The (Un)Intended Consequences of Loan-to-Value Ratio Tightening

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Abstract

Loan-to-value (LTV) ratios are among the most widely used macroprudential instruments globally, yet the magnitude and persistence of their effects remain insufficiently understood. This paper studies LTV tightening in a two-agent flexible-price model where entrepreneurs borrow against housing collateral. A central finding is that the effects of tightening depend critically on the initial LTV ratio — a one percentage point temporary tightening leads to a housing price decline exceeding one percent at impact when the initial LTV is 0.90, with substantially smaller effects at lower initial ratios. Remarkably, the model shows a persistent decline in real wages following a temporary tightening — an unintended consequence that emerges through the collateral channel without any nominal rigidity. A quasi-permanent tightening generates permanent declines in housing prices and debt, and unlike models with nominal frictions, also in investment, output, wages, and aggregate consumption, with patient household lenders and impatient entrepreneur borrowers affected in opposing directions. The initial LTV ratio also amplifies the effects of TFP, housing demand, and labor supply shocks, suggesting that macroeconomic vulnerability to any contractionary shock is increasing in the economy's initial leverage. These results have direct implications for the calibration of LTV caps across different credit environments.

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1 Introduction

A one percentage point tightening of loan-to-value (LTV) ratios — a seemingly modest regulatory adjustment — can generate housing price declines exceeding one percent, persistent real wage depression, and, when permanent, lasting contractions in output, investment and consumption. These effects are substantially larger than existing estimates suggest and depend critically on the initial level of the LTV ratio at which tightening begins. While prevalence of LTV ratios as a common macroprudential tool, particularly for loans backed by real estate, is widely documented (Akinci and Olmstead-Rumsey, 2018; Gatt, 2022; Acharya, Bergant, Crosignani, Eisert, and McCann, 2022; Alam, Alter, Eiseman, Gelos, Kang, Narita, Nier, and Wang, 2024),[1] the existing literature suffers from two important gaps. First, most of the current literature focuses on impact of these tools on mortgages and households (Alpanda and Zubairy, 2017; Morgan, Regis, and Salike, 2019). Second, the costs of these macroprudential tools (Richter, Schularick, and Shim, 2019; Ono, Uchida, Udell, and Uesugi, 2021) remain understudied. In this paper, I focus on corporate loans (Ono, Uchida, Udell, and Uesugi, 2021) — a channel that has received less attention than household mortgages — and show that LTV tightening through this channel can have very large and persistent macroeconomic consequences.[2]

I document five key results in the paper. First, the effects of LTV tightening depend critically on the level at which the tightening begins. Second, a temporary tightening can lead to persistent wage decline through decrease in investment and output. Third, a permanent LTV tightening leads to larger and permanent declines not only in housing prices and credit but also output, investment, aggregate consumption and wages. Fourth, high initial LTV ratios increase fragility across the board by leading to larger effects of other common macroeconomic shocks such as TFP, housing and labor shocks. Fifth, a countercyclical LTV ratio targeting changes in housing prices dampens the effects of TFP shocks but suppresses housing reallocation between agents and generates asymmetric consumption consequences — benefitting household lenders while keeping entrepreneur borrowers leveraged and consumption-depressed for longer.

I incorporate time-variation in LTV ratios in a flexible price two-agent model containing a

[1] See Gatt (2024) for a survey on LTV as a macroprudential policy tool and Duca, Muellbauer, and Murphy (2021) for a survey on housing price cycle.

[2] While Alam, Alter, Eiseman, Gelos, Kang, Narita, Nier, and Wang (2024) report relatively modest side effects of LTV tightening in a large cross-country panel, the present model suggests that these costs might be substantially larger in high-leverage economies — a finding consistent with Richter, Schularick, and Shim (2019) who "...show that changes in maximum LTV ratios have substantial effects on credit and house price growth."

patient household lender and an impatient entrepreneur borrower. Households in this model consume non-durable goods, hold a durable good (housing), supply labor and lend to entrepreneurs who consume non-durables, hire labor and borrow from households. Differently from Liu, Wang, and Zha (2013) who examine the macroeconomic effects of land price fluctuations, I focus on LTV as an explicit policy tool and examine how its calibration affects the severity and distribution of macroeconomic consequences.[3] When lending standards (LTV ratios) are tightened, it reduces the amount of loans that entrepreneurs can borrow and invest in productive capital. They respond by deleveraging and, at higher initial LTV ratios, fire-selling their real estate holdings dramatically to relax their borrowing constraint which depresses housing prices. Their housing is bought by households who are the unconstrained agent in the model. Part of the proceeds from these forced sales flows into entrepreneur consumption, as investment in housing becomes unprofitable at depressed prices. A permanent tightening of lending standards permanently reduces the amount by which they can take out loans by posting their assets as collateral.[4] Entrepreneurs, in this case, deleverage more dramatically and it has substantially larger and more persistent impact on housing prices and macroeconomic variables through a collateral spiral — fire sale by entrepreneurs reduces the amount of housing they have that they can post as collateral and at the same time, the sell-off lowers the price of housing which reduces the value of their remaining assets.

I show that LTV tightening can have large impact on housing prices and wider economic activity — a one percentage point temporary reduction in LTV ratios (meaning, for example, LTV ratio 0.90 becomes 0.89 after the shock), housing prices decline by more than 1 percent on impact before recovering slowly. At higher steady state LTV ratios, entrepreneurs sell off a much larger amount of their housing which combined with drop in housing prices, results in greater fall in economic activity. When LTV ratios are permanently tightened, these effects become stronger and more persistent — a one percentage point permanent decline in LTV ratio from 0.90 to 0.89, leads to more than 4 percent initial drop in housing prices before it recovers partially and decreases permanently by more than 2 percent. These effects are larger than those documented previously in the literature — for instance, De Veirman (2023)

[3]The durable good in the model, in effect, is real estate. While it might more naturally be called housing in case of households and (commercial) land in case of entrepreneurs (following the terminology used by Liu, Wang, and Zha, 2013 and others), I stick with the term 'housing' throughout this paper for consistency.

[4]Alpanda and Zubairy (2017); Bruneau, Christensen, and Meh (2018) and De Veirman (2023) conduct similar experiments. Bruneau, Christensen, and Meh (2018) report that Canada took such a regulatory action when it reduced the maximum LTV ratio from 100% to 95% in October 2008.

documents that, in Iacoviello (2005) model, housing prices decline by 1 percent after a one percentage point permanent decline in LTV ratios from 0.95. These findings also highlight unintended consequences of LTV tightening and speak directly to the costs of macroprudential policies (Richter, Schularick, and Shim, 2019; Ono, Uchida, Udell, and Uesugi, 2021). In case of temporary LTV tightening, wages decline persistently driven by contraction in investment and output. Similarly, in case of permanent LTV tightening, investment, wages, output and consumption decline permanently — indicating the potential unintended consequences of LTV tightening.

I also consider other common macroeconomic shocks such as negative TFP shock, housing demand shock and labor shock and show that higher steady state LTV ratios increase economic fragility across the board. In this model, TFP shocks have large and persistent effects on housing prices and macroeconomic activity and their impact operates through large reallocation of housing across agents. A negative TFP shock reduces the return entrepreneurs expect on their deployed capital, leading them to deleverage and sell off their housing stock which persistently depresses its price. The sharp liquidation of real estate — exceeding 40% when LTV ratio is 0.90 — combined with the resulting decline in housing prices of more than 3% at impact, tightens entrepreneurs' borrowing constraint. Consequently, investment falls along with aggregate consumption and output. Large and persistent decline in investment results in persistent decline in wages — a novel result which highlights how increased leverage can interact with TFP shocks to generate prolonged wage depression. Capital prices recover faster in this model but housing prices decline persistently given their fixed supply and this plays an important role across all shocks. These effects are greater at higher steady-state LTV ratios since entrepreneurs deleverage more and sell off larger part of their housing stock at higher steady-state LTV ratios.

Housing and labor shocks have smaller impact in this model and the mechanism — unlike TFP shocks where it operates on entrepreneurs' side — works differently and the shocks originate on households' side. A negative housing shock decreases the weight households place on housing and this directly reduces its utility, leading to a drop in housing prices of 0.5% at impact when LTV ratio is 0.90. Entrepreneurs respond by selling their real estate holdings which is absorbed by households — although valuing housing less following the shock, they serve as the residual absorbers of entrepreneurial housing sales given the fixed aggregate supply and the absence of any other buyer in the economy — a general equilibrium reallocation driven by the collateral constraint rather than household preferences. As housing shock gradually dissipates, housing prices recover. Decrease in entrepreneurial housing stock and borrowing, and the resulting housing prices are greater at higher steady-state LTV ratios. I finally consider a negative labor supply shock which increases the disutility of working and results in persistent employment decline. Wages initially rise as labor supply contraction raises the marginal product of labor but subsequently fall as the output decline dominates. A labor shock reduces the return on entrepreneur's deployed capital who respond by reducing their borrowing, selling off part of their housing stock and cutting down their consumption. Housing prices fall (slightly more than 0.2% at impact when LTV ratio is 0.90) due to sell-off by entrepreneurs which further tightens their borrowing constraint. As wages decline, household consumption also drops. Aggregate consumption, output, investment and capital decline with these effects being larger at higher initial LTV ratios.

Finally, I consider a countercyclical LTV rule that responds to changes in housing prices and show that it can dampen the effects of negative TFP shocks by endogenously loosening LTV ratios during downturns, thereby allowing entrepreneurs to access larger amounts of credit. While the rule eases entrepreneurs' borrowing constraint and stabilises aggregate variables, it almost completely eliminates the general equilibrium reallocation of housing from entrepreneurs to households that would otherwise occur. This generates an unexpected distributional consequence — the rule benefits patient household lenders in consumption terms, whose consumption falls less and recovers faster under a strong rule, while entrepreneur borrowers remain leverage-constrained and consumption-depressed for longer despite the rule being designed to ease their borrowing conditions. A policy intended to protect constrained borrowers ends up benefiting unconstrained lenders more in consumption terms — an unintended consequence that aggregate stabilisation metrics do not capture.

The findings in this paper carry direct implications for housing markets and LTV tightening as a macroprudential policy tool. The findings in the paper showing large changes in housing prices in response to a modest change in LTV ratios when leverage is high, indicate that LTV caps must be carefully calibrated according to the credit environment and 'one size fits all' policy actions may not be fit for the purpose. The persistent drop in wages after a temporary LTV tightening, and in case of a permanent tightening, permanent decreases not only in housing prices and debt but also in investment, wages, output and consumption further suggest a careful approach towards LTV tightening since it can have substantial unintended macroeconomic consequences.

Contact with Literature

The paper contributes to the literature on housing, use of LTV ratios as a macroprudential policy tool and macroeconomic consequences of collateral constraints. Empirically, Richter, Schularick, and Shim (2019) and Alam, Alter, Eiseman, Gelos, Kang, Narita, Nier, and Wang (2024) document widespread use of LTV caps and find significant effects on credit and housing prices while Ono, Uchida, Udell, and Uesugi (2021) and Acharya, Bergant, Crosignani, Eisert, and McCann (2022) show that corporate and entrepreneurial credit are increasingly targeted by these instruments. This paper provides theoretical foundations for those empirical findings by tracing the mechanism through which LTV tightening propagates in the economy where entrepreneurial borrowing is collateral-constrained.

Existing theoretical studies have typically abstracted from borrowing constraints on agents when examining impact of LTV shocks. For example, Justiniano, Primiceri, and Tambalotti (2015) look at impact of LTV shocks in a nominal model where agents are never financially constrained and conclude that these shocks have relatively little macroeconomic impact. This work shows that when financial constraint for agents is taken into account, LTV shocks can have significant and persistent effects on housing prices and economic activity. Jensen, Ravn, and Santoro (2018) and Jensen, Petrella, Ravn, and Santoro (2020) study positive changes in credit limits and leverage in a three-agent framework. Unlike them, I investigate the impact of credit-constrained investment and steady-state changes in LTV ratios by incorporating LTV tightening in a flexible price two agent model where all the investment is made by credit-constrained entrepreneurs.

Other papers such as Kiyotaki, Michaelides, and Nikolov (2011, 2024), Favilukis, Ludvigson, and Van Nieuwerburgh (2017) and Kaplan, Mitman, and Violante (2020) study the effects of changes in credit limits in an overlapping generations framework. Huo and Ríos-Rull (2016) examine the joint role of LTV and interest rate shocks in a heterogeneous agent model. Ferrero (2015) and Boz and Mendoza (2014) examine the effects of changing LTVs in open-economy models. Differently from these papers, I focus specifically on entrepreneurial collateral constraints in a tractable closed-economy two agent flexible price framework, isolating the corporate credit channel and its interaction with initial leverage.

The paper that is closest to the analysis in this work is De Veirman (2023) who embeds the nominal three agent model in Iacoviello (2005) with time-varying LTV shocks and studies their impact. Unlike De Veirman (2023), I focus on LTV tightening on corporate debt in a flexible price two agent model featuring only one collateral-constrained borrower (entrepreneurs) and an unconstrained lender (households). Also the results differ starkly from De Veirman (2023) who shows that consumption, investment and output fall in the aftermath of a permanent LTV tightening and return to their steady state after a few quarters. In my model, permanent LTV tightening results in permanent decline in macroeconomic aggregates such as aggregate consumption, investment and output. This difference reflects the absence of nominal frictions in my model, which otherwise act as a buffer absorbing part of the collateral shock. Liu, Wang, and Zha (2013) study the macroeconomic effects of land price fluctuations using a collateral constraint framework, but focus on land price dynamics as an endogenous source of fluctuations rather than LTV policy as an explicit regulatory instrument – a distinction that is central to the present paper's contribution.

To the best of my knowedge, this paper documents for the first time persistent decline in wages even after a temporary LTV tightening and permanently lower wages when the tightening is permanent — findings which carry implications not only for the use of LTV caps as a macroprudential policy tool but also for labor income. Beyond LTV tightening, I show that higher initial leverage increases economic fragility across the board by amplifying the effects of other common macroeconomic shocks such as TFP, housing and labor shocks, establishing the steady state LTV ratio as a general amplification parameter. Finally, the paper documents that a countercyclical LTV policy that targets changes in housing prices can mitigate the effects of negative TFP shocks by relaxing entrepreneurs' borrowing constraint during a downturn and thereby suppressing the forced reallocation of housing from entrepreneurs to households but generates asymmetric consumption consequences — benefitting household lenders while keeping entrepreneur borrowers leverage-constrained and consumption-depressed for longer.

The remainder of this paper is structured as follows. Section 2 presents the model. Section 3 discusses the model solution and parameterization. Section 4 presents results and discussions. Finally, Section 5 concludes.

2 Model

The paper features a two-agent flexible-price model which bears similarities with those in Iacoviello (2005) and Liu, Wang, and Zha (2013).[5] It has (patient) households who consume non-durable consumption goods, supply labor and derive utility from holding a durable good (housing). The (impatient) entrepreneurs, in turn, consume non-durable consumption goods, hire labor from households and run firms in the economy. Firms are owned by the entrepreneurs who are subject to a collateral constraint which limits their borrowing to a fraction of expected value of their total assets which include physical capital and housing (commercial land or real estate). Because of $\beta^E < \beta^P$, households act as lenders and entrepreneurs act as borrowers in the equilibrium. In what follows, I describe each agent's optimization problem.

