributional implications. Indeed, households with high LTVs benefit most from accommodative monetary policy.

Overall, our results show that monetary policy accommodation plays a key role in reducing the negative impact of stricter LTV regulation. When monetary policy is more accommodative, LTV tightening can be implemented with lower economic costs. However, when monetary policy accommodation is limited, such as by the effective lower bound on interest rates, the economic and welfare costs of tighter LTV regulation can be substantial and more unevenly spread across households. Therefore, our findings suggest that it is crucial for monetary and macroprudential authorities to take these interactions into account when making policy decisions.

Related Literature.

Our paper belongs to the literature that studies the redistributive effects of policies in Heterogeneous-Agent New Keynesian ("HANK") models. While the existing literature has provided important insights into the aggregate and redistributive effects of monetary policy (see e.g. Gornemann et al., 2016; McKay et al., 2016; Kaplan et al., 2018; Auclert, 2019; Auclert et al., 2023; Hedlund et al., 2017), the exploration of the aggregate effects of macroprudential policies and their distributive implications is still scant. A distinguishing feature of our work is the explicit focus on the transmission of shocks to LTV limits in a

HANK model with housing and collateral constraints a la Kiyotaki and Moore (1997).

The focus on monetary policy in this paper complements a number of papers that study the effects of household credit conditions on consumption in heterogeneous agent models that abstract from nominal frictions and monetary policy (see e.g. Garriga and Hedlund, 2020; Guerrieri and Lorenzoni, 2017; Greenwald and Guren, 2021; Kaplan et al., 2020; Castellanos et al., 2024; Favilukis et al., 2017). Our main contribution to this literature is to uncover the role of the aggregate demand effects in shaping the aggregate and redistributive implications of LTV shocks.

Finally, our paper also links to the growing literature on the interaction of monetary and macroprudential policy (Mendicino et al., 2020; Van der Ghote, 2021; Carrillo et al., 2021).[1] In particular, we connect to the papers that study borrower-based macro-prudential policy tools and their interaction with monetary policy (Ferrero et al., 2024; Lambertini et al., 2013; Angelini et al., 2014; Chen et al., 2023). Differently from previous studies, the main focus of our paper is on the distributive implications of LTV changes. We show that monetary policy also affects the distributive effects of changes in LTV limits. Hence, our work also complements previous papers that examine the effects of monetary policy on the housing market in quantitative models of collateral constraints (Iacoviello, 2005; Iacoviello and Neri, 2010).

The paper is organized as follows. Section 1. outlines our model economy and Section 2. details the model calibration. Section 3. presents the transmission of LTV changes to the aggregate economy and disentangles the quantitative importance of the underlying channels. Section 4. examines the distributional effects. Section 5. illustrates the amplifying role of nominal frictions and examines the role of monetary policy in determining the aggregate and distributional effects of LTV changes.

[1]See also Martin et al. (2021) for a review of the literature.

1. Model

We develop a HANK model with housing. Households face idiosyncratic income risk, choose the consumption of both non-durable goods and housing services and can save in liquid bonds. They can consume housing services from either rental or owner-occupied units. When buying a home, they can take up a mortgage subject to a loan-to-value constraint. Mortgages are long-term nominal loans with a minimum amortization payment per period and a variable interest rate. Housing markets are segmented and the housing stock is in fixed supply.

The rest of the model is standard in the HANK literature. Wages are sticky and prices are flexible. The production of non-durable goods is linear in aggregate labor. Total labor supply is chosen by a union to maximize average household welfare. Monetary policy follows a standard Taylor rule. Fiscal policy is neutral.

1.1 Households

1.1.1 Environment

The economy is populated by a continuum of ex-ante identical infinitely lived households, denoted with subscript i.

Preferences: Households derive utility from consuming final goods $c_{i,t}$ and housing services $s_{i,t}$. Their utility function is given by (1), where $x_{i,t} = c_{i,t}^{\gamma} s_{i,t}^{1-\gamma}$ is composite consumption with housing weight $(1-\gamma)$, and σ is the risk aversion parameter.

$$u(c_{it}, s_{it}) = \left(\frac{x_{it} - 1}{1-\sigma}\right)^{1-\sigma} \tag{1}$$

Income: Households face uninsurable idiosyncratic productivity z_{it}. Their individual risk $z_{i,t}$ follows an AR(1) process given by (2), where ρ is the persistence and ε_{it} is a white noise process with variance σ^z. Their net labor income Y_{it} is given by (3) where τ_t is labor income tax rate, and W_t is the aggregate nominal wage.

$$\ln(z_{it}) = \rho \ln(z_{it-1}) + \varepsilon^z_{it}, \qquad \varepsilon^z_{it} \sim \mathbb{N}(0, \sigma^z). \tag{2}$$

$$Y_{it} = (1 - \tau_t) z_{it} n_{it} W_t \tag{3}$$

Liquid Savings: To insure their individual risk, households can save in nominal one-period debt B_{it+1} paying nominal interest rate $1 + i_t$ next period. Households cannot borrow in uncollateralized debt, which implies

$$B_{it+1} \geq 0. \tag{4}$$

Housing: Households can choose whether they want to rent housing services s_{it} at real per unit price f_t, or to own housing $h_{it+1} > 0$, which trades at real price q_t and provides housing services $s_{it} = h_{it+1}$. Homeowners must pay a fraction δ of the value of their current home in maintenance costs and a fraction ζ of the value of the home in transaction costs when moving. In contrast, renting is cost-less to maintain and adjust.

Mortgages: To finance the purchase of a new home, households can request mortgage credit M_{it+1} subject to a collateral constraint

$$M_{it+1} \leq \lambda_t P_t q_t h_{it+1}, \tag{5}$$

where P_t is the aggregate price level, q_t is the real house price, and λ_t is the regulatory loan-to-value (LTV) limit. Mortgage contracts feature variable nominal interest rates $i_{m,t} = i_t$ and have amortization payments given by a fraction χ of the outstanding mortgage balance. Therefore, given time outstanding balance M_{it}, the mortgage payments M^p_{it} are given by (6), and the outstanding mortgage balance evolves according to (7).

$$M_{it}^{p} = (\chi + i_{m,t})M_{it} \tag{6}$$

$$M_{it+1} = (1 - \chi)M_{it} \tag{7}$$

1.2 Household Problem

In this section we cast the formal household problem in real terms. We first introduce some notation. Let the real debt balance $m_{it} = \frac{M_{it}}{P_{t-1}}$ and real liquid savings as $b_{it} = \frac{B_{it}}{P_{t-1}}$. The real interest rate is $1 + r_t = \frac{1+i_t}{1+\pi_t}$. Let $\Omega_{it} = [b_{it}, h_{it}, m_{it}, z_{it}]$ be the individual state vector, where b_{it} is the real holdings of liquid assets, h_{it} is size of the home the household owns, m_{it} is the real mortgage balance, and z_{it} is the idiosyncratic productivity. Since renters own no housing and have no mortgage credit, it follows that $h_{it} = m_{it} = 0$.

1.2.1 Renters

They start the period with liquid assets b_{it} and idiosyncratic productivity z_{it} and make a discrete choice between staying a renter and choosing housing quality $\mathbf{s}_{it} \in \mathcal{H}^r$ or becoming a homeowner and choosing house quality $\mathbf{h}_{it+1} \in \mathcal{H}^o$. Let $j \in \mathcal{J}$ be set of discrete choices. The problem of the renter is given by

$$V_t^r(\Omega_{it}) = \max_j \left[V^{r,r}(\Omega_{it}; \mathbf{s}_{it}), V^{r,o}(\Omega_{it}; \mathbf{h}_{it+1})\right] \tag{8}$$

$$\mathbf{s}_{it} \in \mathcal{H}^r \tag{9}$$

$$\mathbf{h}_{it+1} \in \mathcal{H}^o \tag{10}$$

where V_t^r is the value of starting as a renter at time t, $V_t^{r,r}$ be the value of remaining a renter, and $V_t^{r,o}$ is the value of transitioning to home-ownership. We now outline their problem conditional on each discrete choice.

Stay renter. If the household stays a renter, they must choose consumption c_{it}, rental quality s_{it}, and liquid savings b_{it+1} to maximize

$$V_t^{r,r}(\Omega_{it}; s_{it}) = \max_{c_{it}, b_{it+1}} u(c_{it}, s_{it}) + \beta \mathbb{E} V_{t+1}^r(\Omega_{it+1}) \tag{11}$$

subject to the budget constraint

$$b_{it+1} + c_{it} + f_t s_{it} = \frac{(1+i_t)}{1+\pi_t} b_{it} + (1-\tau_t) y_{it}(z_{it}) \tag{12}$$

which states that the sum of liquid assets returns and gross labor income must equal the sum of non-durable consumption and rental costs.

Purchase home. If the household becomes a homeowner, it must choose a house size h_{it} consumption c_{it}, mortgage debt m_{it+1} and liquid savings b_{it+1} to maximize

$$V_t^{r,o}(\Omega_{it}; h_{it+1}) = \max_{c_{it}, b_{it+1}} u(c_{it}, s_{it}) + \beta \mathbb{E} V_{t+1}^o(\Omega_{it+1}) \tag{13}$$

subject to the following constraints

$$b_{it+1} + c_{it} + h_{it+1} q_t + \zeta q_t h_{it+1} = \frac{1+i_t}{1+\pi_t} b_{it} + (1-\tau_t) y_{it}(z_{it}) + m_{it+1} \tag{14}$$

$$m_{it+1} \leq \lambda_t h_{it+1} q_t \tag{15}$$

$$s_{it} = h_{it+1} \tag{16}$$

Equation (14) is the budget constraint. It states that savings in liquid assets, consumption of non-durable goods, and costs of purchasing a home must equal the sum of the returns from liquid assets, labor income and new mortgage debt. Equation (15) is the LTV which constraints the value of the mortgage to be be a fraction λ_t of the market value of the home. Constraint (16) requires the household to consume the housing services of the home they purchased.

1.2.2 Owners

They enter the period with their liquid assets b_{it}, idiosyncratic productivity z_{it}, the current house quality h_{it}, and outstanding mortgage debt m_{it}. They make the discrete choice between: 1) not adjusting, 2) adjusting into another house quality $\mathbf{h}_{it+1} \in \mathcal{H}^o$ with a new mortgage, 3) refinancing their mortgage for the current home, or 4) becoming a renter and choosing house quality $\mathbf{s}_{it} \in \mathcal{H}^r$. Formally, their problem is

$$V_t^o(\Omega_{it}) = \max_j \left[V^{o,na}(\Omega_{it}), V^{o,a}(\Omega_{it}; \mathbf{h}_{it+1}), V^{o,re}(\Omega_{it}), V^{o,r}(\Omega_{it}; \mathbf{s}_{it})\right] \tag{17}$$

$$\mathbf{s}_{it} \in \mathcal{H}^r, \tag{18}$$

$$\mathbf{h}_{it+1} \in \mathcal{H}^o \tag{19}$$

where V_t^o is the value of starting as an owner at time t, $V_t^{o,na}$ be the value of not adjusting, $V_t^{o,a}$ is the value of purchasing a new home, $V_t^{o,re}$ is the value of refinancing but staying in the same home, and $V_t^{o,r}$ is the value of becoming a renter. We now outline their problem conditional on each discrete choice.

