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LOAN-TO-VALUE RATIO LIMITS: AN EXPLORATION FOR GREECE

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Abstract

We study the role of the loan-to-value (LTV) ratio instrument in a DSGE model with a rich set of financial frictions (Clerc et al., 2015). We find that a binding LTV ratio limit in the mortgage market leads to lower credit and default rates in that market as well as lower levels of investment and output, while leaving other sectors and agents largely unaffected. Interestingly, when the level of capital requirements is in the neighborhood of its optimal value, implementing an LTV ratio cap has a negative impact on welfare, even if it leads to greater macroeconomic stability. Furthermore, the availability of the LTV ratio instrument does not impact on the optimal level of capital requirements. It seems that once capital requirements have been optimally deployed to tame banks' appetite for excessive risk, the use of the LTV ratio could prove counterproductive from a welfare point of view.

Keywords: Macroprudential Policy, General Equilibrium, Greece.
JEL classification: E3, E44, G01, G21, O52.

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1. Introduction and review of the literature

The global financial crisis drastically shifted the focus of economic and financial research, bringing macroprudential and financial stability issues into focus. In this context the loan to value ratio has been receiving increasing attention from both an academic and a macroprudential policy perspective. Indeed, the role of household indebtedness in general and mortgage loan-to-value ratios in particular was crucial to the unfolding of the crisis. During the pre-crisis period, characterized by small shocks, inflation targeting and financial liberalisation, access to credit was easy. Households –in the US and elsewhere– were routinely granted mortgage loans which were often greater than the collateralized property's value, in anticipation of ensuing capital from increasing house prices. These loans were often bundled into more complex securities and resold by financial intermediaries as prime assets. Once Lehman Brothers collapsed and property values started declining, the unsustainability of the underlying mortgage loan-to-value ratios led to the financial system's unraveling.

Acknowledging the substantial real spillover effects of shocks originating in housing and financial markets, policy makers have responded by trying to design a more effective macroprudential framework which will better safeguard financial stability. Not surprisingly, given the origins of the financial crisis, loan-to-value ratio caps now form a part of many countries' macroprudential policy toolbox.[1] We adopt and appropriately modify a state-of-the-art DSGE model in order to explore how loan-to-value ratio caps interact with the most traditional macroprudential policy tool, bank capital requirements, placing a special emphasis on policy optimality.

Our paper is closely related to a growing literature which explores the effectiveness of macroprudential policy within a general equilibrium framework. A number of these specifically explore the usefulness of loan-to-value ratios. Among the most recent, Pool (2017) builds a model to explore the effects of loan-to-value restrictions on mortgage loans. He shows that loan-to-value caps not only provide a

[1] As of April 2018 nine euro area countries implemented loan-to-value ratio limits: Cyprus, Estonia, Finland, Ireland, Latvia, Lithuania, the Netherlands, Slovakia and Slovenia – see ECB (2018) and ESRB (2018). Greece does not implement loan-to-value ratio limits.

larger buffer to protect borrowers against house price fluctuations, they also attenuate the house price and mortgage supply fluctuations themselves. Furthermore, they contribute towards a reallocation of funds from mortgage to corporate loans, benefiting the economy’s production capacity. Mendicino (2012) uses a business cycle model with credit frictions to demonstrate that loan-to-value ratios which are countercyclical with respect to credit growth can effectively smooth the credit cycle. Overall, this literature finds a stabilising role for the loan-to-value ratio limit, though the latter is considered in isolation, not in conjunction with other policy instruments.

Another strand of the literature considers the interplay between loan-to-value ratio limits and monetary policy. Alpanda and Zubairy (2017), compare the effectiveness of monetary policy, housing-related fiscal policy and a permanent reduction in the LTV ratio in reducing household indebtedness, within a DSGE model featuring long-term fixed-rate borrowing and lending. They find that regulatory loan-to-value ratio limits –applicable only to new loans– are among the most effective and least costly instruments for reducing household debt. A monetary tightening on the other hand is able to reduce the stock of real mortgage debt, but leads to an increase in the household debt-to-income ratio. Gelain et al. (2013) assume that a subset of agents follow a moving average forecast rule rather than rational expectations to model excessive volatility in house prices. They find that loan-to-value ratio caps are effective in containing volatility, though less so than debt-to-income type constraints. However, restrictive loan-to-value ratio caps make impatient households worse off in the steady state. Regarding interest rates, using them to address financial shocks seems to increase inflation volatility.

Rubio and Carrasco-Gallego (2014) focus on policy rules, studying the optimal combination of monetary policy and LTV ratio rules. They suggest that the optimal LTV rule, which responds to credit growth, improves both macroeconomic stability and welfare. They highlight the trade-off between the welfare of savers and borrowers, the former caring more about price stability while the latter about financial stability. This trade-off implies some scope for coordination between monetary policy and macroprudential policy. Similarly, Lambertini et al. (2013)

investigate optimal rules' setting for monetary policy and macroprudential policy, in an economy where mortgage boom-bust cycles are driven by news shocks. They too find that a countercyclical LTV rule responding to credit growth can stabilize the economy better than the interest rate and is also preferable to a constant LTV restriction. Christensen and Meh (2011) consider shocks that replicate a housing boom and increase the borrowing limit of constrained households. They then examine the relative merits of responding using monetary policy against the alternative of a regulatory countercyclical mortgage loan-to value ratio. They conclude that the latter is a more effective stabilization instrument. Tighter monetary policy also limits the housing market expansion and household debt, but generates larger spillover effects on output and inflation.