2.1 Households

Households have the utility function of the following form:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \left(\beta^P\right)^t \left\{ \log\left(C_t^P - \gamma^P C_{t-1}^P\right) - \iota_t N_t + \varsigma_t \log H_t^P \right\} \tag{1}$$

where C_t^P, N_t and H_t^P denote consumption, labor and housing respectively of the households, $\beta^P \in (0,1)$ is a discount factor and γ^P measures the degree of habit formation in consumption. The superscript P denotes (patient) households. Household's preference for leisure is subject to an exogenous shock ι_t, the law of motion of which is given by

$$\log \iota_t = (1-\rho_N)\log \iota + \rho_N \log \iota_{t-1} + \sigma_N \epsilon_{N,t} \tag{2}$$

Here, $\epsilon_{N,t}$ is iid innovation which follows a normal distribution with standard deviation σ_N and where $\iota > 0$ and $\rho_N \in (0,1)$. In similar fashion, ς_t is a housing preference shock as in Liu, Wang, and Zha (2013) which follows the following process

$$\log \varsigma_t = (1-\rho_H)\log \varsigma + \rho_H \log \varsigma_{t-1} + \sigma_H \epsilon_{H,t} \tag{3}$$

[5] Iacoviello (2005) contains nominal rigidities and does not incorporate time variation in LTV ratios. Liu, Wang, and Zha (2013) focus on transmission of land price fluctuations to macroeconomy and they do not examine the effects of LTV shocks as a policy tool and its macroprudential implications across different initial LTV ratios which is the focus of this paper.

where $\epsilon_{H,t}$ is iid innovation which follows a normal distribution with standard deviation σ_H and where $\varsigma > 0$ and $\rho_H \in (0,1)$. The household faces the following budget constraint

$$C_t^P + Q_t^H \left(H_t^P - H_{t-1}^P\right) + R_{t-1} B_{t-1}^P \leq W_t N_t + B_t^P \tag{4}$$

Here, Q_t^H is the price of one unit of housing in terms of consumption goods, W_t is the real wage and R_{t-1} is the gross real interest rate on debt B_{t-1}^P. I assume housing does not depreciate. First order conditions of the households with respect to consumption, debt, housing and labor respectively can be written as

$$\frac{1}{C_t^P - \gamma^P C_{t-1}^P} - \beta^P \mathbb{E}_t \frac{\gamma^P}{C_{t+1}^P - \gamma^P C_t^P} = \lambda_t^P \tag{5}$$

$$\beta^P \mathbb{E}_t \lambda_{t+1}^P = \frac{\lambda_t^P}{R_t} \tag{6}$$

$$\frac{\varsigma_t}{H_t^P} + \beta^P \mathbb{E}_t \left(\lambda_{t+1}^P Q_{t+1}^H\right) = \lambda_t^P Q_t^H \tag{7}$$

$$\iota_t = \lambda_t^P W_t \tag{8}$$

where λ_t^P is the Lagrange multiplier associated with household's budget constraint (4). One can combine household's first-order conditions with respect to consumption (5) and debt (6) to obtain their Euler equation. Equation (7) describes household's Euler equation for housing and links today's housing price to the utility it provides plus the expected capital gain. Equation (8) describes household's consumption-leisure tradeoff. All the derivations of first order conditions have been relegated to the Appendix A.

2.2 Entrepreneurs

Following Iacoviello (2005) and Liu, Wang, and Zha (2013), the representative entrepreneur maximizes the utility obtained from consuming the non-durable consumption goods

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \left(\beta^E\right)^t \log\left(C_t^E - \gamma^E C_{t-1}^E\right) \tag{9}$$

where β^E and γ^E are as defined before. I assume that entrepreneurs are more impatient than the households, that is, $\beta^E < \beta^P$. Entrepreneurs face a collateral constraint à la Kiyotaki and Moore (1997) that limits the borrowing of each entrepreneur to a fraction of expected value of their assets

$$B_t^E \leq \frac{1}{R_t}\theta_t a_t \tag{10}$$

Here, B_t^E denotes entrepreneur's loan, expected value of entrepreneur's assets is a_t and R_t is the lending rate. This constraint limits entrepreneur borrowing to a loan-to-value (LTV) fraction θ_t of the expected value of their assets, capturing the idea that lenders require collateral backing for loans and that a tightening of θ_t directly restricts access to credit. LTV requirement θ_t follows the law of motion[6]

$$\log\theta_t = (1-\rho_\theta)\log\theta + \rho_\theta \log\theta_{t-1} + \sigma_\theta\epsilon_{\theta,t} \tag{11}$$

where $\theta > 0$ is the steady-state LTV ratio, $\epsilon_{\theta,t}$ is iid innovation which follows a normal distribution with standard deviation σ_θ and $\rho_\theta \in (0,1)$. My goal in this paper is to examine the implications of exogenous changes in credit conditions, including for institutional and regulatory reasons.The LTV shock captures changes in lending that are exogenous from point of view of both lenders and borrowers. Expected value of entrepreneur's assets a_t is given by

$$a_t = \mathbb{E}_t\left(Q_{t+1}^H H_t^E + Q_{t+1}^K K_t\right) \tag{12}$$

In the above equation, Q_t^K denotes the value of installed capital in units of consumption goods, K_t stock of capital and H_t^E stock of housing.[7] The constraint depends on the expected future value of assets, which means falling expected housing and capital prices tighten the borrowing constraint contemporaneously — a feature that amplifies shocks through a collateral spiral.

Entrepreneurs produce output using a constant returns to scale production function

$$Y_t = A_t\left(N_t\right)^{1-\alpha}\left\{\left(H_{t-1}^E\right)^{\phi}\left(K_{t-1}\right)^{1-\phi}\right\}^{\alpha} \tag{13}$$

where Y_t is output, N_t labor input and $\alpha, \phi \in (0,1)$ are factor shares. TFP A_t follows the process

$$\log A_t = (1-\rho_A)\log A + \rho_A \log A_{t-1} + \sigma_A\epsilon_{A,t} \tag{14}$$

with iid innovation $\epsilon_{A,t}$ following a normal process with standard deviation σ_A and where $A > 0$

[6]In Section 4.3, I also consider a countercyclical LTV rule where θ_t responds endogenously to housing price deviations from steady state.

[7]Chaney, Sraer, and Thesmar (2012) and Liu, Wang, and Zha (2013) emphasize the importance of real estate as collateral for business loans. See also Ivashina, Kalemli-Özcan, Laeven, and Müller (2025) on corporate debt backed by real estate.

and $\rho_A \in (0,1)$. The evolution of capital obeys the following law of motion

$$K_t = (1-\delta) K_{t-1} + \left[1 - \frac{\Omega}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t \tag{15}$$

where I_t is firm's investment level, $\delta \in (0,1)$ the rate of depreciation of capital stock and $\Omega > 0$ is a cost adjustment parameter. The entrepreneur faces the following budget constraint

$$C_t^E + R_{t-1} B_{t-1}^E \leq Y_t - W_t N_t - I_t - Q_t^H \left(H_t^E - H_{t-1}^E\right) + B_t^E \tag{16}$$

The left-hand side captures current consumption and debt service obligations while the right-hand side represents income sources net of factor payments, investment expenditure, and net housing purchases, plus new borrowing. The FOCs of the entrepreneur with respect to consumption, debt, labor, housing, capital and investment, respectively are

$$\lambda_t^E = \frac{1}{C_t^E - \gamma^E C_{t-1}^E} - \beta^E \mathbb{E}_t \frac{\gamma^E}{C_{t+1}^E - \gamma^E C_t^E} \tag{17}$$

$$\lambda_t^E = \beta^E \mathbb{E}_t \lambda_{t+1}^E R_t + \mu_t^E R_t \tag{18}$$

$$W_t = (1-\alpha)\frac{Y_t}{N_t} \tag{19}$$

$$\lambda_t^E Q_t^H = \beta^E \mathbb{E}_t \left[\lambda_{t+1}^E \left(Q_{t+1}^H + \alpha\phi \frac{Y_{t+1}}{H_t^E}\right)\right] + \mu_t^E \theta_t \mathbb{E}_t Q_{t+1}^H \tag{20}$$

$$\kappa_t^E = \alpha(1-\phi)\beta^E \mathbb{E}_t \left(\frac{\lambda_{t+1}^E Y_{t+1}}{K_t}\right) + \beta^E (1-\delta)\mathbb{E}_t \kappa_{t+1}^E + \mu_t^E \theta_t \mathbb{E}_t Q_{t+1}^K \tag{21}$$

$$\lambda_t^E = \kappa_t^E \left[1 - \frac{\Omega}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \Omega \frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}} - 1\right)\right] + \beta^E \Omega \mathbb{E}_t \left[\kappa_{t+1}^E \left(\frac{I_{t+1}}{I_t}\right)^2 \left(\frac{I_{t+1}}{I_t} - 1\right)\right] \tag{22}$$

where μ_t^E, κ_t^E and λ_t^E are Lagrange multipliers associated with entrepreneur's collateral constraint (10), law of motion of capital (15) and entrepreneur's budget constraint (16). Entrepreneur's first order conditions with respect to consumption (17) and debt (18) may be combined to derive Euler equation for consumption for a collateral-constrained agent. Equation (19) describes entrepreneur's optimal demand for labor. Entrepreneur's Euler equations for land and capital are described by (20) and (21), respectively which relate their price today to their expected resale value tomorrow plus the payoff obtained by holding them for a period as given by their marginal productivity and their ability to serve as a collateral. Finally, entrepreneur's Euler equation for the investment is given by (22). Derivation of these first-order conditions has been consigned to Appendix A.

2.3 Aggregation and Market Clearing

Aggregate output in the economy equals consumption of households and entrepreneurs, and entrepreneurial investment

$$C_t^P + C_t^E + I_t = Y_t \tag{23}$$

The total amount of housing in the economy is fixed at H which implies that

$$H_t^P + H_t^E = H \tag{24}$$

Finally, the total net supply of debt in the economy is zero, i.e.

$$B_t^P + B_t^E = 0 \tag{25}$$

2.4 Transmission Mechanism

The transmission channels behind the effects of LTV tightening can be explained as follows. The borrowing constraint (10) can be log-linearized to yield

$$\widehat{l}_t = \widehat{\theta}_t + \widehat{a}_t - \widehat{R}_t \tag{26}$$

which shows that a decline in LTV ratio $\widehat{\theta}_t$ directly reduces entrepreneur's borrowing. Equation (20) in log-linearized form reads

$$\begin{aligned}\left(\widehat{\lambda}_t^E + \widehat{Q}_t^H\right) = \beta^E \mathbb{E}_t\left(\widehat{\lambda}_{t+1}^E + \widehat{Q}_{t+1}^H\right) + \left(\frac{1}{R} - \beta^E\right)\theta \mathbb{E}_t\left(\widehat{\mu}_t^E + \widehat{\theta}_t + \widehat{Q}_{t+1}^H\right)\\ + \left[\left(1-\beta^E\right) - \theta\left(\frac{1}{R} - \beta^E\right)\right]\mathbb{E}_t\left[\widehat{\lambda}_{t+1}^E + \widehat{Y}_{t+1} - \widehat{H}_t^E\right]\end{aligned} \tag{27}$$

A decline in $\widehat{\theta}_t$ reduces the collateral premium that entrepreneurs attach to housing — visible in the second term of the log-linearised housing demand condition — making housing less attractive to hold. Entrepreneurs respond by selling housing, which depresses $\widehat{Q}_t^H$. Since housing simultaneously serves as collateral and as a productive input, its sale reduces both borrowing capacity through $\widehat{a}_t$ and productive capacity through the production function — a dual channel that amplifies the initial tightening. The log-linearized version of Equation (12) which shows entrepreneur's total assets is given by

$$\widehat{a}_t = \frac{Q^H H^E}{Q^H H^E + Q^K K}\mathbb{E}_t\left(\widehat{Q}^H_{t+1} + \widehat{H}^E_t\right) + \frac{Q^K K}{Q^H H^E + Q^K K}\mathbb{E}_t\left(\widehat{Q}^K_{t+1} + \widehat{K}_t\right) \tag{28}$$

Crucially, this creates a feedback loop — falling $\widehat{Q}^H_t$ reduces $\widehat{a}_t$ which tightens $\widehat{l}_t$ further, inducing additional housing sales that further depress $\widehat{Q}^H_t$. Capital prices recover relatively quickly since investment can rebuild the capital stock, while housing prices remain persistently depressed given the fixed aggregate supply — prolonging the collateral spiral and contributing to the persistent wage decline documented below. Equation (15) yields after log-linearization

$$\widehat{K}_t = (1-\delta)\,\widehat{K}_{t-1} + \delta\widehat{I}_t \tag{29}$$

which shows that a fall in investment reduces the stock of capital which directly leads to a drop in output as shown through log-linearized version of production function (13)

$$\widehat{Y}_t = \widehat{A}_t + (1-\alpha)\,\widehat{N}_t + \alpha\phi\widehat{H}^E_{t-1} + \alpha\,(1-\phi)\,\widehat{K}_{t-1} \tag{30}$$

Log-linearizing the entrepreneur's optimal labor demand condition (19) yields

$$\widehat{W}_t = \widehat{Y}_t - \widehat{N}_t \tag{31}$$

Because output falls proportionally more than employment, real wages decline persistently – a result that requires no nominal rigidity and emerges purely from the collateral channel.

3 Model Solution and Parameterization

A period is a quarter in this model. The model is solved by log-linearizing the equilibrium conditions around the steady state and by using perturbation methods. Appendices B, C and D contain the list of equilibrium equations, the list of steady-state conditions and the system of log-linear equations, respectively. The calibration of parameters is standard and as follows (see Table 1).

I allow for a relatively significant difference between discount factors of households and en-

Table 1: Parameter values

	Value	Description	Source
β^P	0.995	Discount factor, households	Iacoviello (2005)
β^E	0.95	Discount factor, entrepreneurs	Iacoviello (2005)
γ^i, $i = \{P, E\}$	0.6	Habits in consumption, households, entrepreneurs	Smets and Wouters (2007)
ι	3.5	Steady state of labor supply shock	See Text
ς	0.0375	Steady state of housing preference shock	Liu, Wang, and Zha (2013)
α	0.3	Non-labor share of production	Iacoviello (2005)
ϕ	0.1	Land share of non-labor input	Iacoviello (2005)
Ω	1.85	Investment adjustment cost parameter	See Text
δ	0.0285	Capital depreciation rate	Beaudry and Lahiri (2014)
ρ_A	0.95	Persistence of technology shock	Smets and Wouters (2007)
ρ_N	0.97	Persistence of labor supply	See Text
ρ_H	0.99	Persistence of housing preference shock	See Text
σ_A	0.0014	Standard deviation of technology shock	Standard
σ_N	0.0014	Standard deviation of labor supply shock	See Text
σ_H	0.014	Standard deviation of housing preference shock	See Text

trepreneurs so that steady-state value of Lagrange multiplier on entrepreneur's collateral constraint μ_t^E is different from zero. I therefore set $\beta^P = 0.995$ and $\beta^E = 0.95$. The degree of habit formation in consumption is chosen to be 0.6 which is in line with empirical estimates (Smets and Wouters, 2007). The steady-state value of labor shock ι is set so that households work about 25% of their time in steady state. Following Liu, Wang, and Zha (2013), the value of ς is calibrated to obtain a ratio of residential land to output in steady state around 1.45 at an annual frequency. The labor income share is 0.3 which implies a steady-state capital-output ratio of 1.15, in line with US data (Liu, Wang, and Zha, 2013). The input share of land in production is close to the value estimated in Liu, Wang, and Zha (2013) and Iacoviello (2005). The investment adjustment cost parameter is set to 1.85. The literature contains estimates which range from 0 (Liu, Wang, and Zha, 2013) to above 26 (Christiano, Motto, and Rostagno, 2010). The capital depreciation rate implies a steady-state ratio of non-residential investment to output a little above 0.13 (Beaudry and Lahiri, 2014).