No adjustment. Owners that do not adjust choose non-durable consumption c_{it} and liquid savings b_{it+1} to maximize

$$V_t^{o,na}(\Omega_{it}) = \max_{c_{it}, b_{it+1}} u(c_{it}, s_{it}) + \beta \mathbb{E} V_{t+1}^o(\Omega_{it+1})$$

subject to the following constraints

$$b_{it+1} + c_{it} + \delta h_{it} q_t + \underbrace{\frac{1+i_t}{1+\pi_t} m_{it} - m_{it+1}}_{\text{mortgage payments}} = \frac{1+i_t}{1+\pi_t} b_{it} + (1-\tau_t) y_{it}(z_{it}) \tag{20}$$

$$m_{it+1} = (1-\chi) \frac{m_{it}}{1+\pi_t} \tag{21}$$

$$s_{it} = h_{it+1} = h_{it} \tag{22}$$

Equation (20) is the budget constraint which requires savings in liquid assets, nun-durable consumption, home maintenance costs, and mortgage payments to equal income. Equation (21) is the same as evolution of mortgage balances (7), but expressed in real terms. Constraint (16) states that the household consumes the housing services of the home they own.

Adjust. Owners that adjust their home size, choose non-durable consumption c_{it} the quality of the new home h_{it+1}, their mortgage debt m_{it+1} and savings in liquid assets b_{it+1} to solve

$$V_t^{o,a}(\Omega_{it}; h_{it+1}) = \max_{c_{it}, b_{it+1}, m_{it+1}} u(c_{it}, s_{it}) + \beta \mathbb{E} V_{t+1}^o(\Omega_{it+1}) \tag{23}$$

subject to

$$b_{it+1} + c_{it} + h_{it+1} q_t + \zeta q_t (h_{it} + h_{it+1}) + \frac{1+i_t}{1+\pi_t} m_{it} - m_{it+1} = \frac{1+i_t}{1+\pi_t} b_{it} + (1-\tau_t) y_{it}(z_{it}) + (1-\delta) h_{it} q_t \tag{24}$$

as well as the LTV constraint (15) and the restriction that they live in the house they own (16). The budget constraint (24) is similar to that of renters who opt to purchase. The difference is that home-owners must pay the maintenance and transaction costs and pay back their old mortgage.

Refinance. Owners who refinance without moving homes choose non-durable consumption

c_{it}, mortgage debt m_{it+1} and liquid assets b_{it+1} to solve

$$V_t^{o,re}(\Omega_{it}) = \max_{c_{it}, b_{it+1}, m_{it+1}} u(c_{it}, s_{it}) + \beta \mathbb{E} V_{t+1}^o(\Omega_{it+1}, \varepsilon)$$

subject to

$$b_{it+1} + c_{it} + \underbrace{\phi h_{it} q_t}_{\text{refi. costs}} + \frac{1+i_t}{1+\pi_t} m_{it} - m_{it+1} = \frac{1+i_t}{1+\pi_t} b_{it} + (1-\tau_t) y_{it}(z_{it}).$$

as well as the LTV constraint (15) and the restriction that they do not adjust their homo-ownership or their housing services, given by (16). Their budget constraint is similar to that of owners who do not adjust, with the difference that they must pay refinancing costs to be able to issue a new mortgage.[2]

Become a renter. Owners who choose to become renters choose non-durable consumption c_{it} and savings in liquid assets b_{it} to maximize

$$V_{o,t}^r(\Omega_{it}; s_{it}) = \max_{c_{it}, b_{it+1}} u(c_{it}, s_{it}) + \beta \mathbb{E} V_{t+1}^r(\Omega_{it+1}), \tag{25}$$

subject to the budget constraint

$$b_{it+1} + c_{it} + \frac{1+i_t}{1+\pi_t} m_{it} + f_t s_{it} = \frac{1+i_t}{1+\pi_t} b_{it} + (1-\tau_t) y_{it}(z_{it}) + (1-\delta-\zeta) h_{it} q_t, \tag{26}$$

which states that the sum of liquid savings, non-durable consumption, rental costs and mortgage repayment must equal the sum of returns from liquid savings, labor income and earnings from the home sale.

[2] Since interest rates on debt and liquid assets are the same, and debt is costly to issue, when households adjusts it borrows up to the limit. Therefore, there is no pre-payment in the model and adjusting the mortgage balance is always akin to leveraging up.

1.3 Supply

We keep he supply side of the housing market simple. As in Kaplan et al. (2020) the rental units are owned by the foreign sector. Similarly to Hedlund et al. (2017), rents are fixed over time at price $\bar{f}$. For simplicity, all homes in the economy are of the same size $\bar{h}$. The markets for rental and owner-occupied homes are fully segmented: owner-occupied units cannot be transformed into rental units, and vice-versa.[3] There is a fixed amount of housing in the economy given by $\bar{H}$. Given full segmentation, this implies that the supply of homes available for home-ownership and rental are also fixed at $\bar{H}^o$ and $\bar{H}^r$, respectively.

The total production of the non-durable goods (Y_t) is linear in labor (N_t) and follows

$$Y_t = ZN_t \tag{27}$$

where Z is total factor productivity and is normalized to 1. The aggregate labor supply N_t is determined by unions, whose behavior is outlined in the next section.

1.4 Price-Setting

A union employs all households for an equal number of hours N_t, and sets nominal wages to maximise the welfare of the average household. The full optimization problem outlined in Appendix 1.1, and follows the standard formulation for sticky wages à la Auclert et al. (2018). The solution to the union problem delivers a standard wage Phillips curve

$$\pi_t^w(1+\pi_t^w) = \kappa \left[v'(N_t) - \frac{\epsilon - 1}{\epsilon}(1-\tau_t)\frac{W_t}{P_t}u'(X_t) \right] N_t + \beta \pi_{t+1}^w (1+\pi_{t+1}^w), \tag{28}$$

[3] Based on US micro-data, Greenwald and Guren (2021) find strong segmentation in housing markets. Moreover, they find that the impact of credit conditions on price to rent ratios under the level of segmentation in the data is close to the impact under full segmentation.

where $v'(N_t)$ and $u'(X_t)$ are the average marginal utility of labor and composite consumption, respectively. $u(X_t)$ is defined as in (1) and dis-utility from labor is defined as $v(N_t) = \eta \frac{(N_t)^{1+\varphi}}{1+\varphi}$ with the Frisch-elasticity of labor supply φ and a scalar η for the dis-utility of labor. The parameters ϵ and κ measure the elasticity of substitution over labor varieties and the degree of price-stickiness. π_t^w denotes wage inflation and is given by

$$\pi_t^w = \frac{W_t}{W_{t-1}} - 1. \tag{29}$$

The Phillips curve states that conditional on future wage inflation, unions set higher nominal wages when an average of marginal rates of substitution between hours and consumption for households $v'(N_t)/u'(X_t)$ exceeds a marked-down average of marginal after-tax income from extra hours. We assume that prices of the final good P_t are flexible. Under fixed total factor productivity, flexible prices implies

$$1 + \pi_t^w = 1 + \pi_t = \frac{P_t}{P_{t-1}}, \tag{30}$$

which states that wage inflation π_t^w must equal price inflation π_t.

1.5 Government

Fiscal Authority. The government starts the period with outstanding nominal debt B_t^g and must pay nominal interest rate $(1+i_t)B_t^g$. It spends G_t, borrows B_{t+1}^g and levies proportional income taxes $\tau_t Y_t$. Fiscal policy is neutral: the government keeps the tax rate fixed at $\tau_t = \bar{\tau}$ and adjusts expenditure G_t to keep real debt balances fixed at a level $\bar{b}^g$. The fiscal authority must satisfy the budget constraint (31) and the debt stabilization condition (32).

$$(1 + i_t)B_t^g + G_t = B_{t+1}^g + \tau_t Y_t, \tag{31}$$

$$\frac{B_t^g}{P_{t-1}} = \frac{B_{t+1}^g}{P_t} = \bar{b}^g. \tag{32}$$

Central Bank. The central bank sets the nominal interest rate i_t following the Taylor rule (33), where $\bar{i}$, $\bar{\pi}$ and $\bar{N}$ are the steady state values of nominal interest rates, inflation, and labor supply, respectively. The parameters ϕ^π and ϕ^n control how strongly the central bank responds to inflation and output deviations from the steady state, and ε_t is an exogenous monetary policy shock.

$$i_{t+1} = \bar{i} + \phi^\pi(\pi_{t+1} - \bar{\pi}) + \phi^n(N_t - \bar{N}) + \varepsilon_t. \tag{33}$$

1.6 Market Clearing

The market clearing conditions for housing markets are given by equations (34) and (35). These conditions require the total household demand for owner-occupied housing H_t^o and rental units H_t^r to equal their respective supplies $\bar{H}^o$ and $\bar{H}^r$.

$$\bar{H}^o = H_{t+1}^o \equiv \sum_i h_{i,t+1} \tag{34}$$

$$\bar{H}^r = H_{t+1}^r \equiv \sum_i s_{i,t} - \sum_i h_{i,t+1} \tag{35}$$

The market clearing condition for financial assets is given by (36) and requires the total supply of government bonds B_{t+1}^g to equal the total demand of financial assets by the foreign sector B_{t+1}^* and by domestic households B_{t+1}^d.[4] As stated by equation (37), the total household demand for financial assets B_{t+1}^d equals the demand for liquid assets B_{t+1} net of the demand for mortgage credit M_{t+1}.

$$B_{t+1}^d + B_{t+1}^* = B_{t+1}^g \tag{36}$$

[4] Only a small share of total government debt issued by Spain is owned by domestic households, which will be reflected in our calibration

$$B_{t+1}^{d} = B_{t+1} - M_{t+1} \equiv \sum_{i} B_{it+1} - \sum_{i} M_{it+1} \tag{37}$$

We refer the reader to Appendix 1.2 for a definition of the equilibrium. The household block is solved using the endogenous grid method for discrete choices developed by Iskhakov et al. (2017). We solve for the dynamics using the Sequence-Space methods proposed by Auclert et al. (2021). See Appendix B for details regarding our numerical implementation.

2. Calibration

The steady state of the model is calibrated to the Spanish economy at annual frequency. For household-level statistics we calculate moments from the household survey data in the Luxembourg Wealth and Income Study database for the year 2017.[5] Throughout, we normalize steady state output $Y = 1$, TFP $Z = 1$, house price $p = 1$, and wage inflation $\pi^w = 0$. We set the steady state annual safe interest rate to $\bar{r} = 1.5\%$ in line with 10-year Spanish government bond yields for the period between 2015-2023.

Housing - For the housing market we set the depreciation of housing that has to be maintained by households each period to $\delta = 1.5\%$. We set steady state price-rent ratio to an annual value of 25. The maximum LTV in steady state is $\lambda = 0.8$ corresponding to a down payment of 20%. We assume the housing market to be fully segmented and non-convertible. That means the rental housing stock is not available for owner-occupancy and vice versa. We pick a single house size for home-owner occupied and rental homes to match the average house size of 5.0 times average income in the data.