Robinson and Yao (2016) also consider a permanent lowering of the loan-to-value ratio cap against a countercyclical LTV rule and explore their implications for business and credit cycles. A permanently lower LTV limit is found to decrease both the proportion of time spent in a recession and the average depth of the recessions and has an even stronger impact on the credit cycle. A countercyclical rule can also improve the characteristics of business and credit cycles, but rules based on house prices are superior to those based on the credit-to-GDP ratio. The authors argue this is because output responds to shocks faster than the stock of long-term mortgages does. As a consequence, using the credit-to-GDP ratio to guide LTV policy results in imprecisely timed policy interventions and thus worse economic outcomes. Lozej, Onorante and Rannenberg (2017) also report a similar finding, although their focus is not on the LTV ratio but on capital requirements.

A subset of the literature explores these themes in the context of a monetary union. Funke and Paetz (2012) examine loan-to-value ratio rules in a New Keynesian DSGE model for Hong Kong (whose monetary authority is precluded from conducting independent monetary policy under the currency board system) and argue that a non-linear rule, implemented in response to episodes of very high property price inflation can limit the transmission of house price shocks to the real economy. Motivated by the fact that euro area imbalances were largely driven by real estate booms in peripheral economies, Brzoza-Brzezina, Kolasa and Makarski (2015) construct a two-country DSGE model to explore whether using an LTV ratio limit as a macroprudential tool can enhance macroeconomic stability in the euro area periphery. They find that it is indeed able to substantially lower the amplitude of credit and output fluctuations in the periphery, provided it is decentralised. Quint and Rabanal (2014) also study the optimal mix of monetary and macroprudential policies in an estimated two-country model of the euro area and find that the introduction of a macroprudential rule reduces macroeconomic volatility, improves welfare and can partially substitute for the lack of national monetary policies. However, its effect on borrowers' welfare depends on the type of shock that hits the economy.

The aforementioned literature is insightful, concluding overall that there is scope for using macroprudential policy to complement monetary policy. However, it typically does not consider the loan to value ratio in conjunction with capital requirements. An exception are Angelini et al. (2011) who consider both macroprudential instruments, i.e. a capital requirement and an LTV ratio, but only one at a time. They find that countercyclical macroprudential policy has little to contribute in normal times (when the economy is driven by supply shocks) but is valuable when faced with shocks to the financial sector or the housing market.

Another limitation of most of this literature is that, with few exceptions it does not allow for mortgage default in equilibrium. In a paper related to ours, Nookhwun and Tsomocos (2017) embed mortgage default into a New Keynesian DSGE model that features housing and a non-trivial banking sector. They introduce three alternative macroprudential measures, namely loan-to-value ratio caps, countercyclical capital buffers and a state-contingent LTV ratio, and explore whether they improve economic stability and welfare. They find that imposing LTV caps benefits mortgage borrowers in the steady state as, by bringing down the steady-state probability of default, impatient households face a lower mortgage spread and are able to obtain more mortgages for consumption and housing accumulation. Therefore, their welfare improves, while the banking system becomes safer. Moreover, LTV caps are effective in limiting a surge in mortgage default in the face of housing risk shocks. However state-contingent LTV caps relax impatient households' borrowing constraint during the crisis period but this exacerbates default and eventually reduces their welfare.

We employ the model of Clerc et al. (2015), which allows default to take place in equilibrium in three sectors of the economy, households, banks and firms, in the manner of Bernanke, Gertler and Gilchrist (1999). Limited liability and deposit insurance induce banks to make more loans than it is optimal. The imposition of regulatory capital requirements can taper this incentive. In this paper, we introduce an additional macro-prudential rule, namely, a loan-to-value ratio cap. We investigate the properties of the model as we vary the loan-to-value ratio cap and under different levels of capital requirements.

The model has been calibrated to the Greek economy. In the aftermath of the global financial crisis, the Greek economy suffered a sovereign debt crisis and a deep, protracted recession. The output loss was accompanied by a collapse in property prices, a rapid accumulation of non-performing loans and a sharp decline in credit flows. In view of the pre-crisis credit boom, one may wonder what the imposition of LTV limits might have achieved. The model of Clerc et al. (2015) is particularly well suited to such an exploration as, in its context, banks are exposed to rises in loan default rates caused by aggregate shocks and declining collateral values. Thus is provides rich insights into the dynamic linkages between financial stability and real economic activity.

We find that a binding limit on the loan-to-value ratio in the mortgage market leads to lower credit and lower default rates in that market, while leaving other sectors and agents largely unaffected. Indeed, a sufficiently low loan-to-value ratio can eliminate default, with only a modest decline in total credit. The reduction in mortgage credit is more substantial though, while a loan-to-value ratio cap also leads to lower levels of investment and output. Allowing for some flexibility around a binding loan-to-value ratio limit magnifies the economy’s response to shocks, thus generating relatively greater macroeconomic instability.