To capture the effects of LTV tightening, I consider a range of steady-state LTV values – 0.60, 0.70, 0.80 and 0.90. I then examine the effects of one percentage point temporary (when $\rho_\theta = 0.90$) and quasi-permanent (when $\rho_\theta = 1 - 10^{-10}$) LTV tightening, that is, 0.90 becomes 0.89 after the shock. For calibration of other shocks, I follow Smets and Wouters (2007) and set persistence of technology shock to 0.95 and its standard deviation to 0.0014 which is standard in the literature. Smets and Wouters (2007) do not include shocks to housing preferences or labor and I therefore rely on Liu, Wang, and Zha (2013) for their calibration who find these shocks, particularly housing preference shock, more persistent than technology shock. They also find that standard deviation of housing preference shock is an order of magnitude larger than that of technology and labor shocks. I set these shocks accordingly.

4 Results and Discussion

In this section, I discuss the effects of LTV tightening and other shocks. I first consider a one-time temporary tightening of LTV ratios and show how it affects housing prices and economic activity. I also highlight how a temporary tightening can lead to an unintended consequence in terms of protracted decline in household wages. I then consider a quasi-permanent tightening of LTV ratios and find that it leads to larger and permanent declines in housing prices and debt. The results also capture unintended consequences of quasi-permanent LTV tightening — it leads to permanent drop in macroeconomic variables such as investment, output, aggregate consumption and household wages. I will show that in both cases – temporary and quasi-permanent tightening — the effects are highly dependent on initial LTV ratios. I then proceed to examine a series of other negative shocks — a TFP shock, a housing demand shock and a labor supply shock, and show that their effects depend across the board on steady-state LTV ratios. Finally, I consider a countercyclical LTV policy that responds to housing prices and show that it significantly lessens the impact of a negative TFP shock on housing and other macroeconomic variables but its stabilizing effects come at the price of shutting down the reallocation of housing from entrepreneurs to households and it has unintended consequences in terms of agents' consumption. Table 2 provides a summary of peak responses of key variables across steady-state LTV ratios and across various shocks.

Table 2: Peak Impulse Responses Across Shocks and Steady-State LTV Ratios

		Steady-State LTV Ratio			
Shock	Variable	0.90	0.80	0.70	0.60
Temporary LTV	Output	-0.87	-0.77	-0.69	-0.63
	Investment	-2.82	-2.83	-2.83	-2.81
	Wages	-1.20	-0.76	-0.57	-0.45
	Housing Price	-1.32	-0.84	-0.62	-0.49
Permanent LTV	Output	-2.66	-1.86	-1.48	-1.24
	Investment	-9.84	-8.12	-7.26	-6.68
	Wages	-1.88	-0.89	-0.58	-0.51
	Housing Price	-3.94	-1.95	-1.23	-0.87
Negative TFP	Output	-3.53	-2.94	-2.49	-2.16
	Investment	-10.03	-8.99	-7.94	-6.99
	Wages	-2.74	-2.06	-1.82	-1.69
	Housing Price	-3.10	-2.25	-1.92	-1.75
Negative Housing	Output	-0.19	-0.15	-0.12	-0.10
	Investment	-0.59	-0.55	-0.50	-0.45
	Wages	-0.13	-0.06	-0.03	-0.02
	Housing Price	-0.50	-0.46	-0.45	-0.44
Negative Labor	Output	-0.24	-0.20	-0.17	-0.15
	Investment	-0.66	-0.59	-0.52	-0.46
	Wages‡	-0.05	-0.02	-0.02	-0.01
	Housing Price	-0.21	-0.16	-0.13	-0.12

Note: All values report the peak (trough) percentage deviation from steady state — computed as the minimum value over the 40-quarter horizon — following a one percentage point shock in case of LTV tightening (both temporary and permanent) and for other shocks, as reported in Table 1. ‡ Wages exhibit sign-switching under the labor disutility shock; the reported value is the peak negative response following the initial positive spike.

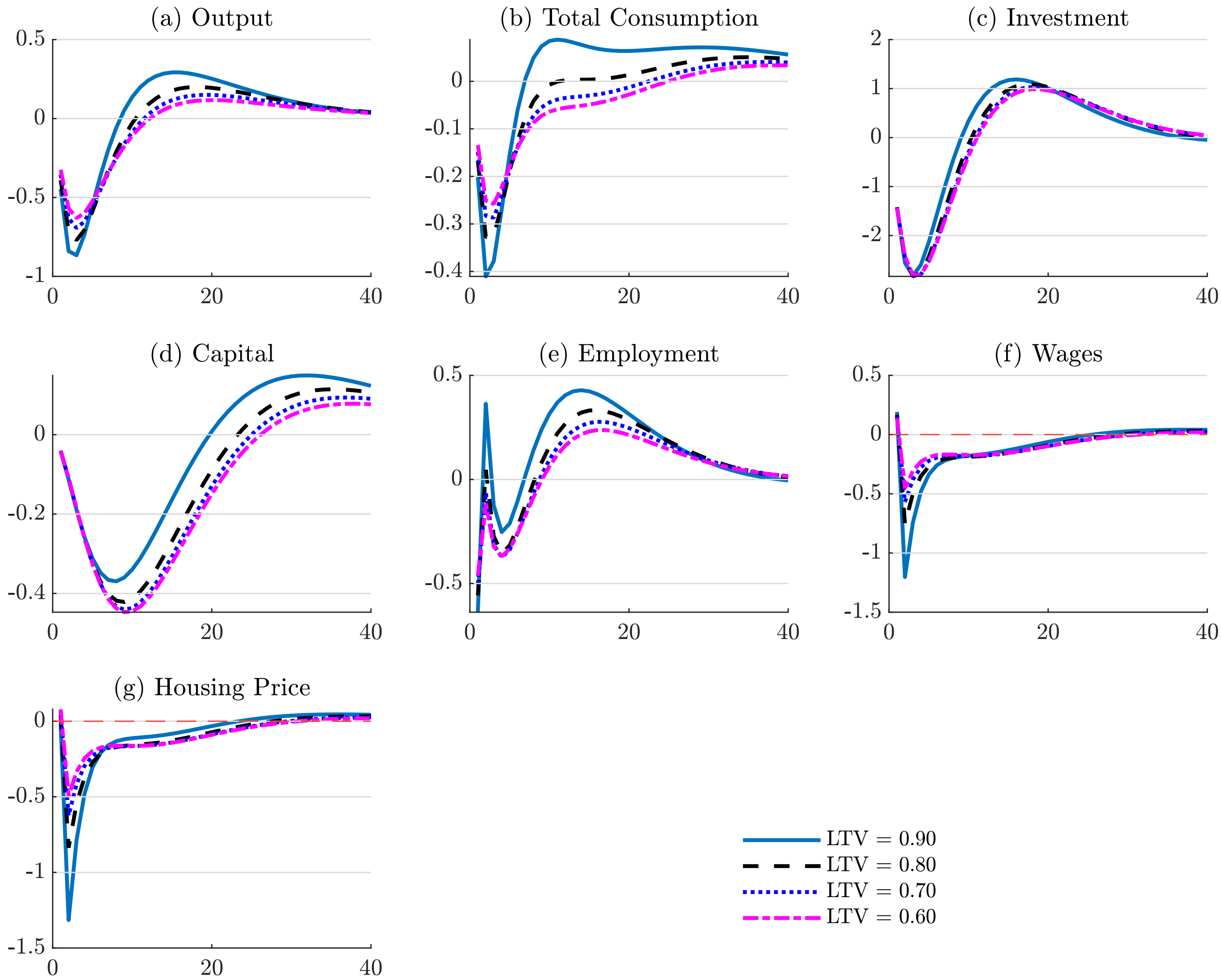
4.1 Effects of a Shock to LTV Ratios

This subsection describes effects of LTV shocks under different steady-state LTV ratios and shows that impacts of both temporary and permanent LTV shocks display strong dependence on initial LTV ratios. I first discuss impact of a transitory LTV shock before studying effects of a permanent LTV shock. Given the focus in this paper on LTV tightening, I look at negative shocks. For the clarity of exposition and to keep the discussion and presentation manageable, I consider four steady-state LTV ratios – 0.90, 0.80, 0.70 and 0.60.

4.1.1 Effects of a Transitory LTV Tightening

I consider the macroeconomic implications of a temporary negative shock implying a 1 percentage point reduction in steady-state LTV ratios on impact, that is, 0.90 becomes 0.89 after the shock. After a shock, the LTV ratios come back to their steady-state value at the rate $\rho_\theta = 0.90$. A temporary LTV shock leads to a tightening of entrepreneur's collateral constraint who

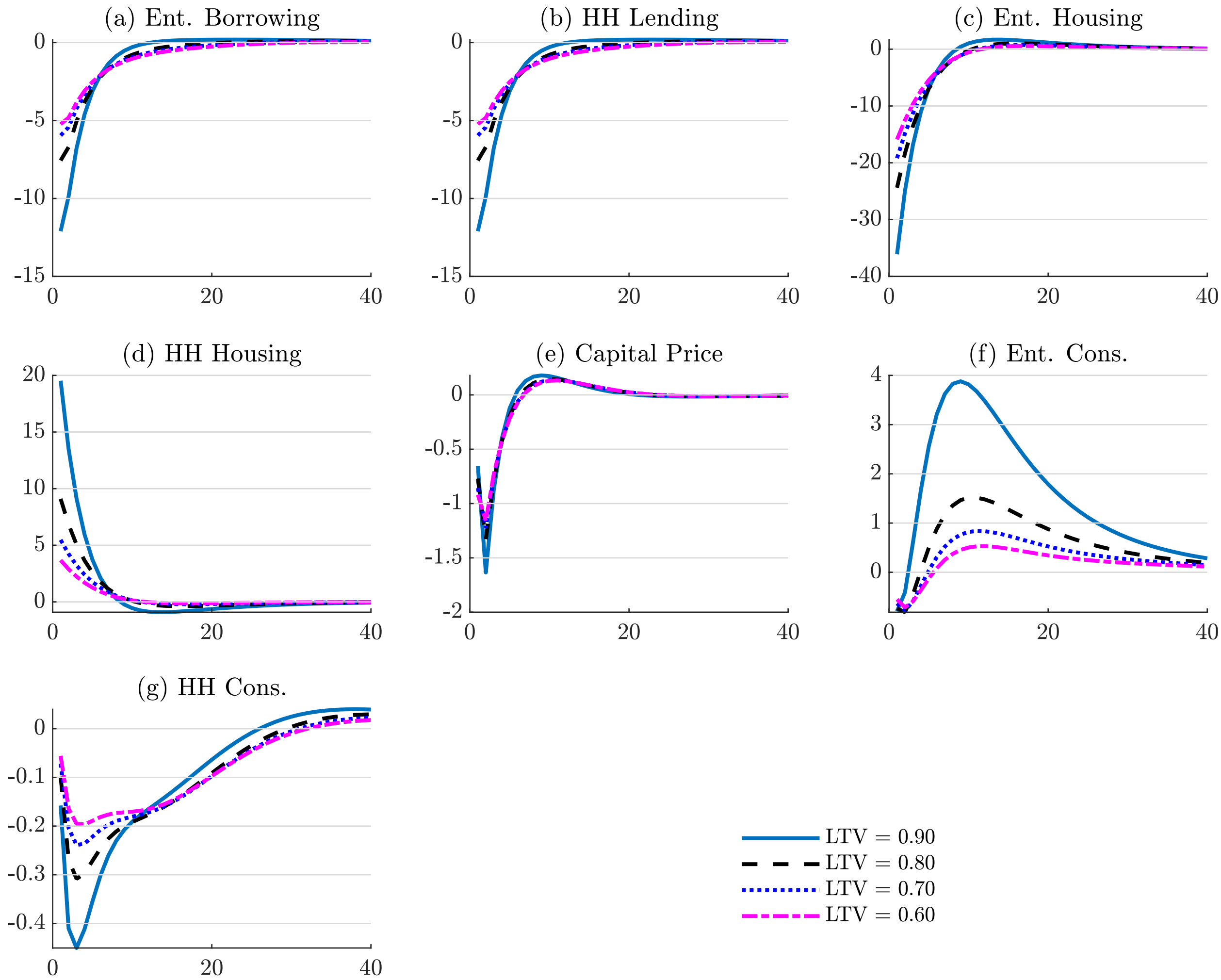
Figure 1: Impact of a Temporary LTV Shock



Note: Impact of a temporary shock that leads to 1 percentage point decline in LTV ratio from its steady-state value. Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

respond by reducing their borrowing and selling their housing (see Figure 1). After the LTV tightening, entrepreneurs consider their assets less useful in terms of how much they can help them borrow through their use as collateral. Consequently, entrepreneurs sell their housing and part of proceeds from sale of their housing flows into their consumption. This collateral tightening has downstream effects on investment since entrepreneurs cannot borrow now as much as they were able to before which translates into a fall in capital stock, wages, aggregate consumption and a reduction in aggregate output (see Section 2.4). In virtually every case, the higher the steady-state LTV ratio, the bigger the drop. This shows that steady-state LTV ratios when the LTV tightening begins play an important role in determining the magnitude of the impact. For example, a drop in LTV ratios from 0.90 leads to a fall in entrepreneurial borrowing by more than 10% (see Figure 2). Entrepreneurs sell more than 30% of their housing which leads to a drop

Figure 2: Transmission Channels – Temporary LTV Shock



Note: Impact of a temporary shock that leads to 1 percentage point decline in LTV ratio from its steady-state value. Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

in housing prices by close to 1.5%. Households absorb the housing sold by entrepreneurs, with their consumption declining as wages and output fall while entrepreneurs' consumption rises by close to 4%. It is noteworthy that difference in increase in peak entrepreneurial consumption when steady-state LTV ratio is 0.90 versus when it is 0.80 is more than 3 times which is not the case when comparing other steady-state LTV ratios such as 0.80, 0.70 and 0.60. This points towards effects of LTV shocks that are highly dependent on initial LTV ratios.