Government - The tax rate is set to correspond to the average effective tax rate $\tau = 0.23$, and government debt $d^g/y = 0.99$ is taken from Eurostat for 2018-2019. The balanced bud-

[5] https://www.lisdatacenter.org/

get in (31) implies government consumption of $\bar{g} = 0.22$. Foreign held government debt is set to the residual of government debt and household liquid assets $d^f/y = 0.82$. We do this to account for a realistic level of government debt while maintaining accurate empirical ratios of household assets. This assumption is in line with the empirical ownership of Spanish sovereign debt. To better isolate the monetary policy mechanism, in our baseline the monetary authority does not react to the output gap $\phi^n = 0.0$. This is also consistent with the primary objective of the European Central Bank (ECB). The monetary authority raises rates for positive inflation with a standard stance on inflation of $\phi^\pi = 1.5$. We experiment with other values in our exercise.

Households - On the household side, we use a standard income process with a persistence of $\rho_z = 0.9$ and a standard deviation of the innovation of $\sigma_z = 0.2$. We approximate the income process by a 9-point Markov chain using Tauchen (1986) method. We set the risk aversion $\sigma = 2$ and inverse Frisch elasticity $\varphi = 1$. Disutility of labor is set to $\eta = 0.66$ to obtain a standardized labor supply of $N = 1$. To reduce the internally calibrated parameter space, we set the refinancing cost to the transaction cost of adjusting your house, which we calibrate internally along with the discount factor β and the consumption weight γ to match a number of key moments of the distribution. In particular, we jointly target a homeownership rate of 72%, financial wealth-to-GDP of 0.17, housing wealth-to-GDP of 3.53 and an average howeowners leverage of 23%. Given the four targets, the parameters are overidentified. The calibration yields values of $\beta = 0.956$, $\gamma = 0.80$ and $\zeta = 0.017$. We are able to closely match homeownership at 72%, financial wealth at 0.18% and housing wealth at 3.56. Our model slightly overstates average leverage at 31%.

Phillips Curve - On the union side, we set $\epsilon = 5$ and $\kappa = 0.08$. These two parameters govern the shape of the wage Phillips curve. Both values are in line with the literature on wage Phillips curves in heterogeneous agent model, however, we also experiment with

Table 1: Model Parameters

Parameter	Description	Value	Comment
Preferences			
β	Discount	0.956	Internal
σ	CRRA	2.0	Standard
γ	Housing pref.	0.80	Internal
ψ	Inv. Frisch	1.0	Standard
η	Disutility labor	0.66	Internal
Income			
ρ	Persistence z	0.9	Standard
σ^z	Std. z	0.2	Data
Housing			
ζ	Transaction cost	0.017	Internal
δ	Maint./Deprec.	1.5%	Standard
$\{\underline{h}^r, ..., \bar{h}^r\}$	Rental sizes	{5.0}	Internal
$\{\underline{h}^o, ..., \bar{h}^o\}$	House sizes	{5.0}	Internal
λ	LTV	0.8	Industry Standard
Union			
ϵ	Elast.	5	Standard
κ	Wage stick.	0.08	Standard
Government			
$\bar{d}$	Debt	0.99	Data
$\bar{d}^f$	Debt held by foreign	0.82	Data
$\bar{g}$	Govt Spending	0.22	Data
τ	Tax	0.23	Data
Monetary Policy			
ϕ^π	Stance on inflation	1.5	Standard
ϕ^n	Stance on output	0.00	Standard
Prices			
$\frac{p}{f}$	Price-rent	25	Data
$\bar{r}$	Real rate	1.5%	Internal
$\bar{\pi}$	Inflation	0.0%	Standard
$\bar{i}$	Nominal rate	1.5%	Standard

alternative degrees of wage rigidity.

Table (1) summarizes the parameters and table (2) provides an overview of both targeted and untargeted moments. While the average LTV is slightly overstated, the model slightly understates the right tail with a leverage of 0.67 at the 90th percentile versus 0.77 in the data. Since net-wealth is the sum of financial and housing wealth we are able to come very close with 3.74 to the empirical counterpart of 3.71 given that we target the latter two moments. To assess how well the model does in terms of the right households selecting into homeownership we calculate the ratio of average income by tenure status. We find that homeowners have, on average, a 50% higher income than renters which is remarkably close to the empirical estimate of 45%. This is reassuring as it validates the decomposition of the income channel by tenure group in our analysis.

Table 2: Model Moments

Description	Model	Data (ES 2017)	Internal
Financial Wealth	0.18	0.17	Y
Housing Wealth	3.56	3.53	Y
Ownership	0.72	0.72	Y
LTV (mean)	0.31	0.23	Y
Net-Wealth	3.74	3.71	N
LTV (90p)	0.67	0.77	N
Y^{owner}/Y^{renter}	1.5	1.45	N
Gov't Spending	0.22	0.41	N

Notes: Aggregates & Distribution model moments. Normalized by output where applicable. Data comes from the LWS household survey data for Spain in 2017. Y stands for internally calibrated parameters and N stands for non-targeted moments.

3. Aggregate effects and transmission channels

We examine the impact of a tightening in the LTV on the aggregate economy and its distributional implications. Our analysis focuses on a temporary but persistent change in the LTV, which determines households' ability to borrow against the value of their house. We consider a 10 percentage point decrease in the LTV, that lasts for 10 approximately periods.[6] In this section we examine how the economy responds to the shock at the aggregate level and analyze the transmission channels in detail.

[FIGURES 1 - 3 HERE]

Aggregate dynamics. What are the aggregate effects of limiting households' capacity to borrow? Our results show that overall, a decrease in the LTV regulatory limit leads to

[6] Our experiment is designed as follows: In period t = 0, the economy starts at the deterministic steady state associated with the initial LTV requirement, λ. At period t=1, agents are surprised by an MIT shock to the LTV which follows an AR(1) process with persistence 0.7

an economic downturn. Figure 1 shows the aggregate responses to a persistent decrease in the parameter λ_t, which in the model represents the LTV regulatory limit.

The LTV is the fraction of the home's value that is not covered by the household's down payment when it borrows. A tightening of the LTV limits the ability of households to borrow and thus reduces their ability to buy houses which result in a decline in house prices. Households use their liquid savings to partly compensate for the negative impact of the shock. However, total demand for savings (i.e. liquid savings minus mortgage debt) increase, which requires the real interest rates to fall.

Sticky wages induce unions to reduce their labor supply. As a result, labor income falls. Aggregate consumption falls sharply. In response to the decline in aggregate demand both total output and inflation fall. Monetary policy responds to the fall in inflation by lowering the policy rate. The real interest rate rises on impact, before falling and then slowly recovering.

Transmission Mechanism. What are the transmission channels of a LTV tightening to the real economy? Our model enables us to examine both the direct and indirect effects of the shock. The latter operate through the equilibrium response of prices.

Following Kaplan et al. (2018) we quantify the importance of these different channels by decomposing the general equilibrium responses of key aggregate variables into their partial equilibrium changes due to movements in different prices. Figure 2 reports counterfactual dynamics computed by allowing only one market price at a time to follow its realized general equilibrium path, while keeping all the others at their steady state levels. In particular, we focus on the contribution of labor income, house prices, inflation and the policy rate.

The figure reveals the key role of general equilibrium effects. The direct impact of the exogenous shift in the LTV ratio is captured by the dotted line in yellow. A persistent reduction in the LTV limit directly affects households borrowing conditions, with direct implications for the reduction of mortgage debt. In the absence of other mitigating factors, the direct impact of the LTV limits would imply a very large drop in mortgage debt and, consequently, in housing demand and limited effects on non-durable consumption and liquid savings.

The fall in house prices plays an offsetting role for housing demand and mortgages. This reflects the willingness of some households to take advantage of falling house prices to increase their house purchases, which also mitigate the decline in mortgage credit. In order to meet the higher down payments required in the credit market, households have to reduce their consumption and their liquid savings. The fall in house prices contributes to the decline in consumption and liquid savings.

The real interest rate and labor income are also important determinants of the transmission of the LTV shock to aggregate consumption, with opposite effects. While the fall in labor income contributes to the drop in consumption, the dynamics of the real interest rate have a dampening effect. On the contrary, both channels play a modest role in shaping the response of other variables.

Overall, the general equilibrium channels account for about 80 percent of the decline in aggregate consumption on impact and 60 percent in cumulative terms. Table 3 disentangles the contribution of the different channels. While falling house prices account for most of the impact in the short run, the decline in labor income plays a large role in the cumulative effects.

Table 3: Consumption Changes by Channel

Channel	**Impact**		**Cummulative**	
	(1)	**(2)**	**(3)**	**(4)**
Total	-0.57		-3.61	
LTV	-0.14	20.2	-1.9	43.5
House Price	-0.48	71.3	2.79	-63.9
Income	-0.23	33.9	-5.22	119.4
Real Rate	0.17	-25.4	-0.04	1.0

Note: Consumption change by different channels on impact and cumulative. The first row displays the overall change in consumption. Column 1 and 3 report consumption changes in %, Column 2 and 4 report the relative contributions of each channel. Relative contributions are calculated with respect to the total effects.

Welfare. Finally, we compute the welfare impact of the LTV tightening.[7] To this end, we compare households' expected value functions after the shock hits the economy with their steady state values. Figure 3 reports results in terms of consumption equivalent units, i.e. the consumption households are willing to permanently forego in order to remain in the initial steady state and avoid the consequences of the LTV change.

On average, welfare declines by about 0.15 % in consumption equivalent terms due to the tightening of the LTV limits. The left panel of Figure 3 also depicts the contribution of the direct and indirect channels of transmission. Overall, the welfare losses are mainly due to general equilibrium effects. The income channel turns out to be the largest contributor, as it reduces the resources available for consumption for all households and therefore has a strong impact on welfare.

4. Heterogeneity

[FIGURES 4 - 5 HERE]

Next, we examine the distributive implications of a tightening of the LTV. First, we assess the heterogeneity in the consumption response across three categories of households. We examine the impact of the shock on households that were renters or homeowners prior to the shock. For the latter category, we distinguish between high and low LTV households.[8]

The left panel of Figure 4 displays the consumption responses by these categories. The LTV tightening implies a decline in consumption for all types of households, with the most pronounced effects for high LTV households. Consumption of low LTV households declines

[7] Individual consumption equivalent (CE) measure: $CE_i = \left[100\left(\frac{V_1(\Omega_i)-V^{ss}(\Omega_i)}{V^{ss}(\Omega_i)}+1\right)^{\frac{1}{1-\sigma}}-1\right]$, where Ω_i is the individual state of agent i, V^{ss} is the value function in steady state and V_1 is the value function in the first period of the realization of the shock for renters and owners, respectively

[8] The cut-off for high and low LTV groups is an LTV of 40 %. In the model the distribution of LTVs across households broadly reflects their position in the income distribution, with renters being income poor, high LTV being middle income, and low LTV being the upper income.

less because these are richer and less credit constrained, and can use their liquid savings as a buffer against the shock. Consumption of renters falls slightly more than aggregate consumption but less than high LTV households as they delay their decision to buy a house.