Interestingly, when the level of capital requirements is in the neighborhood of its optimal value, implementing a loan-to value ratio cap always has a negative impact on welfare, even if it leads to greater macroeconomic stability. Moreover, the availability of loan-to-value ratio instrument does not affect the optimal level of capital requirements. That is, once capital requirements have been chosen optimally, there is nothing to be gained by imposing additional restrictions on bank lending.

The remainder of the paper is structured as follows: Section 3 presents the benchmark 3D model and briefly discusses the calibration. Section 4 presents the modeling of the loan-to-value ratio limit and illustrates its effects on the steady-state for different levels of capital requirements. Section 5 presents an impulse response analysis. Finally, Section 6 concludes.

2. The 3D model[2]

The model economy consists of households, entrepreneurs, and bankers. Households are infinitely lived and consume, supply labour in a competitive market and invest in housing. There are two types of households, patient and impatient, that differ in their subjective discount factor. In equilibrium, patient households are savers and impatient households are borrowers. The latter negotiate limited liability non-recourse mortgage loans from banks using their holdings of housing as collateral. They can individually choose to default on their mortgage, with the only implication of losing the housing units on which the mortgage is secured.

Entrepreneurs are the owners of the physical capital stock and finance their purchases of physical capital with the inherited net worth and corporate loans provided by banks that are subject to limited liability and default risk.

Bankers are the providers of inside equity to perfectly competitive financial intermediaries, the “banks”. The latter provide mortgage and corporate loans that are financed from saving households’ deposits and by raising equity from bankers. The banks are subject to regulatory capital constraints and must back a fraction of their loans with equity funding. They operate under limited liability and may default due to both idiosyncratic and aggregate shocks to the performance of their loan portfolios. In the case of a bank default deposits are fully guaranteed by a deposit

[2] This section summarily presents the 3D model of Clerc et al. (2015), following their sections 3 and 4, to facilitate the reader.

insurance agency (DIA). However, depositors may pay a risk premium that depends on the default probability of banks, thus raising the funding cost of banks when their default risk is high.

Finally, regarding the production sector, there are perfectly competitive firms that produce the final good and new units of capital and housing.

Households

There are two representative dynasties of ex ante identical infinitely lived households that differ only in the subjective discount factor. One dynasty, indexed by the superscript s, is made up of relatively patient households with a discount factor β^s. The other dynasty, identified by the superscript m, consists of more impatient households with a discount factor $\beta^m < \beta^s$. In equilibrium, the patient households save and the impatient households borrow from banks.

Saving Households

The dynasty of patient households maximizes

$$E_t\left[\sum_{i=0}^{\infty}(\beta^s)^{t+i}[\log(c_{t+i}^s) + v^s\log(h_{t+i-1}^s) - \frac{\varphi^s}{1+\eta}(l_{t+1}^s)^{1+\eta}\right] \quad (1)$$

subject to

$$c_t^s + q_t^H h_t^s + d_t \leq w_t l_t^s + q_t^H(1-\delta_t^H)h_{t-1}^s + \tilde{R}_t^D d_{t-1} - T_t + \Pi_t^s \quad (2)$$

where c_t^s denotes the consumption of non-durable goods, h_t^s denotes the total stock of housing, l_t^s denotes hours worked, η is the inverse of the Frisch elasticity of labour supply and v^s and φ^s are preference parameters. Also, q_t^H is the price of housing, δ_t^H is the depreciation rate of housing units and w_t is the real wage rate. As owners of the firms, households receive profits, Π_t^s, that are distributed in the form of dividends. $\tilde{R}_t^D$ is defined as $\tilde{R}_t^D = R_{t-1}^D(1-\gamma PD_t^b)$, where R_t^D is the gross fixed interest rate received at t on the savings and PD_t^b is the economy-wide probability of bank default in period t. In the case of a bank default the principal and the interest of bank deposits are fully guaranteed by a deposit insurance agency (DIA) by imposing a lump-sum tax T_t. However, it is assumed that households face linear transaction costs denoted by γ that create a wedge between the return to deposits and the risk-free interest rate and a link between the probability of default and the cost of funding for the banks. The presence of a deposit risk premium raises the funding cost for banks while, in addition, the fact that this premium depends on the economy-wide default risk rather than on their own default risk induces an incentive for banks to take excessive risk and provides a rationale for macroprudential policy.