Households respond to a temporary tightening in lending standards by increasing their holdings of housing stock being sold by entrepreneurs. Recall that housing is in fixed supply so when the entrepreneurs sell it, it is the households who buy. Unlike entrepreneurs, households respond to the LTV shock by reducing their consumption and increasing their holdings of housing stock. Lending by households falls since entrepreneurial borrowing plummets and in this model there is one-to-one mapping between the two — households lend and entrepreneurs borrow. There is no financial sector and funds move directly between the two agents. Most of the variables return to their steady state after the initial change at the time of the shock which is in line with the transitory nature of the LTV tightening.

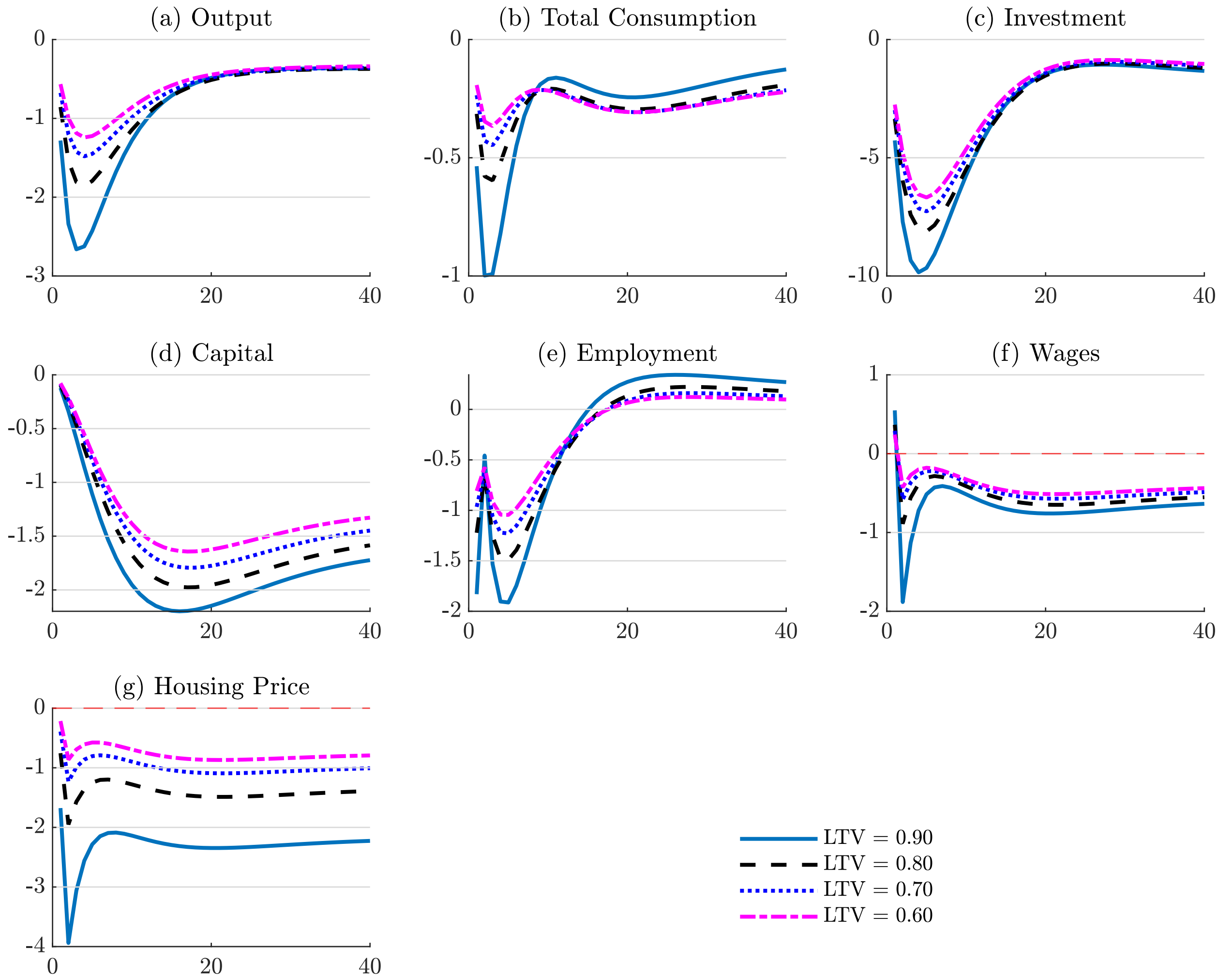
4.1.2 Effects of a Permanent LTV Tightening

I now look at the effects of a quasi-permanent shock to steady-state LTV ratios.[8] The analysis here focuses on impacts of shocks implying a 1 percentage point decline in steady-state LTV ratios on impact (that is, 0.90 becomes 0.89 after the shock) and after which LTV ratios come back to their steady-state value at a rate governed by $\rho_\theta = 1 - 10^{-10}$. Figure 3 shows the response of different variables to a permanent tightening in LTV ratios. After the permanent tightening, entrepreneurs drastically deleverage and sell off their housing as it now does not allow them to borrow as much as it did before. When the steady-state LTV is 0.90, entrepreneur's holding of housing stock falls over 60% on impact and house prices, as a result, fall by 4% on impact before recovering and then persistently stay more than 2% below their pre-shock level. De Veirman (2023) and Kiyotaki, Michaelides, and Nikolov (2024) document permanent housing price declines in New Keynesian and OLG models, respectively. The present model generates substantially larger effects — housing prices fall by nearly 4% on impact at LTV=0.90 and permanently settle more than 2% below steady state — reflecting the absence of nominal frictions that otherwise buffer the collateral shock.

Part of proceeds from housing sales is used by entrepreneurs to finance their increased consumption since they no longer invest as much as they did before which leads to a persistent decline in investment, capital stock and output. All these effects are much more pronounced and persistent than in the case of a transitory shock. Interestingly, investment, capital stock and output do not return to their steady-state value even after 10 years (40 quarters). This points towards highly persistent effects of permanent LTV tightening and is in contrast to the finding in De Veirman (2023) who reports that after a permanent tightening, aggregate consumption, investment and output return to their previous equilibrium after a few quarters. A novel finding in the paper that points directly to unintended consequences of LTV tightening is that after a permanent tightening of lending standards, wages drop by close to 2% at impact before declin-

[8] Alpanda and Zubairy (2017), Bruneau, Christensen, and Meh (2018) and De Veirman (2023) conduct similar experiments.

Figure 3: Impact of a Permanent LTV Shock

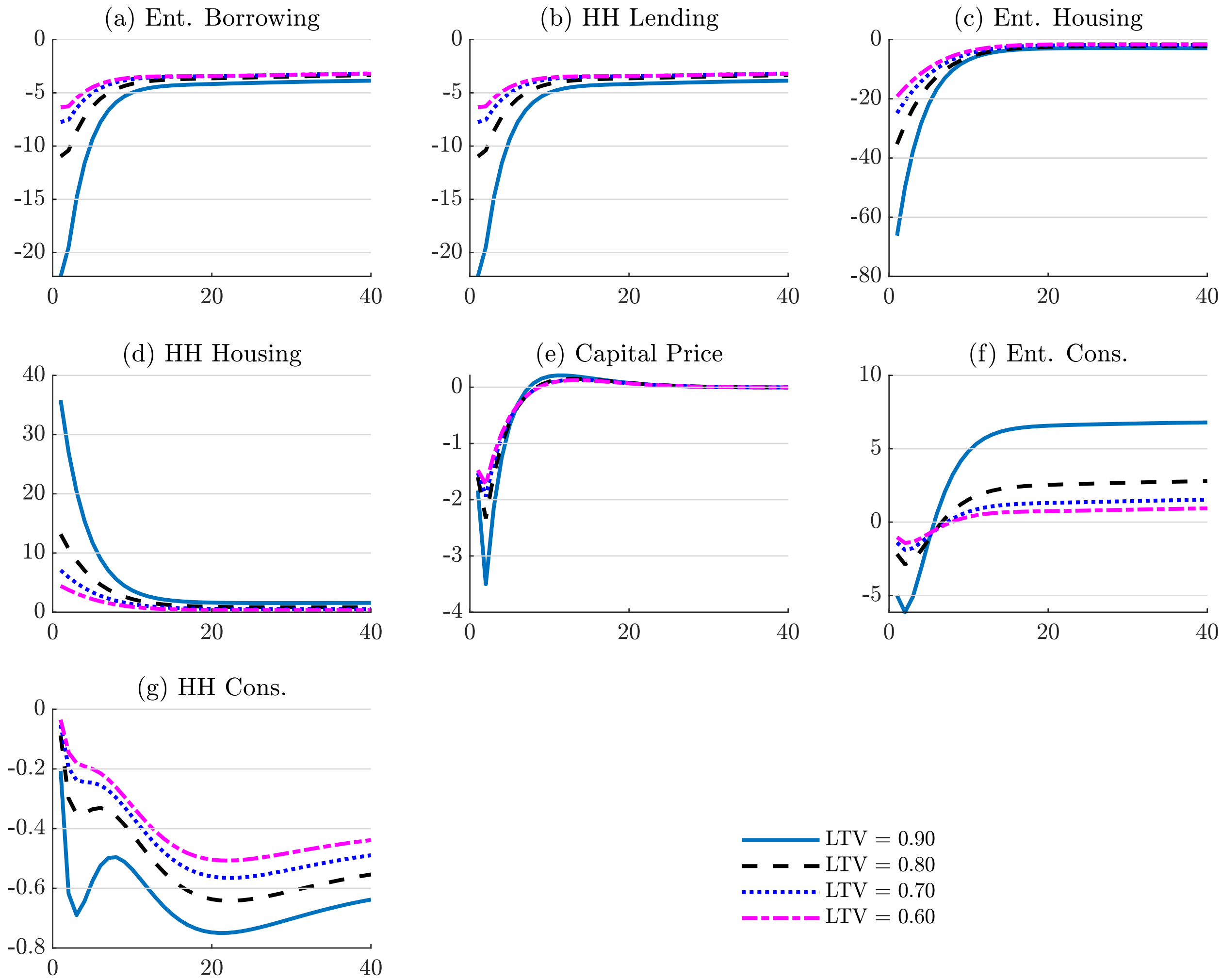


Note: Impact of a permanent shock that leads to 1 percentage point decline in LTV ratio from its steady-state value. Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

ing permanently which is due to persistent collapse in investment and highly sustained drop in capital stock.

Households, as in the case of a transitory LTV tightening, respond by reducing their consumption and substantially increase their housing stock by more than 30% (see Figure 4). Household's buying of housing varies substantially across different steady-state LTV ratios. When the permanent LTV tightening takes place at the steady-state LTV ratio 0.80, households buy less than 15% of housing stock but increase it up to more than 35% when the steady-state LTV ratio is 0.90 — a difference of more than 100%. Lending by households drops by over 20% which is almost the double the fall in lending by households in the case of a transitory LTV shock. Entrepreneurs' borrowing declines by an equal magnitude as they cut down on their borrowing and investment and their consumption rises. These effects are much stronger than in the case of

Figure 4: Transmission Channels – Permanent LTV Shock



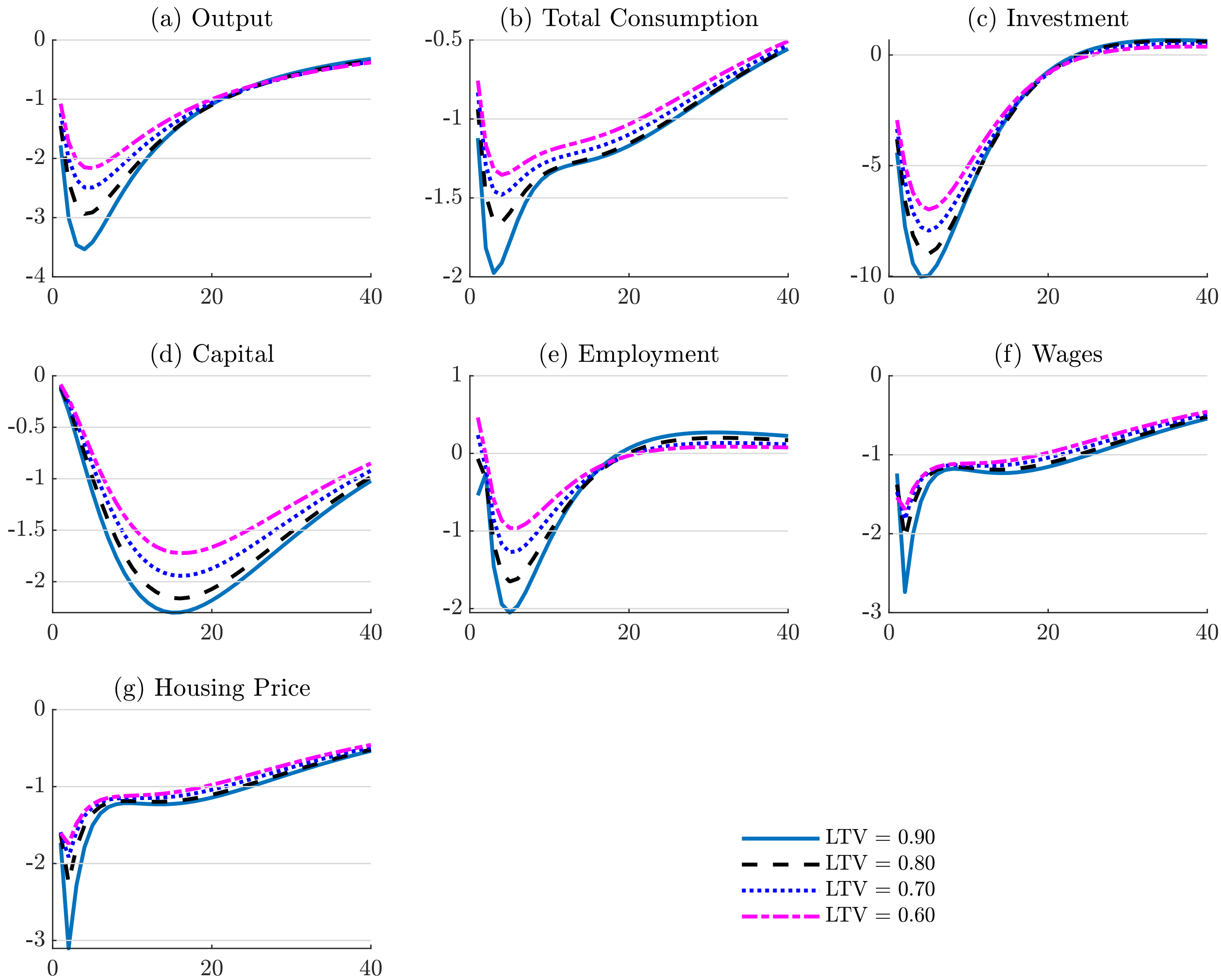
Note: Impact of a permanent shock that leads to 1 percentage point decline in LTV ratio from its steady-state value. Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

a temporary LTV tightening and effects of a permanent tightening of lending standards continue to depend critically on steady-state LTV ratios. The paper documents, differently from nominal models (Alpanda and Zubairy, 2017; Bruneau, Christensen, and Meh, 2018; De Veirman, 2023), that a permanent tightening of lending standards can lead to a permanent drop not only in housing prices but also credit, investment, wages and output, and indicates towards unintended consequences such policies may have.