Importantly, the LTV tightening does not affect all households in the same way. Figure 5 shows the direct effect of the LTV shift on consumption by household type. This is negative for the consumption of homeowners, with a stronger cumulative effect for high LTV households than for low LTV households (-3.25 % and -0.14%, respectively). Households in our model own houses for precautionary reasons, in order to self-insure against idiosyncratic risk by refinancing their mortgages (see e.g. Guerrieri et al., 2020). The LTV tightening reduces their ability to refinance their mortgages. In contrast, the renters' consumption increases as the result of the direct impact of the LTV shock as it makes it more difficult for them to buy houses. As a result, they postpone their homeownership decision and increase their current consumption. The heterogeneous response of consumption to the direct shift in LTV explains the limited reaction of aggregate consumption to the direct effect of the shock. This heterogeneity suggests that the share of renters in the economy helps to shape the aggregate demand effects of tighter LTV.

Overall, the endogenous response of the economy amplifies the negative effects of LTV changes on homeowners and more than offsets the increase in the consumption by renters due to the direct effect of the LTV shift.[9]

Welfare. The heterogeneity in consumption responses is also reflected in the welfare effects of the LTV tightening shown in the right panel of the same figure. As expected, low LTV households are the least affected by the shock. High LTV households instead experience the largest welfare losses, of about 0.25 % in consumption equivalent terms. Renters also lose from a LTV tightening, with effects close to the average effects in the economy.

Why are high LTV households more affected by LTV tightening than renters? To gain some insight, we examine the importance of different transmission channels for different

[9]See also Appendix Figure A.1.

groups of households.

Heterogeneity in the welfare effects of the direct impact of the LTV shift are small relative to the overall welfare differences across households. Figure 5 shows that the direct effect of the LTV is only slightly stronger for high LTV households than for renters. Instead, the general equilibrium channels affect the two types of households in heterogeneous ways.

The welfare losses for renters are mainly driven by the fall in labor income, while the fall in house prices acts as a mitigating factor. Interestingly, the real interest rate redistributes resources from borrowers to savers. Both renters and low LTV households are net savers in our model.

The fall in house prices exacerbates financial accelerator effects, which further limit the ability of homeowners to borrow against their house collateral. This effect is particularly pronounced for households facing high LTVs.[10] On the contrary, ceteris paribus, a decline in house prices favors renters, who can more easily transition into homeownership.

5. Strength of Transmission

What are the factors that influence the strength of the transmission of a LTV tightening? Our results show a LTV tightening affects the economy through aggregate demand effects. We therefore now examine the role of two key drivers of aggregate demand: nominal rigidities and monetary policy.

5.1 Nominal Rigidities

[FIGURES 6 - 7 HERE]

Our results point to the importance of general equilibrium effects, with labor income representing a key transmission channel. We now examine the role of price rigidities. Figure

[10] see Berger et al. (2018) for a discussion on marginal propensities to consume out of housing wealth.

6 compares the aggregate effects of a reduction in the LTV under the baseline degree of wage rigidity ($\kappa = 0.08$) with those under more flexible wages ($\kappa = 0.25$).

Nominal rigidities substantially affect the impact of the LTV tightening on aggregate dynamics. As expected, in a more flexible wage economy, nominal variables respond more strongly, while the response of consumption response is significantly muted. A larger adjustment is in the price of the final consumption goods, which requires a smaller response from labor supply, leading to a stronger reaction of the policy rate. Overall, more flexible prices reduce the cumulative decline in consumption and income by about half, and in house prices by about a quarter. In contrast, mortgage debt and liquid savings do not change significantly.

Overall, the general equilibrium effects of the LTV tightening are much weaker under a lower degree of nominal rigidities, as shown in Figure 7 left panel. This reflects, both the more limited role of the income and house price channels and a stronger offsetting effect coming from the real interest rate channel. As a result, the welfare losses of a reduction in the LTV limit are smaller. However, the distributional effects are qualitatively unchanged. The welfare losses are reduced by half for all types of households compared to the baseline case. [11]

5.2 Monetary Policy

[FIGURES 8 - 10 HERE]

How does monetary policy affect the transmission of tightening of the LTV? As the LTV tightening affects the economy through a standard aggregate demand channel, the strength of the transmission crucially depends on the degree of monetary policy accommodation. Figure 8 compares the aggregate effects of a LTV reduction under the baseline monetary

[11] Appendix Figure A.2 depicts the change in the contribution of the indirect channels to welfare.

policy response ($\phi_\pi = 1.5$) with those under both a stronger ($\phi_\pi = 2$) and a weaker ($\phi_\pi = 1$) monetary policy response.

To gauge the importance of monetary policy in affecting the various transmission channels, Figure 9 decomposes the response of inflation under different assumptions for the degree of policy accommodation. Overall, relative to the baseline, a more aggressive response to inflation dampens the response of consumption to the shock on impact while a less aggressive response amplifies it.[12] As expected, monetary policy affects the aggregate consumption response via the real interest rate channel, which plays a stronger counteracting role when monetary policy is more accommodative. Furthermore, in both cases changes in the degree of accommodation significantly affect the importance of the labor income channel and to a lesser extent also of the house price channel.

The degree of monetary policy accommodation also significantly affects the welfare losses implied by a tightening of the LTV ratio. When monetary policy is more responsive to aggregate dynamics, households experience smaller welfare losses, with significantly larger easing effects for high LTV households. See Figure 7, right panel, which shows that for high LTV househols, the welfare gains from a more accommodative monetary policy are about twice as large compared to those of renters, and three times as large compared to those of low LTV agents.

Why are the losses suffered by high LTV households more severe than those experience by renters? The welfare decomposition reported in Figure 10 helps us to gain insights. Households generally benefit from the more limited reduction in labor income. The more moderate fall in house prices, on the other hand, benefits high LTV households but hurts renters. Decomposing the impact of the policy rate from inflation also highlights a similar redistributive effect coming from the inflation channel. Instead, the policy rate channel is largely broadly unaffected. Overall, in the case of renters, the dampening effect of a more

[12] In cumulative terms, the drop in aggregate consumption is of about -5.18%, -3.65% and -2.63% with $\phi_\pi = 1, 1.5, 2$, respectively.

accommodative monetary policy on house prices and inflation partly offsets the positive effects of the mitigation of labor income effects. Conversely, high LTV households benefit from a more responsive monetary policy via its effect on all indirect channels. These results are consistent with those of a monetary policy easing shock, as shown in Appendix Figures A.3- A.4.

In sum, our results suggest that the degree of monetary policy accommodation is a crucial factor in mitigating the adverse effects of more stringent LTV regulation. When monetary policy is more accomodative, LTVs can be tightened at a more moderate cost to the economy. Conversely, if accommodation is constrained, for instance by an effective lower bound on interest rates, the economic and welfare costs of tighter LTV regulation may be large.

6. Conclusion

This paper examines the effects of a tightening in LTV limits. We focus on its impact on the aggregate economy as well as on its heterogeneous effects across different household types. We show that a persistent decrease in the LTV limits leads to an economic downturn driven by aggregate demand effects which result in a reduction of the policy rate.

Our findings point to the importance of general equilibrium effects in the transmission of LTV changes. While the direct effects of a shift in the LTV are especially important for understanding the impact on mortgages, general equilibrium effects – such as falling house prices and lower labor income – further exacerbate the decline in aggregate consumption.

The welfare impacts of LTV tightening vary according to household type, with high LTV households suffering the most. LTV tightening affects households unevenly, primarily through falling house prices. While declining labor income impacts all households negatively, falling house prices worsen the financial conditions for borrowers, particularly those with high LTV ratios. On the other hand, renters benefit from lower house prices.

Furthermore, the analysis also highlights the role of monetary policy and nominal rigidities. In particular, more accommodative monetary policy helps mitigate some of the negative effects of tighter LTV limits. Ultimately, the aggregate and redistributive effects of stricter LTV policies depend heavily on the stance of monetary policy and household debt levels. High LTV households are particularly vulnerable to this type of shocks, and are thus more sensitive to monetary policy adjustments.

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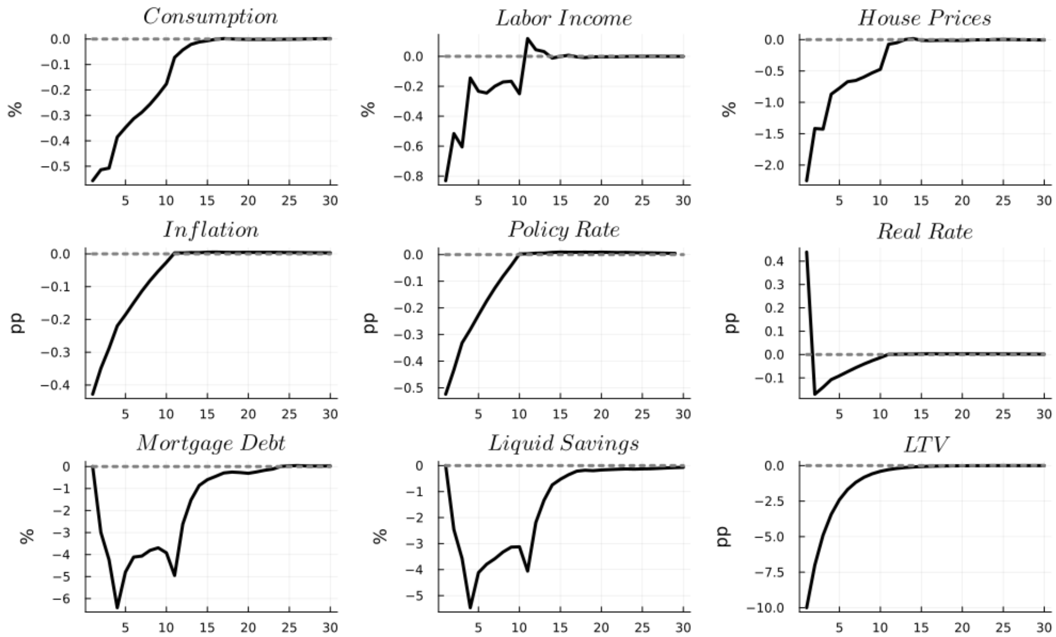
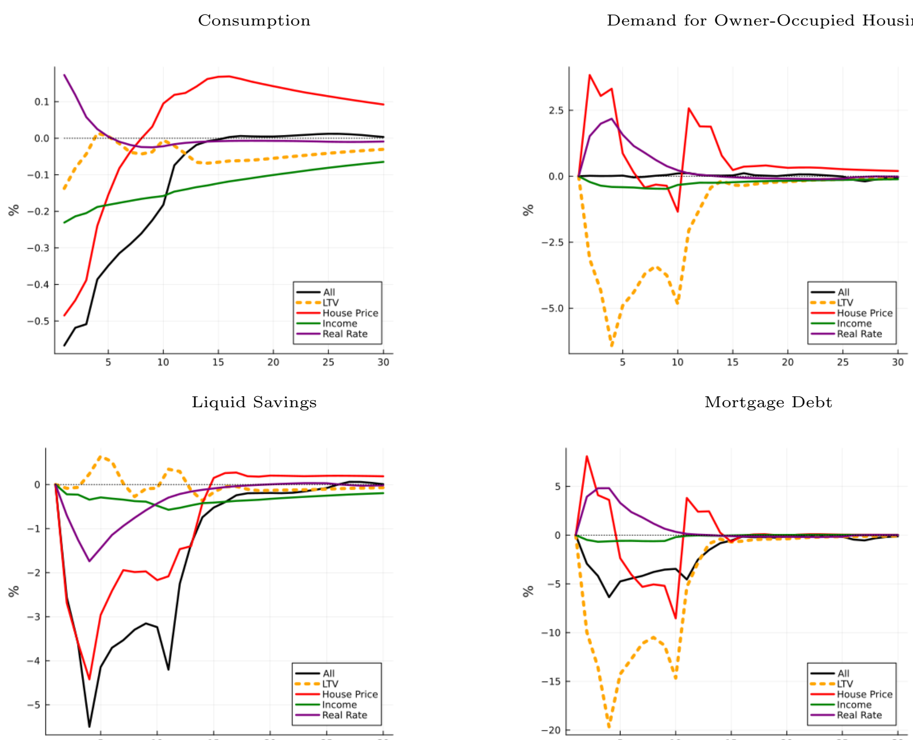
Tables and Figures