Borrowing Households

Impatient households have the same preferences as patient households except for the discount factor, which is $\beta^m < \beta^s$. The budget constraint of the representative dynasty is:

$$c_t^m + q_t^H h_t^m - b_t^m \leq w_t l_t^m + \int_0^\infty \max\{\omega_t^m q_t^H (1-\delta_t^H) h_{t-1}^m - R_{t-1}^m b_{t-1}^m, 0\}\, dF^m(\omega_t^m) \tag{3}$$

where b_t^m is aggregate borrowing from the banks and R_{t-1}^m is the contractual gross interest rate on the housing loan agreed upon in period $t-1$. ω_t^m is an idiosyncratic shock to the efficiency units of housing owned from period $t-1$ that each household experiences at the beginning of each period t. The shock is assumed to be independently and identically distributed across the impatient households and to follow a lognormal distribution with density and cumulative distributions functions denoted by $f(.)$ and $F(.)$, respectively. This shock affects the effective resale value of the housing units acquired in the previous period, $\tilde{q}_t^H = \omega_t^m q_t^H (1-\delta_t^H)$, and makes default on the loan *ex post* optimal for the household whenever $\omega_t^m q_t^H (1-\delta_t^H) h_{t-1}^m < R_{t-1}^m b_{t-1}^m$. The term in the integral reflects the fact that the housing good and the debt secured against it are assumed to be distributed across the individual households that constitute the dynasty.

After the realization of the shock, each household decides whether to default or not on the individuals loans held from the previous period. Then, the dynasty makes the decisions for consumption, housing, labour supply and debt in period t

and allocates them evenly across households. As shown in Clerc at al. (2015), individual households default in period t whenever the idiosyncratic shock ω_t^m satisfies:

$$\omega_t^m \leq \overline{\omega}_t^m = \frac{x_{t-1}^m}{R_t^H} \tag{4}$$

where $R_t^H = \frac{q_t^H(1-\delta_t^H)}{q_{t-1}^H}$ is the ex post average realized return on housing and $x_t^m = \frac{R_t^m b_t^m}{q_t^H h_t^m}$ is a measure of household leverage. The net housing equity after accounting for repossessions of defaulting households can be written as:

$$\left(1 - \Gamma^m(\overline{\omega}_t^m)\right) R_t^H q_{t-1}^H h_{t-1}^m,$$

where $\Gamma^m(\overline{\omega}_t^m) = \int_0^{\overline{\omega}_{t+1}^m} (\omega_t^m f^m(\omega_t^m)) d\omega_t^m + \overline{\omega}_{t+1}^m \int_{\overline{\omega}_1^m}^{\infty} (f^m(\omega_t^m)) d\omega_t^m$ is the share of gross returns (gross of verification costs) accrued by the bank and $\left(1 - \Gamma^m(\overline{\omega}_t^m)\right)$ is the share of assets accrued to the dynasty.

Since each of the impatient households can default on its loans, the loans taken in period t should satisfy the participation constraint for the lending banks:

$$E_t(1 - \Gamma^H(\overline{\omega}_t^H))(\Gamma^m(\overline{\omega}_{t+1}^m) - \mu^m G^m(\omega_{t+1}^m)) R_{t+1}^H q_t^H h_t^m \geq \rho_t \phi_t^H b_t^m \tag{5}$$

The left-hand side of the inequality accounts for the total equity returns associated with a portfolio of housing loans to the various members of the impatient dynasty. The interpretation of the banking participation constraint is that the expected gross return for bankers should be at least as high as the gross equity return of the funding of the loan from the bankers, $\rho_t \phi_t^H b_t^m$, where ρ_t is the required expected rate of return on equity from bankers (defined below) and ϕ_t^H is the capital requirement on housing loans. The term $\mu^m G^m(\omega_{t+1}^m)$ is the expected cost of default, where μ^m is the verification cost and $G^m(\omega_{t+1}^m) = \int_0^{\overline{\omega}_{t+1}^m} (\omega_{t+1}^m f(\omega_{t+1}^m)) d\omega_{t+1}^m$ is the share of assets that belong to households that default. Finally, $(1 - \Gamma^H(\overline{\omega}_t^H))$ is the share of assets accrued to bankers in the case of a bank default, where $\overline{\omega}_t^H$ is the threshold level to the idiosyncratic shock of banks that specialize in mortgage loans (defined below).

Given the above, the problem of the representative dynasty of the impatient households can be written compactly as a contracting problem between the representative dynasty and its bank. In particular, the problem of the dynasty is to maximize utility subject to the budget constraint and the participation constraint of the bank:

$$\max_{\{c_{t+1}^m,\, h_{t+1}^m,\, l_{t+1}^m,\, b_{t+1}^m\}_{i=0}^{\infty}} E_t \left[\sum_{i=0}^{\infty} (\beta^m)^{t+i} [\log(c_{t+i}^m) + \, v^m \log(h_{t+i}^m) - \frac{\varphi^m}{1+\eta} (l_{t+1}^m)^{1+\eta}\right] \tag{6}$$

subject to

$$c_t^m + q_t^H h_t^m - b_t^m \leq \omega_t l_t^m + \left(1 - \Gamma^m \left(\frac{x_t^m}{R_{t+1}^H}\right)\right) R_{t+1}^H q_t^H h_t^m \tag{7}$$

and

$$E_t \left[(1 - \Gamma^H(\bar{\omega}_{t+1}^m)) \left(\Gamma^m \left(\frac{x_t^m}{R_{t+1}^H}\right) - \mu^m G^m \left(\frac{x_t^m}{R_{t+1}^H}\right)\right) R_{t+1}^H\right] R_{t+1}^H q_t^H h_t^m = \rho_t \phi_t^H b_t^m \tag{8}$$