4.2 Effects of Other Shocks

I now discuss the implications of changes in steady-state LTV ratios for other shocks commonly studied in the macroeconomics literature. Specifically, I consider a TFP shock, a housing demand shock and a labor supply shock. I show that the steady-state LTV ratios act as an amplification parameter for any shock hitting the economy. A higher LTV economy is more fragile across the board — to demand shocks, supply shocks, and credit shocks alike.

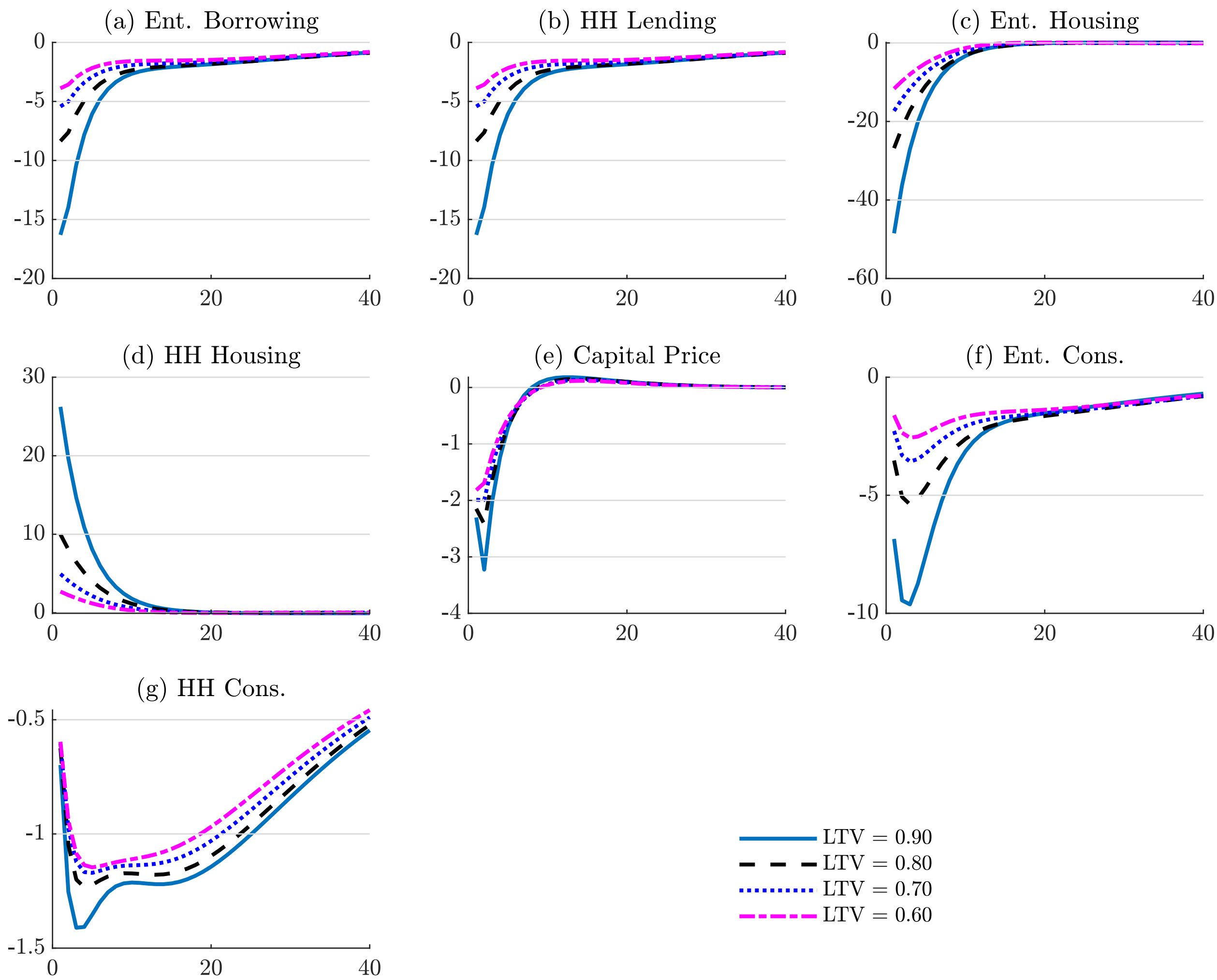
Figure 5: Impact of a Negative TFP Shock



Note: Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

Figure 5 shows effects of a negative TFP shock which is a real shock unlike LTV tightening which is a credit shock. It is clear that effects of TFP shocks also depend significantly on initial LTV ratios with key variables such as investment, output, housing prices and wages falling more on higher steady-state LTV ratios. A negative shock reduces the productivity of entrepreneurs and the return on deployed capital. Consequently, entrepreneurs sell off their housing stock and curtail their borrowing, leading to a persistent decline in investment, capital stock and wages. Wages fall by close to 3% at LTV = 0.90 — the largest wage decline across all shocks studied in this paper (see Table 2) — reflecting the persistent collapse in investment and capital stock at higher leverage levels. Aggregate consumption also decreases persistently since both households' and entrepreneurs' consumption decline (Figure 6). Housing prices drop significantly at impact by close to 3% when LTV ratio is 0.90 and then decline persistently — indicating that it responds not only to LTV tightening but also to TFP shocks driven by rapid deleveraging by entrepreneurs and liquidation of their housing stock. Capital prices recover relatively quickly since investment can rebuild the capital stock, while housing prices decline persistently given the fixed aggregate supply — a distinction that prolongs the collateral spiral and explains the persistent wage decline at higher LTV ratios.

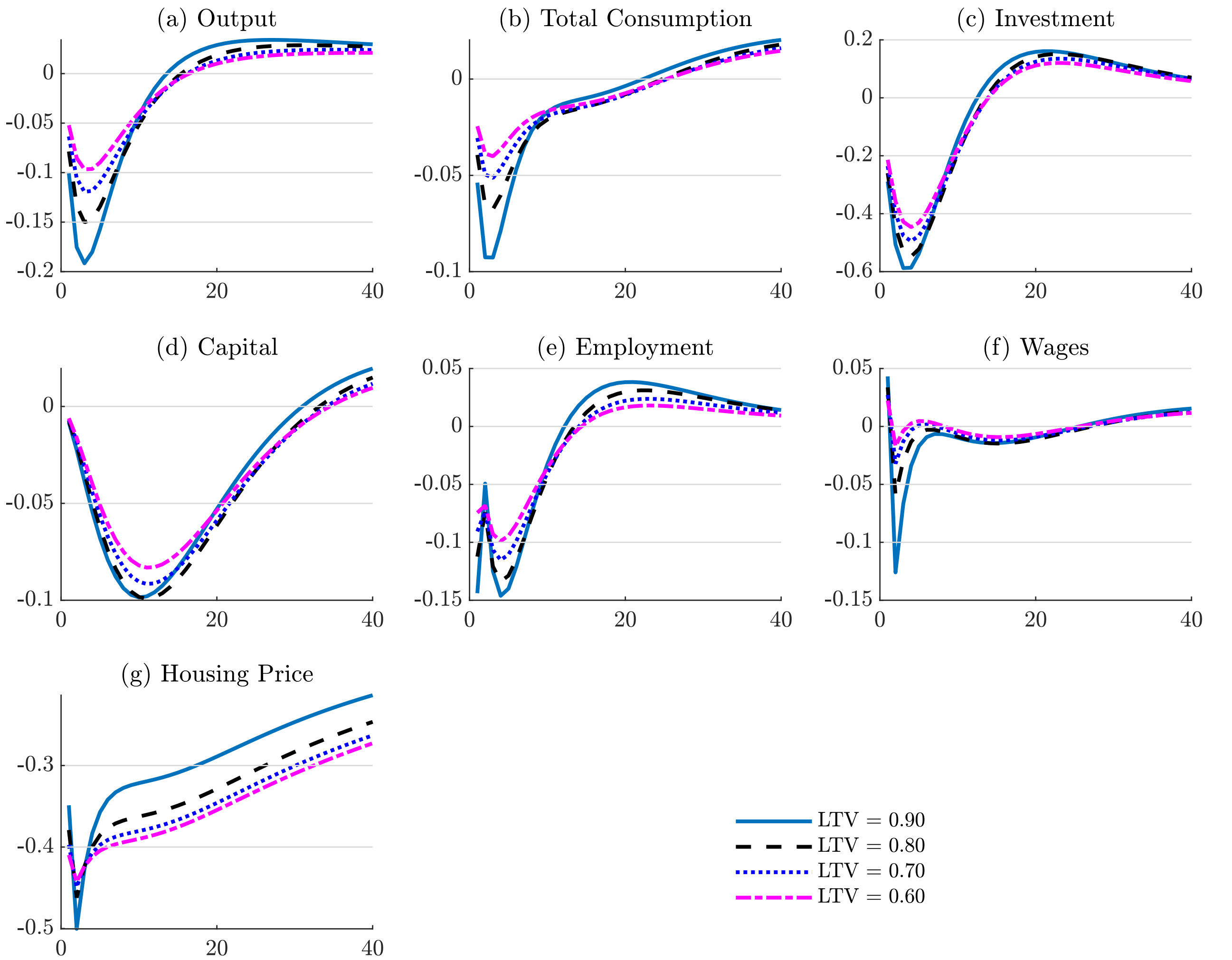
Figure 6: Transmission Channels – Negative TFP Shock



Note: Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

I now examine how steady-state LTV ratios affect the transmission of negative housing demand shocks. These shocks have comparatively smaller but persistent effects on housing prices. Only households obtain direct utility from housing while entrepreneurs hold it as an asset that serves the twin purposes of being a collateral that can be posted for borrowing and an input in the production process. A negative housing shock reduces the weight households place on it and this directly reduces the utility they obtain from holding it. Consequently, households value it less which leads to a drop in housing prices (Figure 7), reducing the entrepreneurs' benefits from it. Entrepreneurs sell off housing, making it cheaper which is then absorbed by households (Figure 8) who are the only buyers in the economy and unlike entrepreneurs, are unconstrained. An important implication of these results is that they show that even a modest disturbance arising from households' preferences about housing can have persistent effects on housing prices through a general equilibrium reallocation driven by the binding collateral constraint rather than household preferences. They also show how this impact is shaped by leverage of the economy.

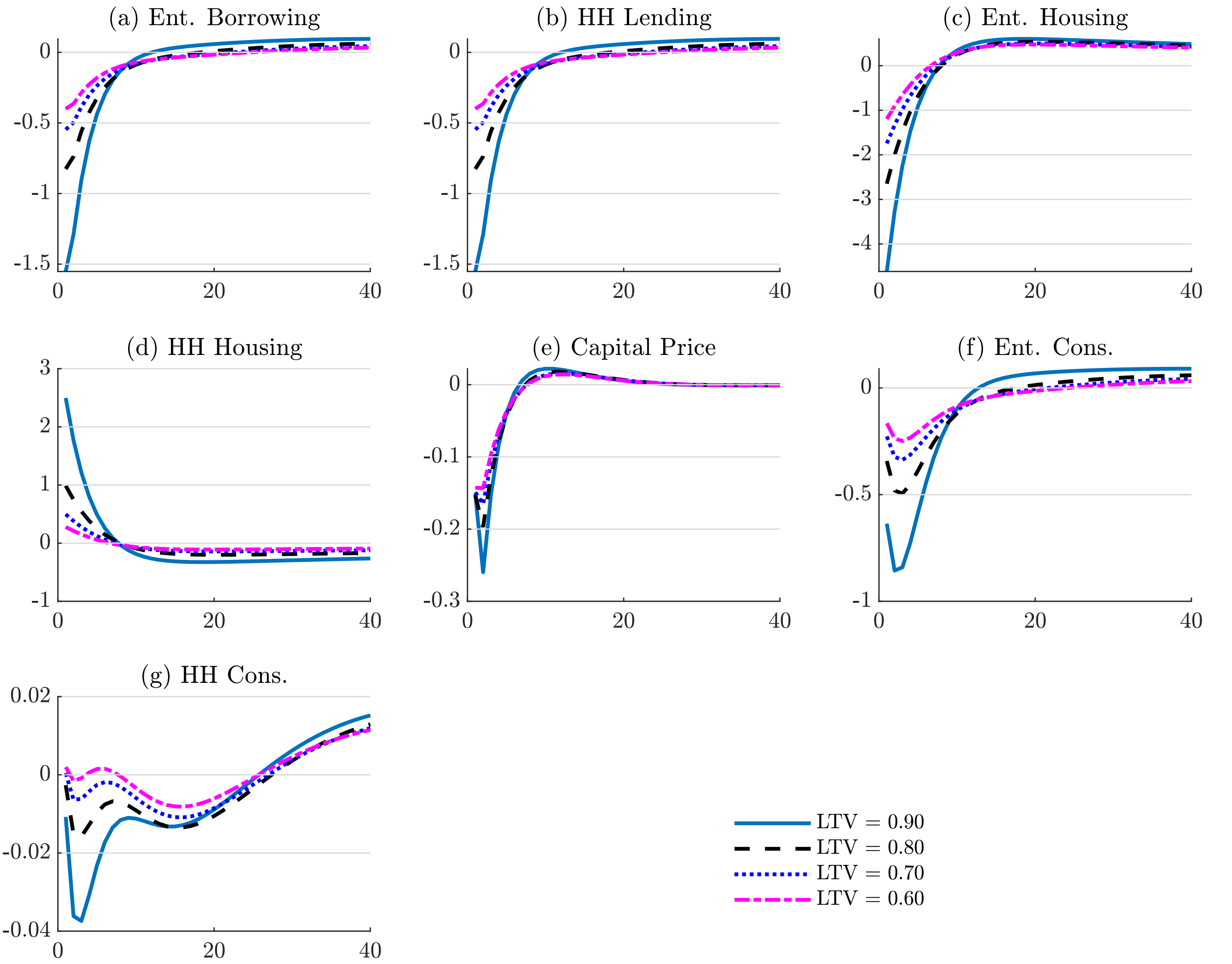
FIGURE 7: IMPACT OF A NEGATIVE HOUSING DEMAND SHOCK



NOTE: Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

The mechanism driving the differential effects of a negative housing demand shock is related to entrepreneurs' deleveraging behavior and how they reduce their housing stock at various steady-state LTV ratios. At higher initial LTV ratios, entrepreneurs respond more forcefully to a negative housing demand shock, deleveraging more and liquidating a larger share of their housing stock which results in a larger fall in housing prices, further tightening their borrow-