Figure 1: LTV Tightening - Aggregate Effects



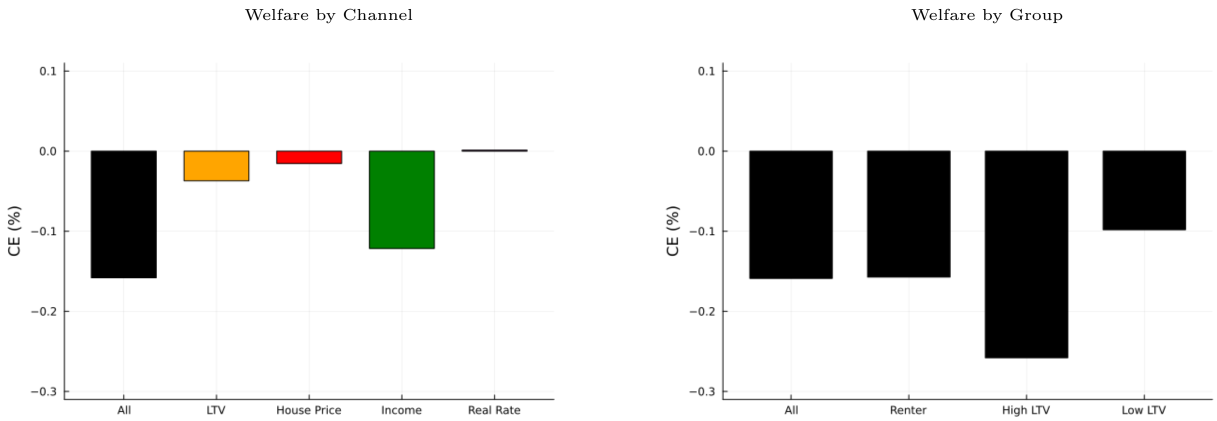
Note: Impulse response functions (IRF) of key model variables to a 10 pp contraction of the LTV.

Figure 2: LTV Tightening - Transmission Channels



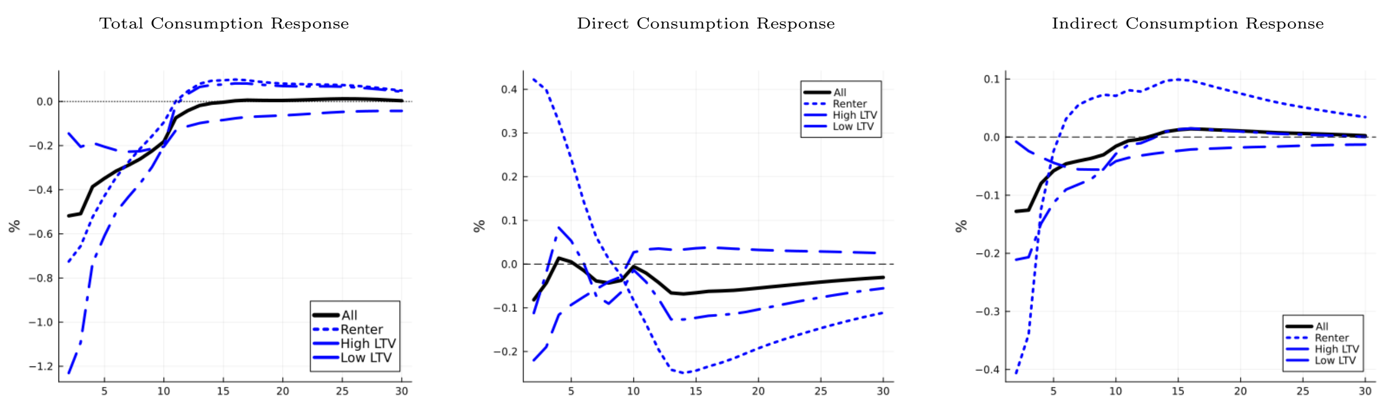
Note: Decomposition of consumption, housing demand, liquid savings and mortgage debt response to the LTV contraction into direct and indirect channels.

Figure 3: LTV Tightening - Welfare Effects



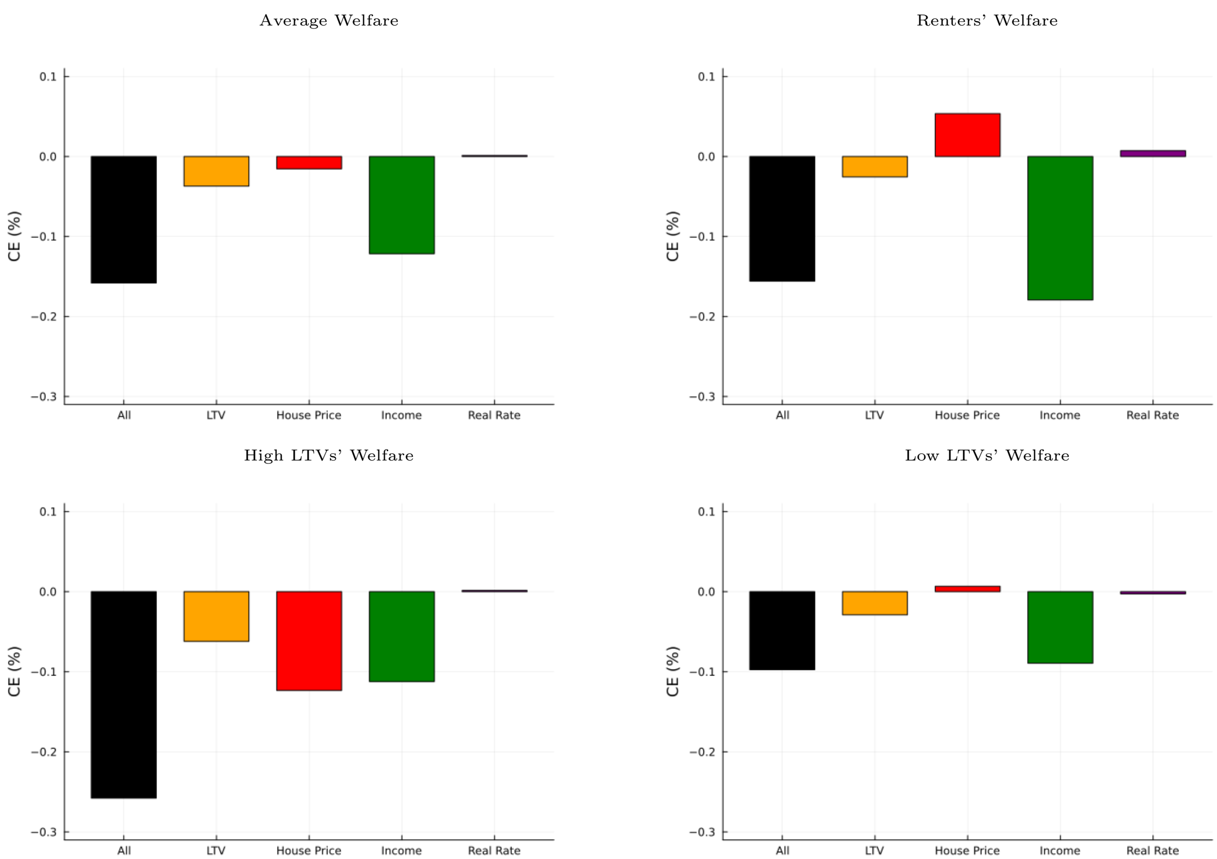
Note: Left panel: Welfare effects by channels. Right panel: Welfare effects by household type.

Figure 4: LTV Tightening - Consumption Heterogeneity



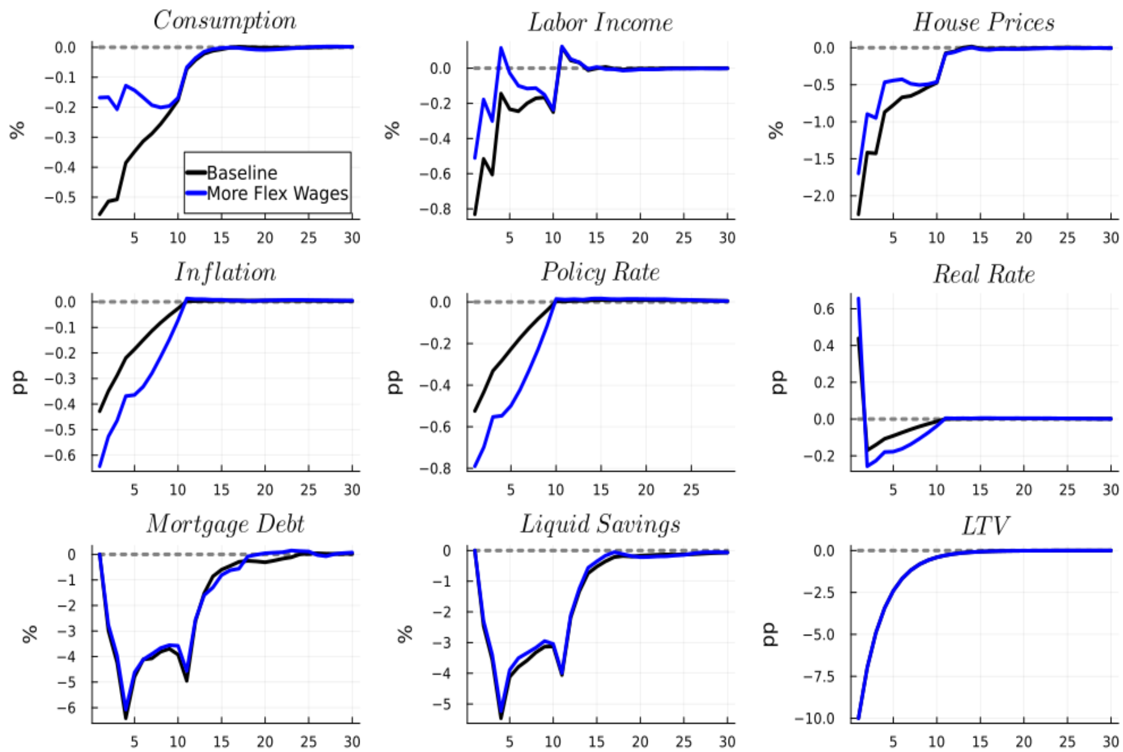
Note: Left panel: Consumption response by household Type. Middle panel: Direct effects to consumption response by household type. Right panel: Indirect effects to consumption response by household type.