Entrepreneurs

Entrepreneurs are risk neutral agents that live for two periods. Each generation of entrepreneurs inherits wealth in the form of bequests and purchases new capital from capital good producers and depreciated capital from the previous generation of entrepreneurs that they rent out to final good producers. They finance capital purchases with their initial wealth and with corporate loans from banks, b_t^e. The entrepreneurs derive utility from the transfers made to the patient households in period $t+1$ (dividends), c_{t+1}^e, and the bequests left to the next cohort of entrepreneurs (retained earnings), n_{t+1}^e, according to the utility function $(c_{t+1}^e)^{\chi^e}(n_{t+1}^e)^{1-\chi^e}$, $x^e \in (0,1)$. Thus, the problem of the entrepreneurs in period $t+1$ is:

$$\max_{\{c_{t+1}^e, n_{t+1}^e\}} (c_{t+1}^e)^{\chi^\varepsilon} (n_{t+1}^e)^{1-\chi^e} \tag{9}$$

subject to $c_{t+1}^e + n_{t+1}^e \leq W_{t+1}^e$, where W_{t+1}^e is the wealth resulting from the activity in the previous period.

The optimization problem of the entrepreneur in period t is to maximize expected wealth:

$$\max_{\{k_t, b_t^e, R_t^F\}} E_t(W_{t+1}^e) \tag{10}$$

subject to the period t resource constraint $q_t^K k_t - b_t^e = n_t^e$ and the banks participation constraint (defined below), where $W_{t+1}^e = \max\{\omega_{t+1}^e \big(r_{t+1}^k + (1-\delta_{t+1}) q_{t+1}^K\big) k_t - R_t^F b_t^e, 0\big\}$, q_t^K is the price of capital at period t, k_t is the capital held by the entrepreneur in period t, b_t^e is the is the amount borrowed from the bank in period t, r_t^k is the rental rate of capital, δ_t is the depreciation rate of physical capital and R_t^F is the contractual gross interest rate of the corporate loan. ω_{t+1}^e is an idiosyncratic shock to the efficiency units of capital which is independently and identically distributed across entrepreneurs. It is realized after the period t loan with the bank is agreed to and prior to renting the available capital to consumption good producers on that date. Similar to the case of borrowing households, entrepreneurs default on their loans whenever $\omega_{t+1}^e \big(r_{t+1}^k + (1-\delta_{t+1}) q_{t+1}^K\big) k_t < R_t^F b_t^e$. As shown in Clerc et al. (2015), the entrepreneur will repay their corporate loan in period $t+1$ whenever the idiosyncratic shock ω_{t+1}^e exceeds the following threshold:

$$\overline{\omega}_{t+1}^e \equiv \frac{R_t^F b_t^e}{R_{t+1}^K q_t^K k_t} \equiv \frac{x_t^e}{R_{t+1}^K} \tag{11}$$

where $R_{t+1}^K = \frac{r_{t+1}^k + (1-\delta_{t+1}) q_{t+1}^K}{q_t^K}$ is the gross return per efficiency units of capital in period $t+1$ of capital owned in period t, $x_t^e = \frac{R_t^F b_t^e}{q_t^K k_t}$ denotes the entrepreneurial leverage that is defined as the ratio of contractual debt repayment obligations in period $t+1$, $R_t^F b_t^e$, to the value of the purchased capital at t, $q_t^K k_t$.

Given the above, the maximization problem of the entrepreneurs in period t can be compactly written as:

$$\max_{x_t^e, k_t} E_t[(1 - \Gamma^e\left(\frac{x_t^e}{R_{t+1}^K}\right)) R_{t+1}^K q_t^K k_t] \tag{12}$$

subject to

$$E_t\big[(1-\Gamma^F(\overline{\omega}_{t+1}^F))\big(\Gamma^e(\overline{\omega}_{t+1}^e) - \mu^e G^e(\overline{\omega}_{t+1}^e)\big)\big] R_{t+1}^K q_t^K k_t = \rho_t \phi_t^F (q_t^K k_t - n_t^e \quad (13)$$

where $\Gamma^e(\overline{\omega}^e_{t+1}) = \int_0^{\overline{\omega}^e_{t+1}} (\omega^e_{t+1} f^e(\omega^e_{t+1})) d\omega^e_{t+1} + \overline{\omega}^e_{t+1} \int_{\overline{\omega}^e_{t+1}}^{\infty} (f^e(\omega^e_{t+1})) d\omega^e_{t+1}$ is the share of gross returns that will accrue to the bank, $G^e(\overline{\omega}^e_{t+1}) = \int_0^{\overline{\omega}^e_{t+1}} (\omega^e_{t+1} f^e(\omega^e_{t+1})) d\omega^e_{t+1}$ is the fraction of the returns coming from the defaulted loans of entrepreneurs, μ^e denotes the verification costs incurred by the bank and $(1 - \Gamma^F(\overline{\omega}^F_t))$ is the share of assets accrued to bankers in the case of a bank default, where $\overline{\omega}^F_t$ is the default threshold level for the idiosyncratic shock of banks that specialize in corporate loans (defined below). Similar to the case of impatient households, the interpretation of the participation constraint is that, in equilibrium, the expected return of the corporate loans must equal to the expected rate of return on equity, ρ_t, that the bankers require for their contribution to the funding of loan, $\phi^F_t(q^K_t k_t - n^e_t)$, where ϕ^F_t is the capital requirement applied on corporate loans.