Figure 8: Transmission Channels – Negative Housing Demand Shock

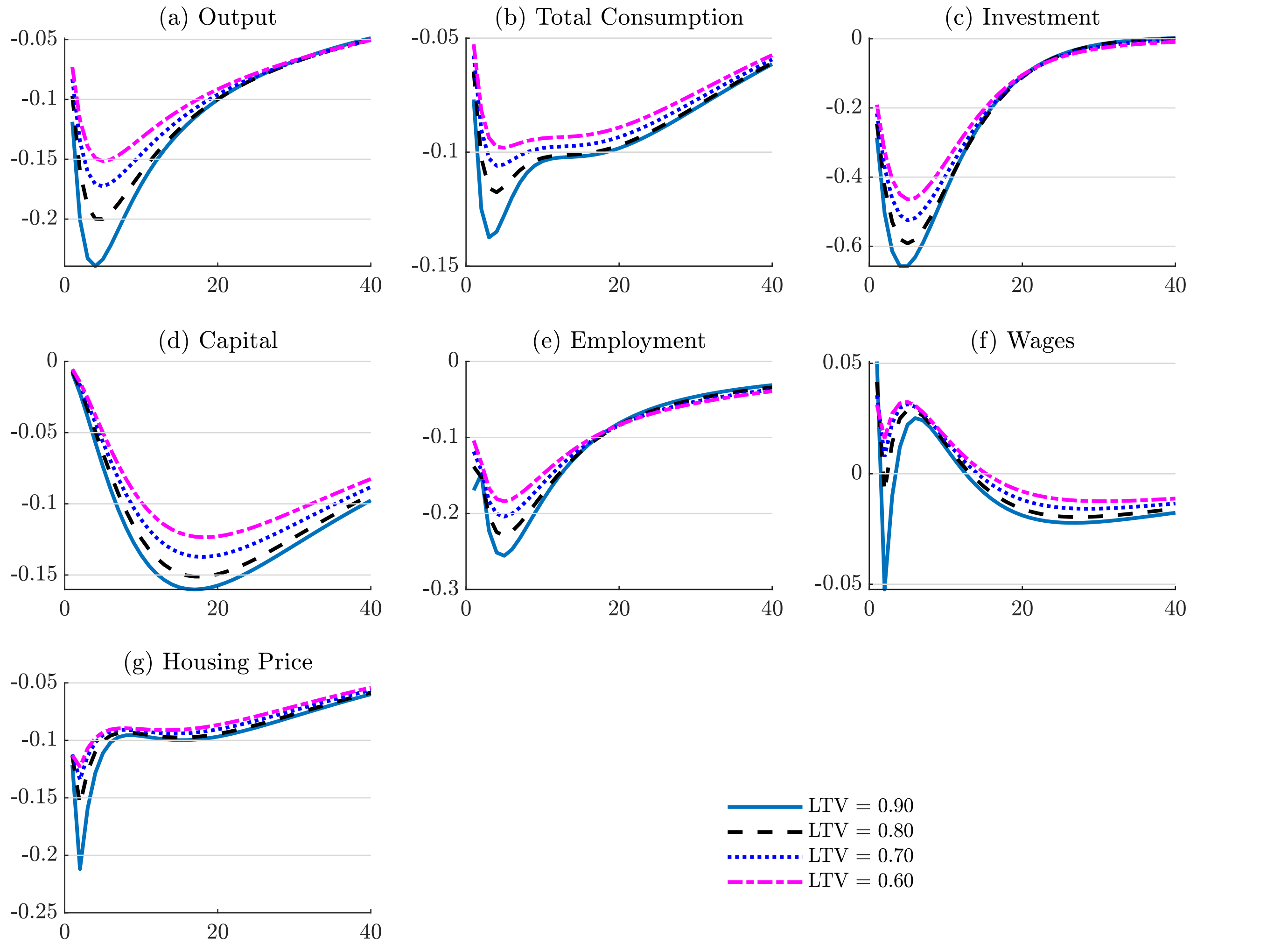


Note: Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

ing constraint. This generates a greater drop in investment at higher initial LTV ratios and additional downstream effects on aggregate consumption and output.

I now investigate how initial LTV ratios shape the effects of a negative labor supply shock in this model. A labor shock increases the disutility from working and leads to a drop in employment (Figure 9). This results in a drop in output and return on assets. Entrepreneurs deleverage and sell off housing which results in a comparatively small but persistent decline in housing prices (Figure 10). These effects are larger at higher initial LTV ratios because entrepreneurs deleverage more and liquidate a greater portion of their housing stock on higher initial LTV ratios to relax their borrowing constraint. Wages exhibit an interesting pattern – initially rising as the labor supply contraction raises the marginal product of labor, before falling persistently as the output decline dominates. This sign-switching is more pronounced at higher initial LTV ratios where the subsequent output collapse is larger.

Figure 9: Impact of a Negative Labor Shock



Note: Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

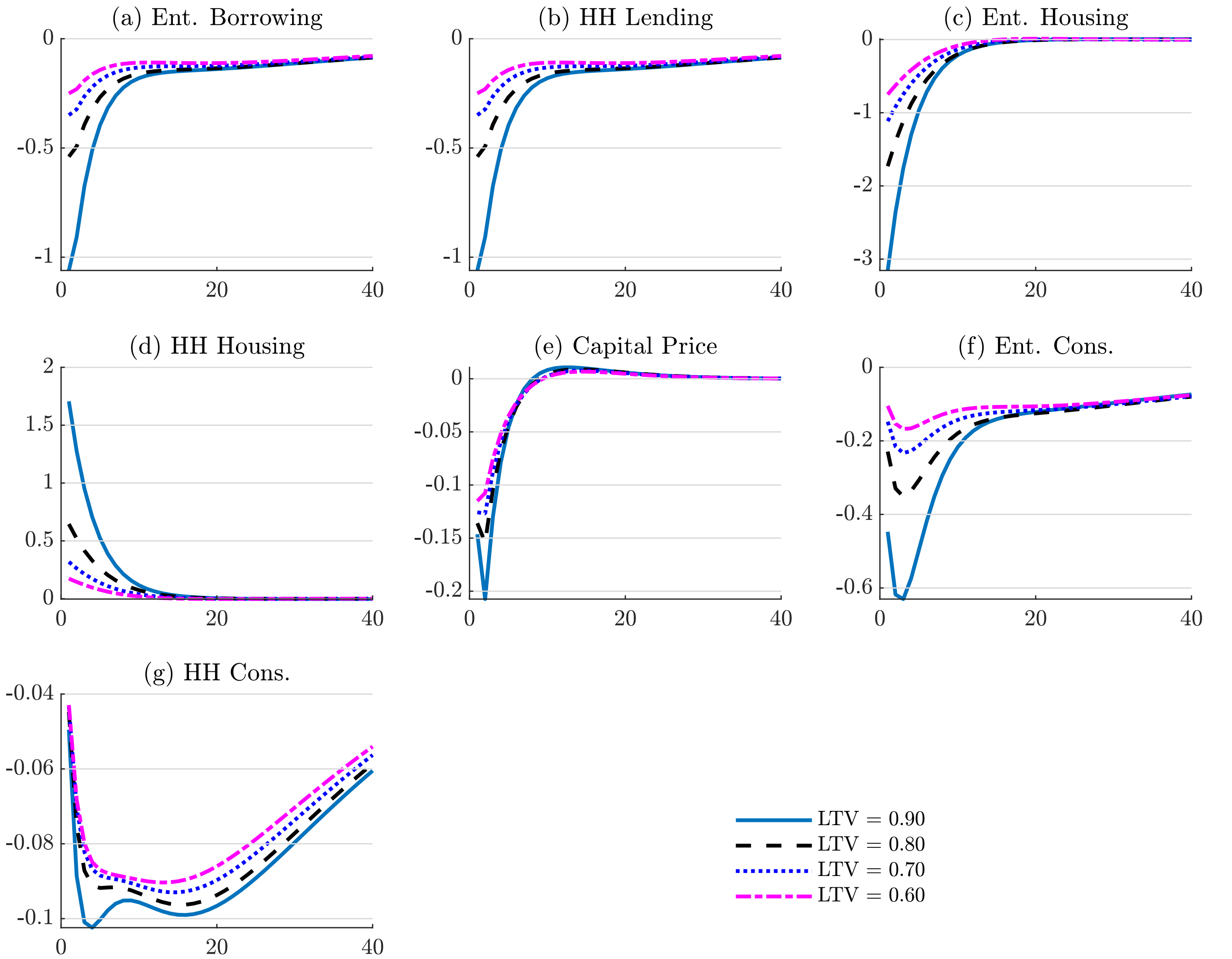
4.3 A Countercyclical LTV Ratio

I posit a countercyclical LTV ratio as follows

$$\theta_t = \theta - \Theta \left(Q_t^H - Q^H \right) \tag{32}$$

which, differently from Equation (11) in Section 2.2, shows that LTV ratio θ_t moves around its steady state value θ and responds to changes in housing prices. I consider three levels of countercyclicity: $\Theta = 0$ (no LTV rule), $\Theta = 0.5$ (mild LTV rule) and $\Theta = 0.85$ (strong LTV rule). The values of Θ are chosen to span a range from no policy response to a strong response that nearly eliminates the housing reallocation observed under no rule and capture increasingly greater degrees of countercyclical reaction to deviation in housing prices from their steady state. When $\left(Q_t^H - Q^H \right) < 0$, the LTV ratio θ_t endogenously relaxes (see Figure 12), allowing borrowers

Figure 10: Transmission Channels – Negative Labor Shock



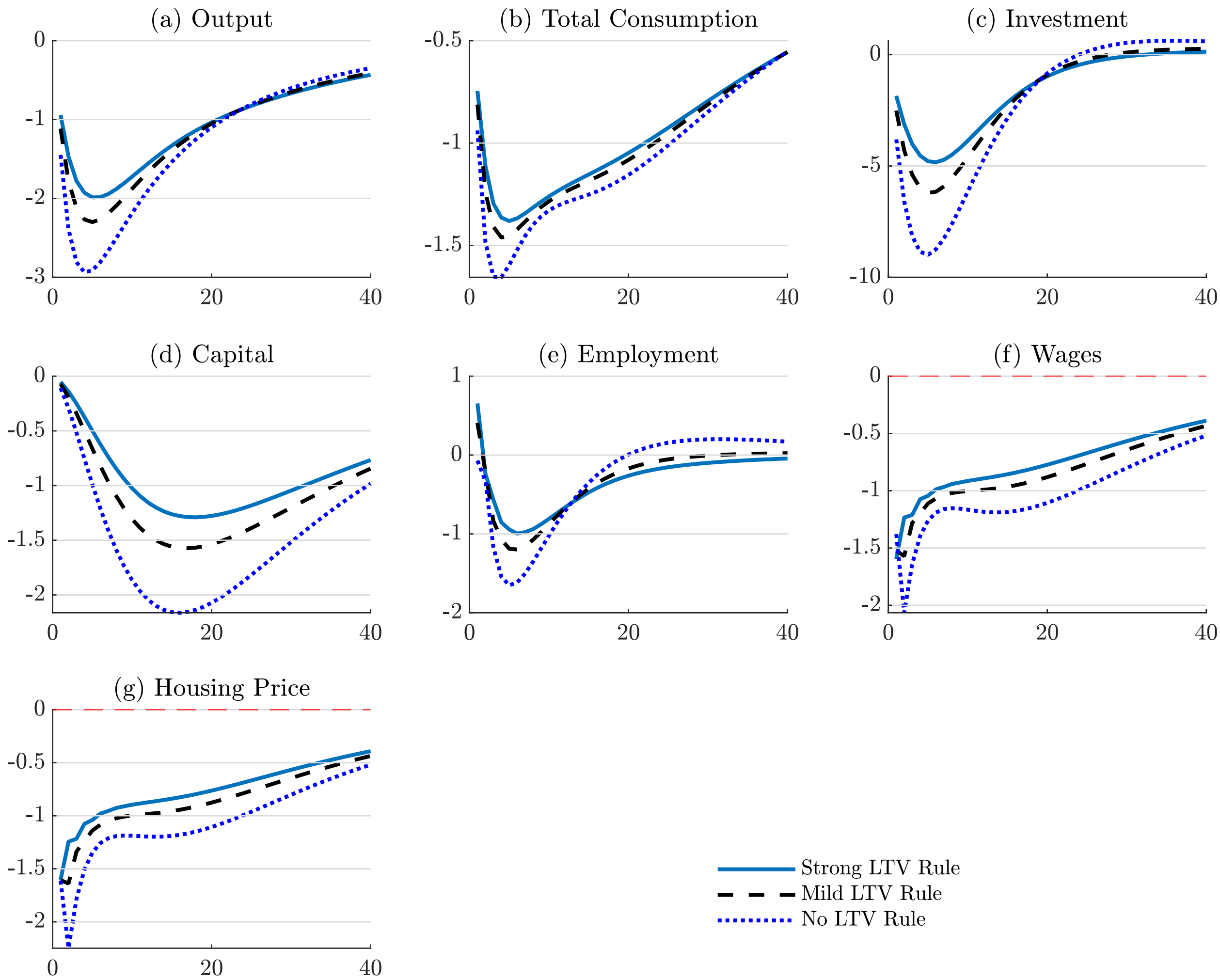
Note: Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

to access larger credit which helps mitigate the negative effects of TFP shocks.

As Figure 11 shows, countercyclical LTV ratios have a significant effect in mitigating the negative effects of TFP shocks. In presence of strong LTV rule, housing prices drop less and recover faster. Economic aggregates such as output and investment also fall significantly less, helping offset partially the effects of TFP shocks. Importantly, strong LTV rule almost completely shuts down the reallocation of housing from entrepreneurs to households. As LTV ratios move countercyclically to limit the effects of TFP shocks, entrepreneurs no longer deleverage and sell off housing as they are no longer as constrained as they were before. This points to an interesting unintended consequence of macroprudential tools like LTV ratios. In this model, the countercyclical LTV ratios help cushion the economy against the negative effects of TFP shocks but it comes at the expense of the asset windfall that patient household lenders would otherwise receive when entrepreneurs sell housing at distressed prices in absence of LTV rule.

When the rule is active, patient household lenders lose this windfall. In terms of consumption, this generates an unexpected distributional consequence — the rule benefits patient household lenders in consumption terms, whose consumption falls less and recovers faster under a strong rule, while entrepreneur borrowers remain leverage-constrained and consumption-depressed for longer despite the rule being designed to ease their borrowing conditions. A policy intended to protect constrained borrowers ends up benefiting unconstrained lenders more in consumption terms — an unintended consequence that aggregate stabilization metrics do not capture.