Figure 5: LTV Tightening - Welfare Effects by Channels and Household Type



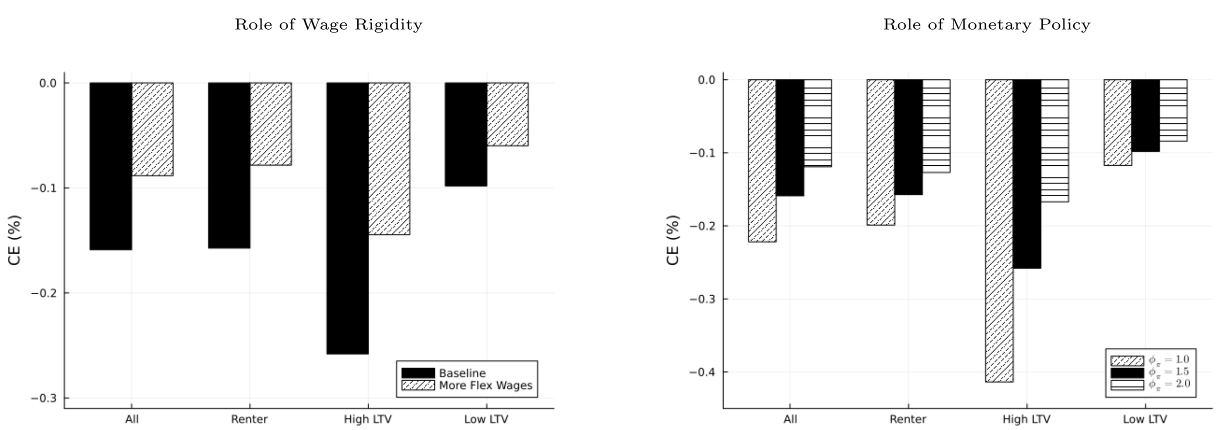
Notes: Decomposition of as welfare effects by household type into direct and indirect channels for different monetary policy response to inflation. Welfare effects measured in consumption equivalent (CE) terms.

Figure 6: LTV Tightening - Wage Rigidity



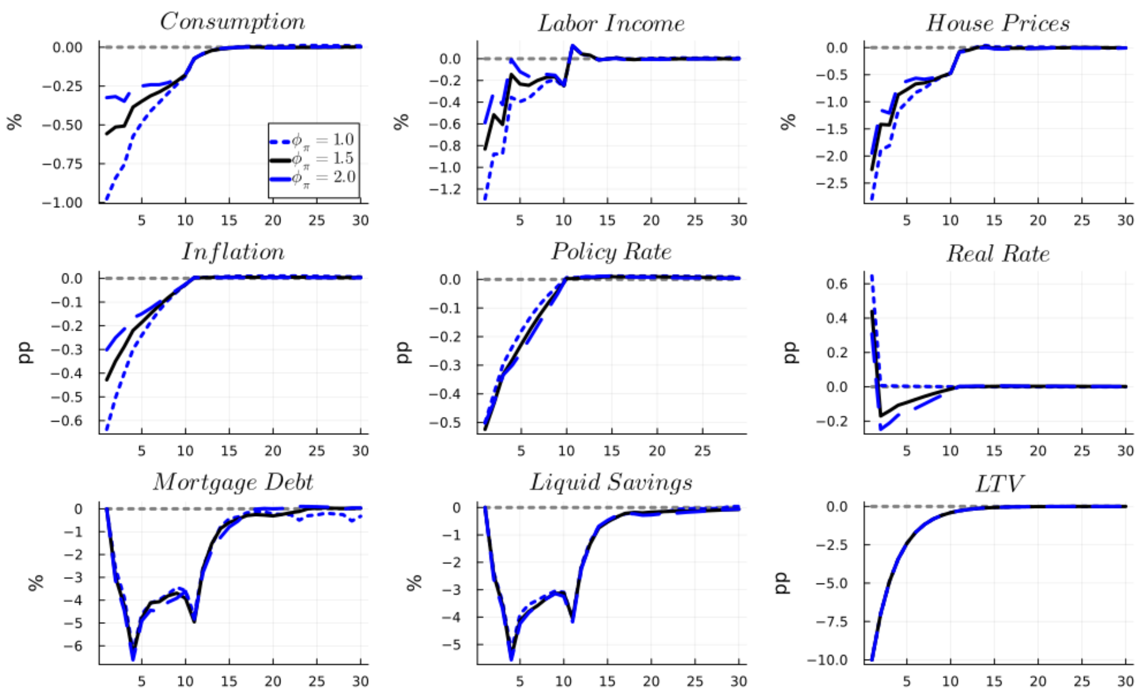
Note: Aggregate impulse response functions (IRF) to the LTV contraction for different degrees of wage rigidity. Solid lines are the baseline rigidity ($\kappa = 0.08$), dashed grey lines are more flexible wages ($\kappa = 0.25$).

Figure 7: Welfare Effects by Household Type - Wage Rigidity and Monetary Policy



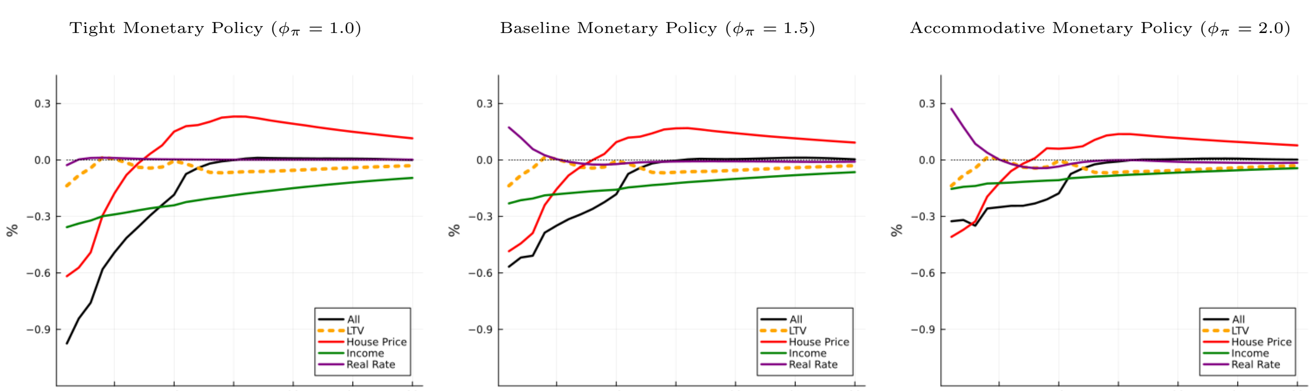
Note: Left panel: Different degrees of wage rigidity. Solid bars are the baseline rigidity ($\kappa = 0.08$), dashed grey bars are more flexible wages ($\kappa = 0.25$). Right panel: Different monetary policy responses to inflation. Solid bars are the baseline stance ($\phi_\pi = 1.5$), dashed bars are a more restrictive stance ($\phi_\pi = 2.0$).

Figure 8: LTV Tightening - Monetary Policy Accommodation



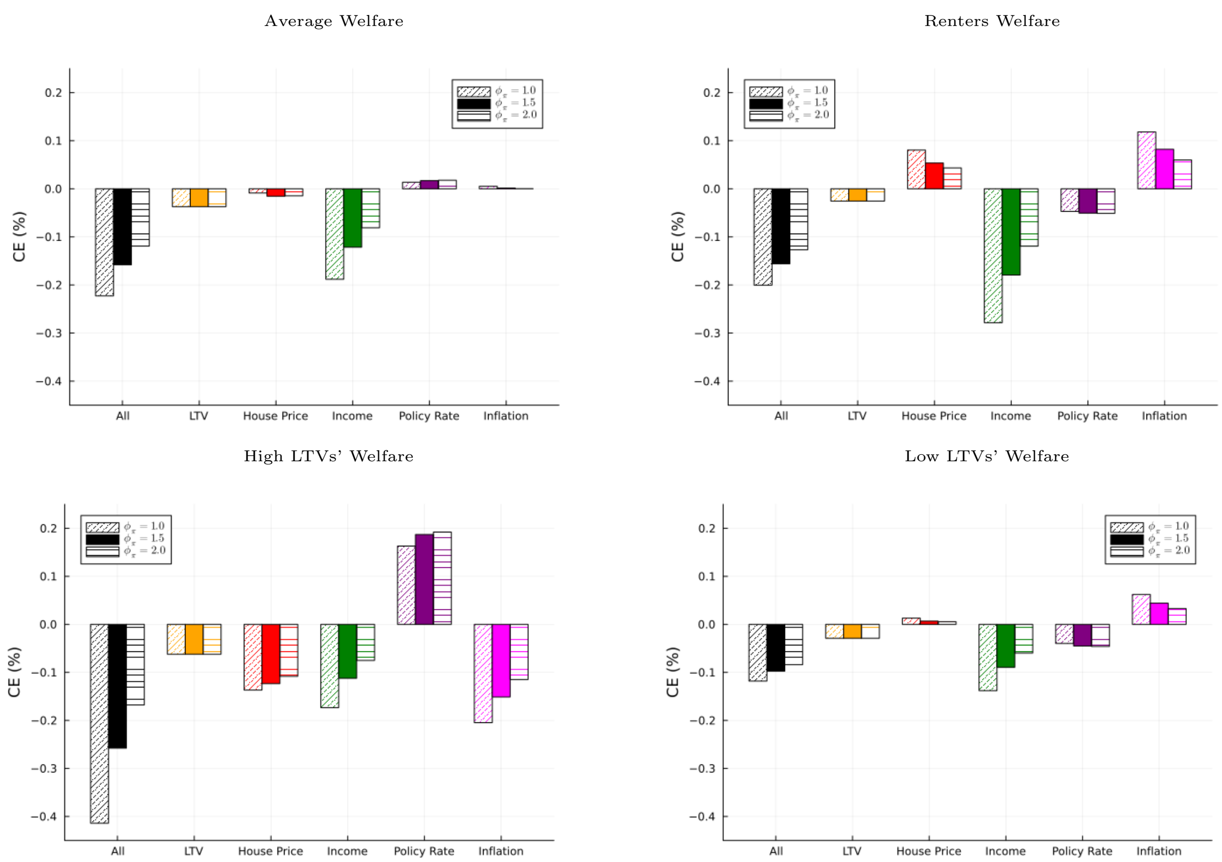
Note: Solid line: baseline monetary policy response to inflation ($\phi_\pi = 1.5$). Dotted line: weaker monetary policy response to inflation ($\phi_\pi = 1$). Dashed Line: stronger monetary policy response to inflation ($\phi_\pi = 2$).

Figure 9: LTV Tightening - Consumption Heterogeneity and Monetary Policy



Note: Left panel: weaker monetary policy response to inflation ($\phi_\pi = 1$). Middle panel: baseline monetary policy response to inflation ($\phi_\pi = 1.5$). Right panel: stronger monetary policy response to inflation ($\phi_\pi = 2$).

Figure 10: Welfare Effects by Household Type and Channels - Monetary Policy



Notes: Decomposition of as welfare effects by household type into direct and indirect channels for different monetary policy response to inflation. Welfare effects measured in consumption equivalent (CE) terms.