Bankers

Like entrepreneurs, bankers are risk-neutral and live for two periods. They invest their initial wealth, inherited in the form of bequest from the previous generation of bankers, n^b_t, as bank's inside equity capital. In period $t+1$ the bankers derive utility from transfers to the patient households in the form of dividends, c^b_{t+1}, and the bequests left to the next generation of bankers (retained earnings), n^b_{t+1}, according to the utility function $\left(c^b_{t+1}\right)^{\chi^b} \left(n^b_{t+1}\right)^{1-\chi^b}$, where $\chi^b \in (0,1)$. Thus, the problem of the banker in period $t+1$ is:

$$\max_{\{c^b_{t+1}, n^b_{t+1}\}} \left(c^b_{t+1}\right)^{\chi^b} \left(n^b_{t+1}\right)^{1-\chi^b} \tag{14}$$

subject to

$$c^b_{t+1} + n^b_{t+1} \leq W^b_{t+1} \tag{15}$$

where W^b_{t+1} is the wealth of the banker in period $t+1$.

Regarding the decision problem of the bankers in period t, the banker born in period t with initial wealth n^b_t decides how much of this wealth to allocate as inside equity capital across the banks that specialize in housing loans (H banks) and the banks that specialize in entrepreneurial loans (F banks). Let e_t^F be the amount of the initial wealth n_t^b invested as inside equity in F banks and the rest, $n_t^b - e_t^F$, in H banks. The net worth of the banker in period $t+1$ is $W_{t+1}^b = \tilde{\rho}_{t+1}^F e_t^F + \tilde{\rho}_{t+1}^H (n_t^b - e_t^F)$, where $\tilde{\rho}_{t+1}^F, \tilde{\rho}_{t+1}^H$ are the ex post gross returns on the inside equity invested in banks F and H respectively. The maximization problem of the banker is to decide on the allocation of their initial wealth in order to maximize the expected wealth:

$$\max_{e_t^F} E_t(W_{t+1}^b) = E_t z_t^b \left(\tilde{\rho}_{t+1}^F e_t^F + \tilde{\rho}_{t+1}^H (n_t^b - e_t^F)\right) \tag{16}$$

where z_t^b is an i.i.d. shock to the bankers' wealth. An interior solution in which both types of banks receive positive equity requires that $E_t \tilde{\rho}_{t+1}^F = E_t \tilde{\rho}_{t+1}^H = \rho_t$, where ρ_t denotes the required expected gross rate of return on equity investment at time t. This expected return is endogenously determined in equilibrium but it is taken as given by individuals and banks.

Banks

Banks are institutions that provide loans to households and entrepreneurs. There are two types of banks: banks indexed by H are specialized in mortgage loans and banks indexed by F are specialized in corporate loans. Both types of banks ($j = H, F$) issue equity bought by bankers and receive deposits from households.

Each bank maximizes the expected equity payoff, $\pi_{t+1}^j = \omega_{t+1}^j \tilde{R}_{t+1}^j b_t^j - R_t^D d_t^j$, that is, the difference between the return from loans and the repayments due to its deposits, where ω_{t+1}^j is an idiosyncratic portfolio return shock, which is i.i.d. across banks and follows a log-normal distribution with mean one and a distribution function $F^j(\omega_{t+1}^j)$, b_t^j and $d_t^j$are respectively the loans extended and deposits taken by bank at period t, R_{t+1}^D is the gross interest rate paid on the deposits taken in period t and $\tilde{R}_{t+1}^j$ is the realized return on a well-diversified portfolio of loans of type j.

Each bank faces a regulatory capital constraint:

$$e_t^j \geq \phi_t^j b_t^j \tag{17}$$

where ϕ_t^j is the capital-to-asset ratio of banks of type j. The regulatory capital constraint states that the bank is restricted to back with equity at least a fraction of the loans made in period t. The problem of each bank j can be written as:

$$\pi_{t+1}^j = max\{\omega_{t+1}^j \tilde{R}_{t+1}^j b_t^j - R_t^D d_t^j, 0\} \tag{18}$$

subject to the aforementioned regulatory capital constraint.

In equilibrium, the constraint will be binding so that the loans and deposits can be expressed as $b_t^j = \frac{e_t^j}{\phi_t^j}$ and $d_t^j = (1-\phi_t^j)\frac{e_t^j}{\phi_t^j}$, respectively. Accordingly, the threshold level of ω_t^j below which the bank defaults is $\bar{\omega}_{t+1}^j = \left(1-\phi_t^j\right)\frac{R_t^D}{\tilde{R}_{t+1}^j}$ and the probability of default of each bank of type j is $F^j(\bar{\omega}_{t+1}^j)$. Thus, bank default is driven by fluctuations in the aggregate return $\tilde{R}_{t+1}^j$ and the bank idiosyncratic shock ω_{t+1}^j. In the case in which a bank defaults, its deposits are taken by DIA.