Figure 11: Impact of a Negative TFP Shock in Presence of Countercyclical LTV Ratio

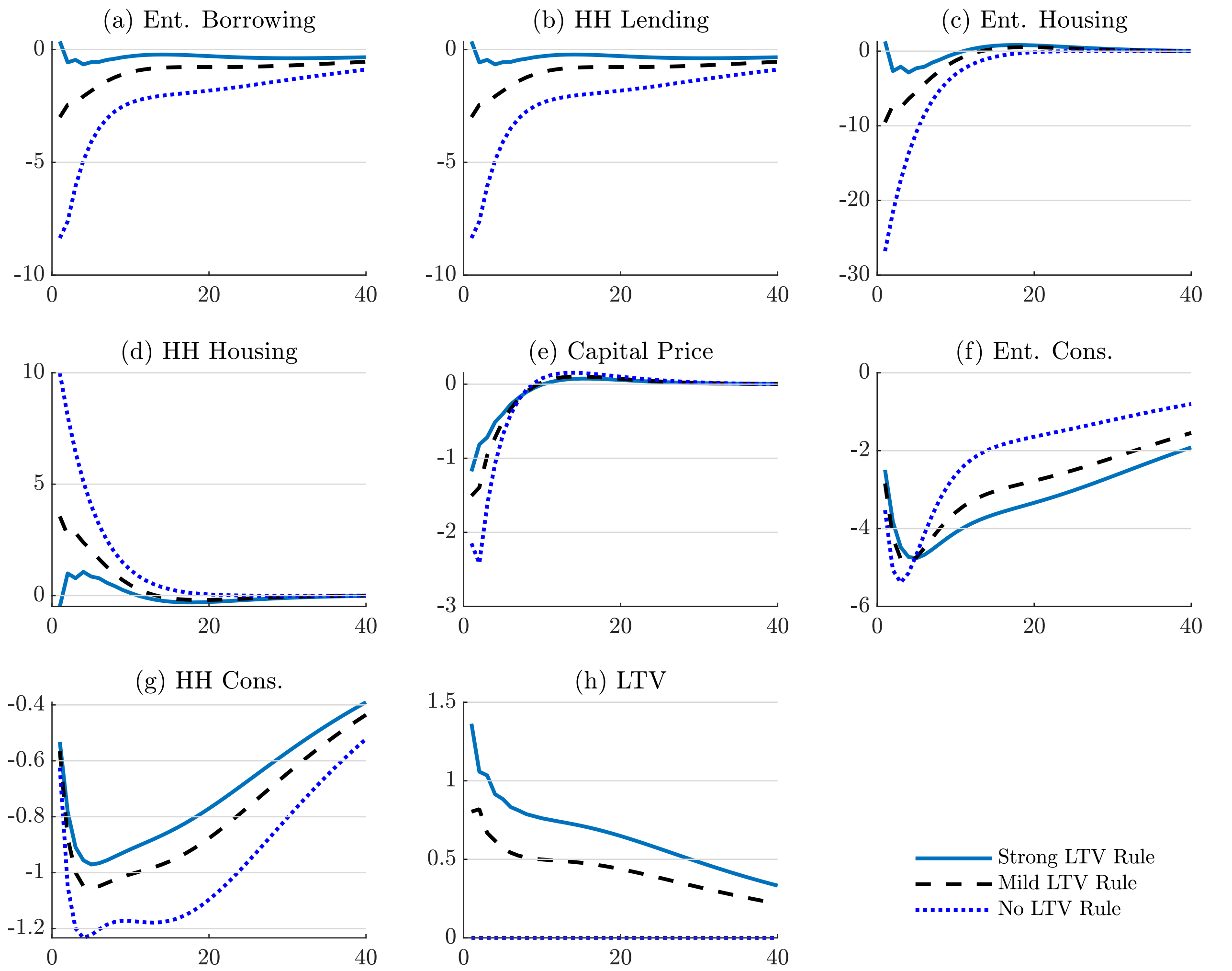


Note: Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

5 Conclusion

Using a flexible price two agent framework with household lenders and entrepreneur borrowers, I show that the impact of loan-to-value (LTV) tightening depends critically on the initial ratio

Figure 12: Transmission Channels – Negative TFP Shock in Presence of Countercyclical LTV Ratio



Note: Numbers on the horizontal axis are quarters since the shock. Numbers on the vertical axis show percentage deviation from steady state.

at which the tightening begins. A temporary tightening leads to a fall in housing prices and wages, and when permanent, results in permanent decline in housing prices, credit, investment, output, aggregate consumption and wages. These effects are very large — a one percentage point temporary tightening leads to more than 1 percent decline in housing prices and wages while a permanent tightening results in more than 2 percent permanent decline in housing prices. I also show that high economy-wide leverage increases fragility across the board by amplifying the effects of other common macroeconomic shocks such as TFP, housing and labor shocks, and thereby establishing steady state LTV ratios as a structural parameter increasing economic fragility.

A countercyclical LTV rule that responds to changes in housing prices mitigates the effects of negative TFP shocks and stabilizes the economy by endogenously relaxing entrepreneurs' borrowing constraint during a downturn and thereby suppressing the forced reallocation of housing from entrepreneurs to households that would otherwise occur. While the rule benefits households in consumption terms — whose consumption recovers faster under a strong rule — it simultaneously eliminates the asset transfer that would otherwise occur, as households no longer acquire housing at distressed prices. The welfare consequences of the rule are therefore multidimensional — households gain in consumption flow but lose in asset accumulation, while entrepreneurs remain leverage-constrained and consumption-depressed despite the rule easing their borrowing conditions.

The findings in the paper have direct policy implications. They show that one-size-fits-all LTV cap policies are not suitable. Amplification of shocks and their persistence hinges critically on leverage ratios in the economy which should be considered when designing policy. These results also point towards potential unintended consequences that these policies might have on credit, investment and output in the economy. As discussed by Ono, Uchida, Udell, and Uesugi (2021), these policies risk throttling credit to the productive sector of the economy which suggests that these policies should be carefully calibrated bearing in mind the initial level of leverage in the economy and the nature of the credit environment. The countercyclical rule analysis further suggests that macroprudential stabilization tools, while effective at the aggregate level, can have asymmetric distributional consequences across borrowers and lenders that policymakers should account for when designing rule-based frameworks.

The framework deliberately abstracts from formal financial intermediation to isolate the direct collateral channel between entrepreneur borrowers and household lenders. Incorporating banks and financial intermediaries — with their own balance sheet constraints and regulatory requirements — could generate additional amplification through a bank lending channel that interacts with the collateral spiral documented here. Examining this interaction, as well as the implications of LTV policy in open economies where entrepreneurs can substitute toward foreign credit, represents a natural extension of the present framework.

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Appendix (For Online Publication)

The (Un)Intended Consequences of Loan-to-Value Ratio Tightening

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Contents

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A Derivation of FOCs

A.1 Households

The Lagrangian of households is

$$\mathscr{L}_t = \mathbb{E}_t \left\{ \sum_{t=0}^{\infty} \left(\beta^P\right)^t \left[\begin{array}{c} \log\left(C_t^P - \gamma^P C_{t-1}^P\right) - \iota_t N_t + \varsigma_t \log H_t^P \\ -\lambda_t^P \left[C_t^P + Q_t^H \left(H_t^P - H_{t-1}^P\right) + R_{t-1} B_{t-1}^P - W_t N_t - B_{t-1}^P \right] \end{array} \right] \right\} \quad \text{(A.1)}$$

The problem yields the following first order conditions:

$$\frac{\partial \mathscr{L}}{\partial C_t^P} : \frac{1}{C_t^P - \gamma^P C_{t-1}^P} - \beta^P \mathbb{E}_P \frac{\gamma^P}{C_{t+1}^P - \gamma^P C_t^P} = \lambda_t^P \quad \text{(A.2)}$$

$$\frac{\partial \mathscr{L}}{\partial B_t^P} : \beta^P \mathbb{E}_t \lambda_{t+1}^P = \frac{\lambda_t^P}{R_t} \quad \text{(A.3)}$$

$$\frac{\partial \mathscr{L}}{\partial H_t^P} : \frac{\varsigma_t}{H_t^P} + \beta^P \mathbb{E}_t \left(\lambda_{t+1}^P Q_{t+1}^H\right) = \lambda_t^P Q_t^H \quad \text{(A.4)}$$

$$\frac{\partial \mathscr{L}}{\partial N_t} : \iota_t = \lambda_t^P W_t \quad \text{(A.5)}$$

A.2 Entrepreneurs

Entrepreneur's optimization problem can be written as

$$\mathscr{L}_t = \mathbb{E}_t \left\{ \sum_{t=0}^{\infty} \left(\beta^E\right)^t \left[\begin{array}{c} \log\left(C_t^E - \gamma^E C_{t-1}^E\right) \\ -\lambda_t^E \left[C_t^E + R_{t-1} B_{t-1}^E - Y_t + W_t N_t + I_t + Q_t^H \left(H_t^E - H_{t-1}^E\right) - B_t^E \right] \\ -\mu_t^E \left[R_t B_t^E - \theta_t \mathbb{E}_t \left(Q_{t+1}^H H_t^E + Q_{t+1}^K K_t\right) \right] \\ -\kappa_t^E \left[K_t - (1-\delta) K_{t-1} - \left\{ 1 - \frac{\Omega}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right\} I_t \right] \end{array} \right] \right\} \quad \text{(A.6)}$$

where $Y_t = A_t (N_t)^{1-\alpha} \left\{ \left(H_{t-1}^E\right)^{\phi} (K_{t-1})^{1-\phi} \right\}^{\alpha}$ may be inserted for Y_t in the budget constraint. Solving entrepreneur's optimization problem, the first order conditions are:

$$\frac{\partial \mathcal{L}}{\partial C_t^E} : \frac{1}{C_t^E - \gamma^E C_{t-1}^E} - \beta^E \mathbb{E}_t \frac{\gamma^E}{C_{t+1}^E - \gamma^E C_t^E} = \lambda_t^E \tag{A.7}$$

$$\frac{\partial \mathcal{L}}{\partial B_t^E} : \lambda_t^E = \beta^E \mathbb{E}_t \lambda_{t+1}^E R_t + \mu_t^E R_t \tag{A.8}$$

$$\frac{\partial \mathcal{L}}{\partial N_t} : W_t = (1-\alpha) \frac{Y_t}{N_t} \tag{A.9}$$

$$\frac{\partial \mathcal{L}}{\partial H_t^E} : \lambda_t^E Q_t^H = \beta^E \mathbb{E}_t \left\{ \lambda_{t+1}^E \left(Q_{t+1}^H + \alpha\phi \frac{Y_{t+1}}{H_t^E} \right) \right\} + \mu_t^E \theta_t \mathbb{E}_t Q_{t+1}^H \tag{A.10}$$

$$\frac{\partial \mathcal{L}}{\partial K_t} : \kappa_t^E = \alpha (1-\phi) \beta^E \mathbb{E}_t \left(\frac{\lambda_{t+1}^E Y_{t+1}}{K_t} \right) + \beta^E (1-\delta) \mathbb{E}_t \kappa_{t+1}^E + \mu_t^E \theta_t \mathbb{E}_t Q_{t+1}^K \tag{A.11}$$

$$\frac{\partial \mathcal{L}}{\partial I_t} : \lambda_t^E = \kappa_t^E \left\{ 1 - \frac{\Omega}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \Omega \frac{I_t}{I_{t-1}} \left(\frac{I_t}{I_{t-1}} - 1 \right) \right\} + \beta^E \Omega \mathbb{E}_t \left\{ \kappa_{t+1}^E \left(\frac{I_{t+1}}{I_t} \right)^2 \left(\frac{I_{t+1}}{I_t} - 1 \right) \right\} \tag{A.12}$$

B List of Equations

B.1 Households

$$\frac{1}{C_t^P - \gamma^P C_{t-1}^P} - \beta^P \mathbb{E}_t \frac{\gamma^P}{C_{t+1}^P - \gamma^P C_t^P} = \lambda_t^P \tag{B.1}$$

$$\beta^P \mathbb{E}_t \lambda_{t+1}^P = \frac{\lambda_t^P}{R_t} \tag{B.2}$$

$$\frac{\varsigma_t}{H_t^P} + \beta^P \mathbb{E}_t \left(\lambda_{t+1}^P Q_{t+1}^H \right) = \lambda_t^P Q_t^H \tag{B.3}$$

$$\iota_t = \lambda_t^P W_t \tag{B.4}$$

B.2 Entrepreneurs

$$\frac{1}{C_t^E - \gamma^E C_{t-1}^E} - \beta^E \mathbb{E}_t \frac{\gamma^E}{C_{t+1}^E - \gamma^E C_t^E} = \lambda_t^E \tag{B.5}$$

$$\beta^E \mathbb{E}_t \left(\lambda_{t+1}^E R_t \right) + \mu_t^E R_t = \lambda_t^E \tag{B.6}$$

$$W_t = (1-\alpha) \frac{Y_t}{N_t} \tag{B.7}$$

$$\lambda_t^E Q_t^H = \beta^E \mathbb{E}_t \left\{ \lambda_{t+1}^E \left(Q_{t+1}^H + \alpha\phi \frac{Y_{t+1}}{H_t^E} \right) \right\} + \mu_t^E \theta_t \mathbb{E}_t Q_{t+1}^H \tag{B.8}$$

$$\kappa_t^E = \alpha(1-\phi)\beta^E \mathbb{E}_t\left(\frac{\lambda_{t+1}^E Y_{t+1}}{K_t}\right) + \beta^E(1-\delta)\mathbb{E}_t\kappa_{t+1}^E + \mu_t^E\theta_t\mathbb{E}_t Q_{t+1}^K \tag{B.9}$$

$$\lambda_t^E = \kappa_t^E\left\{1-\frac{\Omega}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2 - \Omega\frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}}-1\right)\right\} + \beta^E\Omega\mathbb{E}_t\left\{\kappa_{t+1}^E\left(\frac{I_{t+1}}{I_t}\right)^2\left(\frac{I_{t+1}}{I_t}-1\right)\right\} \tag{B.10}$$

$$C_t^E + R_{t-1}B_{t-1}^E = Y_t - W_tN_t - I_t - Q_t\left(H_t^E - H_{t-1}^E\right) + B_t^E \tag{B.11}$$

$$B_t^E = \frac{\theta_t a_t}{R_t} \tag{B.12}$$

$$a_t = \mathbb{E}_t\left(Q_{t+1}^H H_t^E + Q_{t+1}^K K_t\right) \tag{B.13}$$

$$\kappa_t^E = \lambda_t^E Q_t^K \tag{B.14}$$

B.3 Market Clearing and Resource Constraints

$$C_t^P + C_t^E + I_t = Y_t \tag{B.15}$$

$$H_t^P + H_t^E = H \tag{B.16}$$

$$B_t^P + B_t^E = 0 \tag{B.17}$$

$$Y_t = A_t(N_t)^{1-\alpha}\left\{\left(H_{t-1}^E\right)^{\phi}(K_{t-1})^{1-\phi}\right\}^{\alpha} \tag{B.18}$$

$$K_t = (1-\delta)K_{t-1} + \left\{1-\frac{\Omega}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right\}I_t \tag{B.19}$$

C Steady State Conditions

From household's FOC with respect to consumption (B.1) and labor (B.4), I have

$$\frac{1-\beta^P\gamma^P}{(1-\gamma^P)C^P} = \lambda^P \tag{C.1}$$

and

$$\iota = \lambda^P W \tag{C.2}$$

respectively. Household's FOC with respect to debt (B.2) yields the steady-state gross interest rate

$$R = \frac{1}{\beta^P} \tag{C.3}$$

which underscores the fact that the time preference of the most patient agent determines the steady-state rate of interest. (B.3) yields

$$
\begin{aligned}
\frac{\varsigma}{H^P} + \beta^P \lambda^P Q^H &= \lambda^P Q^H \\
\Rightarrow Q^H H^P &= \frac{\varsigma}{\lambda^P \left(1-\beta^P\right)} \\
\Rightarrow H^P &= \frac{\varsigma}{Q^H \lambda^P \left(1-\beta^P\right)}
\end{aligned} \tag{C.4}
$$

I now turn to entrepreneurs. Their consumption FOC (B.5) yields

$$
\frac{1-\beta^E \gamma^E}{\left(1-\gamma^E\right) C^E} = \lambda^E \tag{C.5}
$$

Entrepreneur's FOC with respect to debt (B.6) gives

$$
\begin{aligned}
\beta^E \lambda^E R^L + \mu^E R &= \lambda^E \\
\Rightarrow \mu^E &= \frac{\lambda^E \left(1-\beta^E R\right)}{R}
\end{aligned} \tag{C.6}
$$