Appendix

A Model Details

1.1 Wage Phillips Curve Derivation

We follow closely Auclert et al. (2018). Each worker i belongs to union k. Each union hires from a representative sample of the population and bundles them into a union-specific task $N_{kt} = \sum_i z_i n_{i,k,t} di$. The labor varieties are then bundled into total effective labor N_t by a labor packer and sold to the final good produces. Varieties are aggregated into total labor following

$$N_t = \left(\int_k N_{kt}^{\frac{\epsilon-1}{\epsilon}} dk \right)^{\frac{\epsilon}{\epsilon-1}} \tag{A.1}$$

where ϵ is the elasticity of substitution.

The representative union k chooses wage W_{kt} to maximize

$$\sum_{\tau \geq 0} \beta^{t+\tau} \left(\sum_i \left\{ u\left(x_{it+\tau}\right) - v\left(n_{it+\tau}\right) \right\} - \frac{\psi}{2} \left(\frac{W_{k,t+\tau}}{W_{k,t+\tau-1}} - 1 \right)^2 \right) \tag{A.2}$$

The objective function (A.2) states that when making the union chooses the wage $W_{k,t}$ it minimizes the average labor supply distortions of households accounting for the fact that nominal wages are costly. These costs are assumed to be quadratic and government by adjust cost parameter ψ. Unions make this choice taking the demand for tasks from the labor packer

$$N_{kt} = \left(\frac{W_{kt}}{W_t} \right)^{-\varepsilon} N_t, \tag{A.3}$$

as given, where $W_t = \left(\int W_{kt}^{1-\varepsilon} dk \right)^{\frac{1}{1-\varepsilon}}$ is the price index for aggregate employment services and μ_t is the distribution of agents. The first order condition of the union problem writes

$$\int_i \left\{ u'\left(x_{it}\right) \frac{\partial x_{i,t}}{\partial W_{k,t}} - v'\left(n_{it}\right) \frac{\partial n_{i,t}}{\partial W_{k,t}} \right\} - \psi \left(\frac{W_{k,t}}{W_{k,t-1}} - 1 \right) \frac{1}{W_{k,t-1}} + \beta\psi \left(\frac{W_{k,t+1}}{W_{k,t}} - 1 \right) \left(\frac{W_{k,t+1}}{W_{k,t}} \right) \frac{1}{W_{k,t}} = 0.$$

Multiplying both sides by $W_{k,t}$ and using the fact that in equilibrium all unions set the same price (i.e. $W_{k,t} = W_t$) yields

$$\left(\Pi_t^w - 1\right) \Pi_t^w = \frac{1}{\psi} \sum_i \left\{ u'\left(x_{it}\right) \frac{\partial x_{i,t}}{\partial W_{k,t}} - v'\left(n_{it}\right) \frac{\partial n_{i,t}}{\partial W_{k,t}} \right\} W_t + \beta \left(\Pi_{t+1}^w - 1\right) \left(\Pi_{t+1}^w\right) \tag{A.4}$$

where $\Pi_t^w = \frac{W_{k,t}}{W_{k,t-1}}$. We now calculate $\frac{\partial x_{i,t}}{\partial W_{k,t}}$ and $\frac{\partial n_{i,t}}{\partial W_{k,t}}$.

Consider household i, working for union k. Substituting (A.3) into (3) their total real earnings writes

$$y_{it} = \tau_t \frac{z_{it}}{P_t} W_{kt} \left(\frac{W_{kt}}{W_t} \right)^{-\varepsilon} N_t \tag{A.5}$$

Assuming $\frac{\partial y_{it}}{\partial W_{kt}} = \frac{\partial x_{it}}{\partial W_{kt}}$ and exploiting the fact that in equilibrium $W_{kt} = W_t$ and $N_{k,t} = N_t$ it follows that

$$\frac{\partial x_{it}}{\partial W_{kt}} = (1-\tau_t)\frac{1}{P_t} N_t (1-\epsilon). \tag{A.6}$$

The partial derivative of individual labor supply with respect to individual wages is

$$\frac{\partial n_{it}}{\partial W_{kt}} = -\varepsilon \frac{N_{kt}}{W_{kt}} \tag{A.7}$$

Substituting the derivatives (A.6) and (A.7) into (A.4) yields

$$(\Pi_t^w - 1)\,\Pi_t^w = \frac{1}{\psi} \sum_i \left\{ u'(x_{it})\,(1-\epsilon)(1-\tau_t)\frac{1}{P_t} N_t + v'(n_{it})\,\varepsilon \frac{1}{W_t} N_t \right\} W_t + \beta \left(\Pi_{t+1}^w - 1\right)\left(\Pi_{t+1}^w\right).$$

Re-arranging, we get

$$(\Pi_t^w - 1)\,\Pi_t^w = \kappa \sum_i \left\{ v'(n_{it}) - \frac{(\epsilon - 1)}{\epsilon}(1-\tau_t)\frac{W_t}{P_t} u'(x_{it}) \right\} N_t + \beta \left(\Pi_{t+1}^w - 1\right)\left(\Pi_{t+1}^w\right)$$

where $\kappa = \frac{\epsilon}{\psi}$. Rewriting $u(X_t)$ and $v'(N_t)$ to be the average marginal utilities, we get the following Phillips Curve [13]

$$(\Pi_t^w - 1)\,\Pi_t^w = \kappa \left[v'(N_t) - \frac{(\epsilon - 1)}{\epsilon}(1-\tau_t)\frac{W_t}{P_t} u'(X_t) \right] N_t + \beta \left(\Pi_{t+1}^w - 1\right)\left(\Pi_{t+1}^w\right)$$

1.2 Equilibrium Definition

Definition 1. ***Competitive Equilibrium.*** *Let the vector of idiosyncratic states be* $\Omega_t = \{b_t, h_t, m_t, z_t\}$. *A competitive equilibrium is a set of time-dependent policy function* $\{b_{t+1}(\Omega_t), s_t(\Omega_t), h_{t+1}(\Omega_t), m_{t+1}(\Omega_t)\}$, *sequences of aggregate prices* $\{q_t, r_t, i_t, \pi_t^w, \pi_t, w_t\}_{t=1}^{\infty}$, *government spending* $\{g_t\}_{t=1}^{\infty}$, *labor supply* $\{N_t\}_{t=1}^{\infty}$, *a measure* $\mu_t(\Omega_t)$ *and an exogenous sequence of* $\{\lambda_t\}_{t=1}^{\infty}$ *such that* $\forall\ t$

- *taking prices as given, policy functions solve the household optimization problem in Section (1.2),*
- *the wage Phillips-Curve (A.8) holds*

$$\pi_t^w(1+\pi_t^w) = \kappa \left[v'(N_t) - \frac{\epsilon - 1}{\epsilon}(1-\tau)\frac{W_t}{P_t} u'(X_t) \right] N_t + \beta \pi_{t+1}^w (1 + \pi_{t+1}^w) \tag{A.8}$$

[13] When computing $u'(X_t)$ we use the marginal utilities of average composite consumption instead of average marginal utility. This is akin to assuming the union does not account for consumption heterogeneity when setting wages.

- *nominal rates are set according to the Taylor rule (A.9) and the fisher equation holds (A.10)*

$$i_{t+1} = \bar{i} + \phi^{\pi}(\pi_{t+1} - \bar{\pi}) + \phi^{N}(N - \bar{N}) + \varepsilon_{it} \tag{A.9}$$

$$(1 + i_t) = (1 + \pi_t)(1 + r_t) \tag{A.10}$$

- *the government budget constraint (A.11) is satisfied*

$$r_t \bar{b}^g = g_t + \tau n_t \tag{A.11}$$

- *price and wage inflation relate according to (A.12) and real wages are set according to (A.13)*

$$(1 + \pi_t) = (1 + \pi_t^w) \tag{A.12}$$

$$w_t = Z \tag{A.13}$$

- *aggregate household demands for home-owner occupied housing rental units and bonds follow (A.14), (A.15) and (A.16), respectively*

$$H_t^o = \sum_{\omega \in \Omega_t} h_{t+1}(\Omega_t)\mu(\Omega_t) \tag{A.14}$$

$$H_t^r = \sum_{\omega \in \Omega_t} s_t(\Omega_t)\mu_t(\Omega_t) - \sum_{\omega \in \Omega_t} h_{t+1}(\Omega_t)\mu_t(\Omega_t) \tag{A.15}$$

$$b_{t+1}^d = \sum_{\omega \in \Omega_t} b_{t+1}(\Omega_t)\mu_t(\Omega_t) - \sum_{\omega \in \Omega_t} m_{t+1}(\Omega_t)\mu_t(\Omega_t) \tag{A.16}$$

- *the markets clearing conditions for bonds (A.17), home-owner occupied housing (A.18) and rental units (A.18) hold*

$$b_{t+1}^d + b^* = \bar{b}^g \tag{A.17}$$

$$\bar{H}^o = H_t^o \tag{A.18}$$

$$\bar{H}^r = H_t^r \tag{A.19}$$

B Computational Method

2.1 Steady State

To solve the model numerically we first discretize the state space. We use a log-spaced asset grid $\bar{b}$ with 130 grid points, a mortgage grid $\bar{m}$ with 20 equidistant points and 9 grid points for the income (productivity) states $\bar{z}$. The income process is discretized as a 9-state Markov chain using Tauchen (1986) method.

We then solve for household policy function using discrete choice endogenous gridpoint method (DCEGM) as in Iskhakov et al. (2017). This means that for every individual state $\hat{\omega} \in \{\bar{b}, \bar{h}, \bar{m}, \bar{z}\}$ we calculate the value associated with each discrete choice d. Because the household faces a discrete and continuous (consumption) choice, we solve for the optimal consumption choice conditional on each discrete choice making use of the EGM on the Euler equation. Because of the potential non-concavity of the value function in the presence of discrete choices, the Euler equation is a necessary but not sufficient condition. This means that the function mapping the exogenous to the endogenous grid is not necessarily invertable. Thus we apply an upper envelope condition on the result as outlined in Iskhakov et al. (2017). This yields the discrete choice specific asset policy and value functions. We then obtain the optimal discrete choice by finding the highest value across discrete choices. We repeat this process for all points in the state space which yields and update of policy and value functions. If this update is significantly close to the functions in the prior iteration we have found the steady state policy and value functions (we use the euclidean norm to measure the distance between updates and consider a tolerance level of 1.0×10^{-8} for convergence). To find the distribution and aggregate moments we simulate the economy non-stochastically using Young (2010) method.