Given the above, the equity payoffs can then be written as:

$$\pi_{t+1}^j = \left[\max\{\omega_{t+1}^j - \bar{\omega}_{t+1}^j, 0\}\right]\left(\frac{\tilde{R}_{t+1}^j}{\phi_t^j}\right)e_t^j = \left[\int_{\bar{\omega}_{t+1}^j}^{\infty}\left(\omega_{t+1}^j f^j\left(\omega_{t+1}^j\right)\right)d\omega_{t+1}^j - \bar{\omega}_{t+1}^j \int_{\bar{\omega}_{t+1}^j}^{\infty}\left(f^j\left(\omega_{t+1}^j\right)\right)d\omega_{t+1}^j\right] \times \left(\frac{\tilde{R}_{t+1}^j}{\phi_t^j}\right)e_t^j \tag{19}$$

where $f^j(\omega_{t+1}^j)$ denotes the density distribution of ω_t^j. Then, the equity payoffs can be written as:

$$\pi_{t+1}^j = \frac{\left[1-\Gamma^j(\bar{\omega}_{t+1}^j)\right]\tilde{R}_{t+1}^j}{\phi_t^j} e_t^j \tag{20}$$

and the required ex post rate of return from the bankers that invest in the bank j is:

$$\tilde{\rho}_{t+1}^j = \frac{\left[1-\Gamma^j(\bar{\omega}_{t+1}^j)\right]\tilde{R}_{t+1}^j}{\phi_t^j}, \tag{21}$$

where $\Gamma^j\left(\bar{\omega}_{t+1}^j\right) = \int_0^{\bar{\omega}_{t+1}^j}\left(\omega_{t+1}^j f^j(\omega_{t+1}^j)\right)d\omega_{t+1}^j + \bar{\omega}_{t+1}^j \int_{\bar{\omega}_{t+1}^F}^{\infty}\left(f^j(\omega_{t+1}^j)\right)d\omega_{t+1}^j$ and

$G^j\left(\bar{\omega}_{t+1}^j\right) = \int_0^{\bar{\omega}_{t+1}^j}\left(\omega_{t+1}^j f^j(\omega_{t+1}^j)\right)d\omega_{t+1}^j$.

Finally, the average default rate for banks can be written as:

$$PD_t^b = \frac{d_{t-1}^H F^H(\bar{\omega}_{t+1}^H) + F^F(\bar{\omega}_{t+1}^F)}{d_{t-1}^H + d_{t-1}^F} \tag{22}$$

and the expression for the realized returns on loans after accounting for loan losses can be expressed as:

$$\tilde{R}_{t+1}^H = \left(\Gamma^m\left(\frac{x_t^m}{R_{t+1}^H}\right) - \mu^m G^m\left(\frac{x_t^m}{R_{t+1}^H}\right)\right)\left(\frac{R_{t+1}^H q_t^H h_t^m}{b_t^m}\right) \tag{23}$$

$$\tilde{R}_{t+1}^F = \left(\Gamma^e\left(\frac{x_t^e}{R_{t+1}^K}\right) - \mu^e G^e\left(\frac{x_t^e}{R_{t+1}^K}\right)\right)\left(\frac{R_{t+1}^K q_t^K k_t}{q_t^K k_t - n_t^e}\right) \tag{24}$$

Production sector

The final good in this economy is produced by perfectly competitive firms that use capital, k_t and labour, h_t. The production technology is:

$$y_t = A_t k_{t-1}^a l_t^{1-a} \tag{25}$$

where A_t is total factor productivity and a is the labour share in production.

Capital and housing production

Capital and housing producing firms are owned by patient households. Capital producers combine a fraction of the final good, I_t, and previous capital stock k_{t-1} to produce new units of capital goods that are sold to entrepreneurs at price q_t^K. The law of motion for the physical capital stock is given by:

$$k_t = (1-\delta_t)k_{t-1} + \left[1 - S_K\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{26}$$

where $S_K\left(\frac{I_t}{I_{t-1}}\right) = \frac{\xi_K}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$ is an adjustment cost function that satisfies $S(.) = S'(.) = 0, S''(.) = 0$.

The objective of the representative capital producing firm is to maximize expected profits:

$$E_t \sum_{i=0}^{\infty}(\beta^s)^i (\frac{c_t^s}{c_{t+i}^s})\{q_{t+i}^K I_{t+i} - [1 + S^K(I_{t+i}/I_{t+i-1})]\, I_{t+i}\} \quad (27)$$

Housing producers are modelled in a similar manner. In particular, the law of motion of the aggregate housing stock is:

$$h_t = (1 - \delta_t^h) h_{t-1} + \left[1 - S_H\left(\frac{I_t^h}{I_{t-1}^h}\right)\right] I_t^h \quad (28)$$

And the maximization problem of the representative housing producing firm is:

$$E_t \sum_{i=0}^{\infty}(\beta^s)^i (\frac{c_t^s}{c_{t+i}^s})\{q_{t+i}^H I_{t+i}^H - [1 + S^K(I_{t+i}^H/I_{t+\iota-1}^H)]\, I_{t+i}^H\} \quad (29)$$