The borrowing constraint for entrepreneurs binds only if μ^E is positive. This implies that β^E must be less than R^L. In the baseline calibration, β^E is set to 0.95 whereas the steady state value of R^L is 1.0219 which implies that β^E must be less than 0.9786 which is indeed the case. Entrepreneur's production function is

$$
Y = A\left(N\right)^{1-\alpha}\left[\left(H^E\right)^{\phi}\left(K\right)^{1-\phi}\right]^{\alpha} \tag{C.7}
$$

From firm's labor choice for households (B.7),

$$
W = \left(1-\alpha\right)\frac{Y}{N} \tag{C.8}
$$

Entrepreneur's FOC with respect to housing (B.8) gives

$$
\begin{aligned}
\lambda^E Q^H &= \beta^E \lambda^E \left(Q^H + \alpha\phi \frac{Y}{H^E}\right) + \mu^E \theta Q^H \\
\Rightarrow \frac{Q^H H^E}{Y} &= \frac{\beta^E \alpha \phi R}{\left(1-\beta^E\right) R - \theta\left(1-\beta^E R\right)}
\end{aligned} \tag{C.9}
$$

From aggregate law of motion for capital (B.19)

$$
\begin{aligned}
&K = (1-\delta) K + \left[1 - \frac{\Omega}{2}\left(\frac{I}{I} - 1\right)\right] I \\
&\Rightarrow I = \delta K
\end{aligned}
\tag{C.10}
$$

I have the following steady-state resource constraints

$$Y = C^P + C^E + I \tag{C.11}$$

$$H = H^P + H^E \tag{C.12}$$

$$B^P + B^E = 0 \tag{C.13}$$

Also, I have the following steady-state version of agents' budget constraints (one of them is redundant because of Walras' Law)

$$C^P = WN - (R-1)B^P \tag{C.14}$$

$$C^E = Y - RB^E - WN - I + B^E \tag{C.15}$$

So the steady state is characterized by the vector

$$\left[Y, C^P, C^E, I, H^P, H^E, K, N, W, B^P, B^E, Q^H, Q^K, R, \lambda^P, \lambda^E, \mu^E\right]$$

From entrepreneur's optimal choice of capital (B.9), I have

$$
\begin{aligned}
&\kappa_t^E = \alpha(1-\alpha)\beta^E \mathbb{E}_t\left(\frac{\lambda_{t+1}^E Y_{t+1}}{K_t}\right) + \beta^E (1-\delta)\mathbb{E}_t \kappa_{t+1}^E + \mu_t^E \theta_t \mathbb{E}_t Q_{t+1}^K \\
&\Rightarrow \frac{\kappa^E}{\lambda^E}\left(1 - (1-\delta)\beta^E\right) = \alpha(1-\phi)\beta^E \frac{Y}{K} + \frac{\left(1-\beta^E R\right)}{R}\theta Q^K
\end{aligned}
\tag{C.16}
$$

Entrepreneur's optimal choice of investment (B.10) yields

$$
\begin{aligned}
&\lambda_t^E = \kappa_t^E \left[1 - \frac{\Omega}{2}\left(\frac{I_t}{I_t} - 1\right)^2 - \Omega\frac{I_t}{I_t}\left(\frac{I_t}{I_{t-1}} - 1\right)\right] + \beta^E \Omega \mathbb{E}_t\left[\kappa_{t+1}^E \left(\frac{I_{t+1}}{I_t}\right)^2 \left(\frac{I_{t+1}}{I_t} - 1\right)\right] \\
&\Rightarrow \lambda^E = \kappa^E
\end{aligned}
\tag{C.17}
$$

Combining this with steady state version of

$$\kappa^E = \lambda^E Q^K \tag{C.18}$$

I obtain $Q^K = 1$ in the steady state. Plugging this into (C.16), I obtain the expression for capital-to-output ratio

$$\begin{aligned} \frac{\kappa^E}{\lambda^E}\left(1-(1-\delta)\beta^E\right) &= \alpha(1-\phi)\beta^E\frac{Y}{K} + \frac{\left(1-\beta^E R\right)}{R}\theta Q^K \\ \Rightarrow \frac{K}{Y} &= \frac{\alpha(1-\phi)R\beta^E}{R\left(1-(1-\delta)\beta^E\right)-\theta\left(1-\beta^E R\right)} \end{aligned} \tag{C.19}$$

Next, combining (B.12) and (B.13)

$$B^E = \frac{\theta}{R}\left(Q^H H^E + Q^K K\right) \tag{C.20}$$

Dividing by Y, the above expression becomes

$$\begin{aligned} \frac{B^E}{Y} &= \frac{\theta}{R}\left(\frac{Q^H H^E}{Y} + \frac{Q^K K}{Y}\right) \\ \Rightarrow \frac{B^E}{Y} &= \alpha\theta\beta^E\left[\frac{\phi}{R\left(1-\beta^E\right)-\theta\left(1-\beta^E R\right)} + \frac{(1-\phi)}{R\left(1-(1-\delta)\beta^E\right)-\theta\left(1-\beta^E R\right)}\right] \end{aligned} \tag{C.21}$$

From entrepreneur's budget constraint (B.11)

$$C^E + RB^E = Y - WN - I + B^E \tag{C.22}$$

Rewriting this in ratio to output

$$\begin{aligned} \frac{C^E}{Y} + \frac{RB^E}{Y} &= 1 - \frac{WN}{Y} - \frac{I}{Y} + \frac{B^E}{Y} \\ \Rightarrow \frac{C^E}{Y} &= \alpha - \delta\frac{K}{Y} + (1-R)\frac{B^E}{Y} \end{aligned} \tag{C.23}$$

Steady-state budget constraint of household, in ratio to output, reads

$$\begin{aligned} \frac{C^P}{Y} &= \frac{WN}{Y} + (1-R)\frac{B^P}{Y} \\ &= (1-\alpha) + \frac{(1-R)B^P}{Y} \end{aligned} \tag{C.24}$$

Dividing the above two expressions by each other, I have

$$\frac{\frac{Q^H H^P}{Y}}{\frac{Q^H H^E}{Y}} = \frac{\frac{\varsigma}{Y\lambda^P\left(1-\beta^P\right)}}{\frac{\beta^E\alpha\phi R}{\left(1-\beta^P\right)R-\theta\left(1-\beta^E R\right)}}$$

$$\Rightarrow \frac{H^P}{H^E} = \frac{\varsigma}{Y\frac{1-\beta^P\gamma^P}{\left(1-\gamma^P\right)C^P}\left(1-\beta^P\right)} \frac{\left(1-\beta^E\right)R-\theta\left(1-\beta^E R\right)}{\beta^E\alpha\phi R}$$

$$\Rightarrow \frac{H^P}{H-H^P} = \frac{\varsigma\left(1-\gamma^P\right)}{\left(1-\beta^P\right)\left(1-\beta^P\gamma^P\right)} \frac{\left(1-\beta^P\right)R-\theta\left(1-\beta^E R\right)}{\beta^E\alpha\phi R}\frac{C^P}{Y} \tag{C.25}$$

Steady state version of aggregate resource constraint (B.15) is

$$C^P + C^E + I = Y$$

Dividing by Y

$$\frac{C^P}{Y} = 1 - \frac{C^E}{Y} - \delta\frac{K}{Y} \tag{C.26}$$

Combining (C.1), (C.2) and (C.8) gives steady-state equilibrium condition for households

$$\iota = \lambda^P W$$

$$\Rightarrow \iota = \frac{1-\beta^P\gamma^P}{\left(1-\gamma^P\right)C^P}(1-\alpha)\frac{Y}{N}$$

$$\Rightarrow N = \frac{\left(1-\beta^P\gamma^P\right)(1-\alpha)}{\iota\left(1-\gamma^P\right)}\left(\frac{C^P}{Y}\right)^{-1} \tag{C.27}$$

From (B.18), steady state output is

$$Y = A(N)^{1-\alpha}\left[\left(H^E\right)^{\phi}(K)^{1-\phi}\right]^{\alpha}$$

$$Y^{1-\alpha} = A(N)^{1-\alpha}\left[\left(\frac{H^E}{Y}\right)^{\phi}\left(\frac{K}{Y}\right)^{1-\phi}\right]^{\alpha}$$

$$Y^{1-\alpha} = A(N)^{1-\alpha}\left[\left(\frac{H^E}{Y}\right)^{\phi}\left(\frac{\alpha(1-\phi)R\beta^E}{R\left(1-(1-\delta)\beta^E\right)-\theta\left(1-\beta^E R\right)}\right)^{1-\phi}\right]^{\alpha} \tag{C.28}$$

From (C.4)

$$Q^H = \frac{\varsigma}{H^P\lambda^P\left(1-\beta^P\right)} \tag{C.29}$$

D System of Loglinear Equations

The system of equations log-linearized around their steady state is as below:

D.1 Optimality Conditions of Households

Equations (B.1), (B.2) and (B.4) become

$$\beta^P \gamma^P \mathbb{E}_t \widehat{C}^P_{t+1} - \left(1 + \left(\gamma^P\right)^2 \beta^P\right) \widehat{C}^P_t + \gamma^P \widehat{C}^P_{t-1} = \left(1 - \beta^P \gamma^P\right) \left(1 - \gamma^P\right) \widehat{\lambda}^P \tag{D.1}$$

$$\mathbb{E}_t \widehat{\lambda}^P_{t+1} = \widehat{\lambda}^P_t - \widehat{R}_t \tag{D.2}$$

$$\widehat{\iota}_t = \widehat{\lambda}^P_t + \widehat{W}_t \tag{D.3}$$

Log-linearization of (B.3) yields

$$\left(1 - \beta^P\right) \left(\widehat{\varsigma}_t - \widehat{H}^P_t\right) + \beta^P \mathbb{E}_t \left[\widehat{\lambda}^P_{t+1} + \widehat{Q}^H_{t+1}\right] = \widehat{\lambda}^P_t + \widehat{Q}^H_t \tag{D.4}$$

D.2 Optimality Conditions of Entrepreneurs

From (B.5) and (B.6), I have

$$\beta^E \gamma^E \mathbb{E}_t \widehat{C}^E_{t+1} - \left(1 + \left(\gamma^E\right)^2 \beta^E\right) \widehat{C}^E_t + \gamma^E \widehat{C}^E_{t-1} = \left(1 - \beta^E \gamma^E\right) \left(1 - \gamma^E\right) \widehat{\lambda}^E_t \tag{D.5}$$

and

$$\widehat{\lambda}^E_t = \widehat{R}^L_t + \beta^E R^L \mathbb{E}_t \widehat{\lambda}^E_{t+1} + \left(1 - \beta^E R^L\right) \widehat{\mu}^E_t \tag{D.6}$$

Equation (B.7) yields

$$\widehat{W}_t = \widehat{Y}_t - \widehat{N}_t \tag{D.7}$$

From (B.8), I derive

$$\begin{aligned}\left(\widehat{\lambda}^E_t + \widehat{Q}^H_t\right) = \beta^E \mathbb{E}_t \left(\widehat{\lambda}^E_{t+1} + \widehat{Q}^H_{t+1}\right) + \left(\frac{1}{R} - \beta^E\right) \theta \mathbb{E}_t \left(\widehat{\mu}^E_t + \widehat{\theta}_t + \widehat{Q}^H_{t+1}\right) \\ + \left[\left(1 - \beta^E\right) - \theta \left(\frac{1}{R} - \beta^E\right)\right] \mathbb{E}_t \left[\widehat{\lambda}^E_{t+1} + \widehat{Y}_{t+1} - \widehat{H}^E_t\right]\end{aligned} \tag{D.8}$$

Equation (B.9) becomes

$$\widehat{Q}_t^K = \left[1 - \beta^E (1-\delta) - \theta \left(\frac{1}{R} - \beta^E\right)\right] \mathbb{E}_t \left[\widehat{\lambda}_{t+1}^E - \widehat{\lambda}_t^E + \widehat{Y}_{t+1} - \widehat{K}_t\right]$$
$$+ \beta^E (1-\delta) \mathbb{E}_t \left(\widehat{Q}_{t+1}^K + \widehat{\lambda}_{t+1}^E - \widehat{\lambda}_t^E\right) + \left(1 - \beta^E R\right) \frac{1}{R} \theta \mathbb{E}_t \left[\widehat{\mu}_t^E - \widehat{\lambda}_t^E + \widehat{\theta}_t + \widehat{Q}_{t+1}^K\right] \quad \text{(D.9)}$$

Equation (B.10) is approximated as

$$\widehat{Q}_t^K = \left(1 + \beta^E\right) \Omega \widehat{I}_t - \beta^E \Omega \mathbb{E}_t \widehat{I}_{t+1} - \Omega \widehat{I}_{t-1} \quad \text{(D.10)}$$

Entrepreneur's budget constraint (B.11) becomes

$$C^E \widehat{C}_t^E + R B^E \left(\widehat{R}_{t-1} + \widehat{B}_{t-1}^E\right) = Y \widehat{Y}_t - W N \left(\widehat{W}_t + \widehat{N}_t\right) - I \widehat{I}_t - Q^H H^E \left(\widehat{H}_t^E - \widehat{H}_{t-1}^E\right) + \widehat{B}_t^E B^E \quad \text{(D.11)}$$

The borrowing constraint (B.12) becomes

$$\widehat{l}_t = \widehat{\theta}_t + \widehat{a}_t - \widehat{R}_t \quad \text{(D.12)}$$

Equation (B.13) which shows entrepreneur's total assets, becomes

$$\widehat{a}_t = \frac{Q^H H^E}{Q^H H^E + Q^K K} \mathbb{E}_t \left(\widehat{Q}_{t+1}^H + \widehat{H}_t^E\right) + \frac{Q^K K}{Q^H H^E + Q^K K} \mathbb{E}_t \left(\widehat{Q}_{t+1}^K + \widehat{K}_t\right) \quad \text{(D.13)}$$

Linearized version of (B.14) is

$$\widehat{\kappa}_t^E = \widehat{\lambda}_t^E + \widehat{Q}_t^K \quad \text{(D.14)}$$

D.3 Market Clearing and Resource Constraints

Equations (B.15) and (B.16) yield

$$\widehat{Y}_t = \frac{C^P}{Y} \widehat{C}_t^P + \frac{C^E}{Y} \widehat{C}_t^E + \frac{I}{Y} \widehat{I}_t \quad \text{(D.15)}$$

and

$$H^P \widehat{H}_t^P + H^E \widehat{H}_t^E = 0 \quad \text{(D.16)}$$

(B.17) gives

$$\widehat{B}_t^P B^P + \widehat{B}_t^E B^E = 0 \tag{D.17}$$

From (B.18), I have

$$\widehat{Y}_t = \widehat{A}_t + (1-\alpha)\,\widehat{N}_t + \alpha\phi \widehat{H}_{t-1}^E + \alpha\,(1-\phi)\,\widehat{K}_{t-1} \tag{D.18}$$

Equation (B.19) yields

$$\widehat{K}_t = (1-\delta)\,\widehat{K}_{t-1} + \delta \widehat{I}_t \tag{D.19}$$