2.2 Dynamics

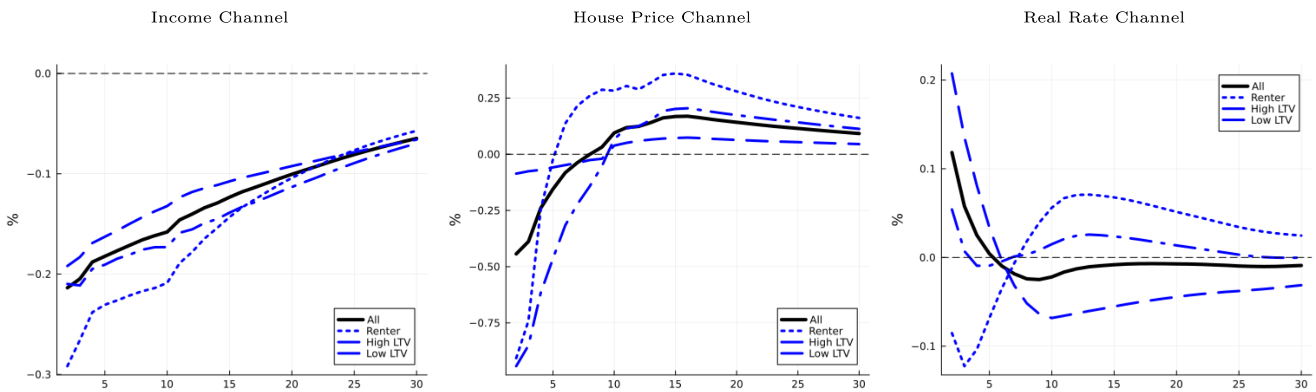
For the dynamics we make use of the insights by Auclert et al. (2021) and calculate the sequence space Jacobians for the household and individual simple blocks of the model. The Jacobians of the household block are approximated using a one-sided finite difference method, where we make use of the insight in Auclert et al. (2021) that only the time distance to the shock matters not the actual timing of the shock. This greatly economizes on the computational burden. For the general equilibrium dynamics we we first calculate the linear solution for the dynamics from the Jacobians. Whereas in many standard HANK models without discrete choices the local linear solution is indistinguishable from global non-linear solutions, we find that, in particular for the shock to the LTV in our model, non-linearities matter. For this reason and because we are interested in a welfare measure, we calculate all impulse responses fully non-linearly: We feed in the exogenous sequence of the shock and solve for the time-variant policy functions backwards using the DCEGM algorithm.[14] We then simulate the time-variant distribution forward, starting at the steady state using the time-variant policy functions and aggregate the moments for housing demand and asset supply. If housing and asset markets do not clear over the entire time path we need to update our guesses for prices. To update house prices and interest rates we are able to make use of the Jacobians using newtons method. This is particularly useful, as interest rates and house prices interact and the Jacobians include all cross-derivatives at all lags and leads. We generally find 15-20 update iterations to be sufficient

[14]we use a sufficiently long time horizon of 100 periods

for convergence.

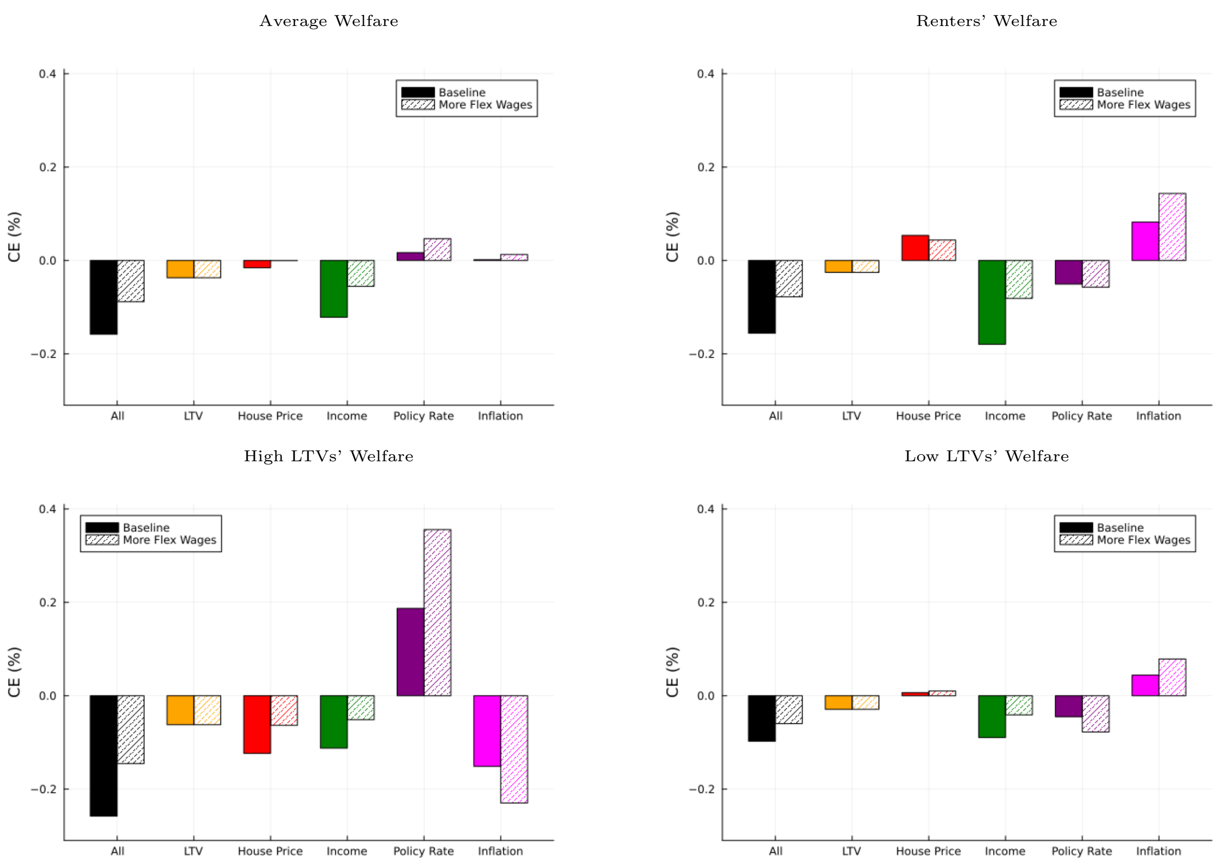
C Additional Results

Figure A.1: LTV Tightening - Consumption Heterogeneity



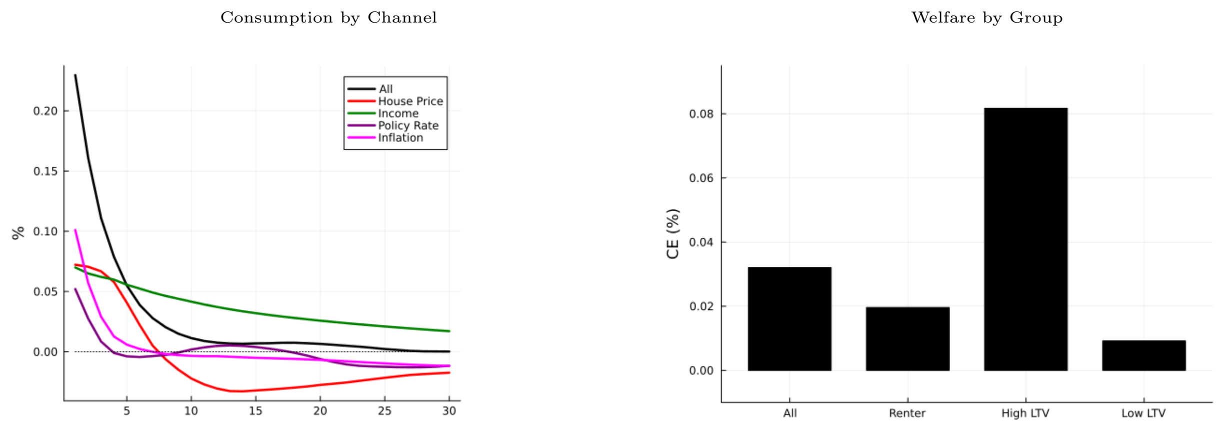
Note: Consumption response by household Type Direct and indirect effects by channel.

Figure A.2: Welfare Effects by Channel and Household Type - Wage Ridigity



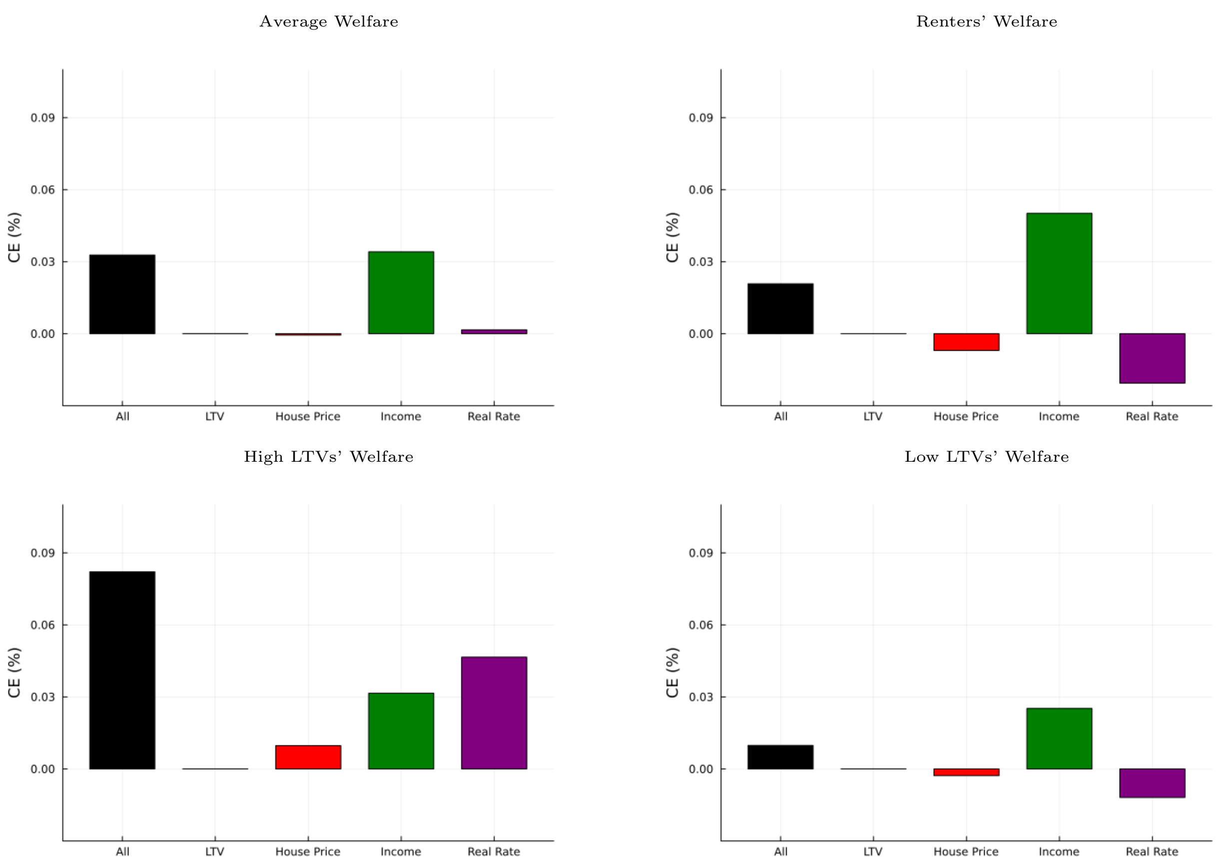
Notes: Decomposition of welfare effects by household type into direct and indirect channels for different degrees of wage rigidity. Solid bars are the baseline rigidity ($\kappa = 0.08$), dashed bars are more flexible wages ($\kappa = 0.25$). Welfare effects measured in consumption equivalent (CE) terms.

Figure A.3: Monetary Policy Shock



Note: Left panel: Aggregate consumption response by channels. Right panel: Welfare effects by household type.

Figure A.4: Monetary Policy Shock - Welfare Effects by Channels and Household Type



Notes: Decomposition of welfare effects by household type into direct and indirect channels. Welfare effects measured in consumption equivalent (CE) terms.