Macroprudential policy

We deviate from the original structure of the 3D model by introducing the loan-to-value ratio as a policy instrument of macroprudential policy. In particular, we assume that the capital requirement ratio is kept constant to a reference level, and the macroprudential authority sets the loan-to-value ratio for mortgage loans in period t according to the following rule:

$$x_t^m = \bar{x}_0^m + z\left[\log(b_t^m) - \log\left(\overline{b^m}\right)\right] \quad (30)$$

where b_t^m denotes total mortgage loans, $\overline{b^m}$ is the long-run value of total mortgage loans, $\bar{x}_0^m$ is the target level of the loan-to-value ratio and $z > 0$ is a feedback parameter that captures the fluctuations in the loan-to-value ratio to changes in mortgage loans.[3] Note that the value of the feedback parameter governs the restrictions imposed on the leverage of households: The lower is the value of the coefficient the tighter are the restrictions on the loan-to-value ratio and vice versa.

[3] Mortgage loans are one-period loans. See Alpanda and Zubairy (2017) for a more general specification in which the LTV ratio is applied to loans with different maturities.

Stochastic environment

Shocks to productivity, housing preferences, the depreciation rates and risk shocks follow an $AR(1)$ stochastic process of the form:

$$lnS_t = \rho^S lnS_{t-1} + \varepsilon_t^S \tag{31}$$

where $S_t = \{A_t, \upsilon_t, \delta_t, \delta_t^H, z_t^b\}$, ρ^S is the persistence parameter and $\varepsilon_t^S \sim (0, \sigma_t^S)$. We also introduce risk shocks in the spirit of Christiano et al. (2014) by allowing the variance of the idiosyncratic shocks to vary over time.

3. Calibration of the model and the long-run solution

The model is calibrated to the Greek economy at a quarterly frequency. The calibration strategy and the data used are the same as in Balfoussia and Papageorgiou (2016). The data sources are Eurostat and the Bank of Greece, unless otherwise indicated, and span the period 2003-2010.[4] The calibrated parameters are summarized in Table 1.

In line with Clerc et al. (2015), capital requirements are set at 8% for corporate loans and 4% for mortgage loans.[5] The discount factor for patient households is calibrated using a quarterly interest rate on deposits equal to 0.77% (3.08% annually). As is usual in the related literature, the discount factor for impatient households is set equal to 0.98 and the Frisch elasticity of labour equal to 0.5. The preference parameters that govern the marginal disutility of labour, φ, and the utility weight of housing, υ, are respectively set equal to one and 0.25 for both types of households.

The depreciation rates on capital and housing investment, δ, δ^H, have been respectively set to match as closely as possible the average values of total investment (net of housing) to GDP and housing investment to GDP over the sample

[4] We choose the pre-sovereign crisis period for the calibration in order to avoid the non-linear effects that the crisis had on most macroeconomic and financial time series.

[5] As regards corporate loans, this is compatible with the weights of Basel I and with the treatment of non-rated corporate loans in Basel II and III. The capital requirement parameterization for mortgage loans is compatible with their 50% risk-weight in Basel I.

period. The labour share is computed from AMECO data that adjusts for the income of the self-employed persons, giving a value equal to 0.6.

We calibrate the parameter of the depositor cost of bank default, γ, to match the average value of the spread between deposit rates and the policy rate, which is used as a proxy for the premium required by depositors in order for them to deposit their money in the risky bank. This gives a value for γ expressed in annual terms equal to 0.24, implying losses of 24% of face value for depositors at failed banks.

The parameters which determine the probabilities of default for household and entrepreneurial loans, σ_H, σ_F are calibrated to pin down the average values of the household debt-to-GDP ratio and the corporate debt-to-GDP ratio found in the data. This yields $\sigma_H = 0.1$ and $\sigma_F = 0.5$, implying higher uncertainty in the corporate sector. Following the study of Clerc et al. (2015), we set the parameters that determine the probabilities of default for the two types of banks to imply a default rate equal to 2%. The bankruptcy cost parameters imply losses of 30% of asset value for creditors repossessing assets from defaulting borrowers. The adjustment cost parameters for capital and housing and the shock persistence parameters are those employed in Clerc et al. (2015). We set the reference value of the loan-to-value ratio, $\bar{x}_0^m$, equal to 0.7162 following Balfoussia and Papageorgiou (2016). Note that in their model the loan-to-value ratio is a choice variable of the borrowing households and its long-run value is pinned down endogenously from the respective first order condition. Given that we use the same parametrization, we obtain the same long-run solution. Thus, 0.7162 is the value of the loan-to-value ratio that would have implied by the model, had households chosen the loan-to-value ratio optimally. Table 2 summarizes the long-run solution of the model, which is in line with key features of the data on the Greek economy and constitutes a reasonable starting point for our experiments.

4. Steady-state effects of the loan-to-value ratio

In this Section we study the long-run properties of the model. We first consider the effects on key model variables and social welfare when we vary the capital requirements ratio and the loan-to-value ratio is endogenously determined in the steady state.[6] We then examine the long-run effects of capping the loan-to-value ratio for mortgages.

Figures 1 - 5 depict the steady-state properties of the model, when the loan-to-value ratio is allowed to be endogenously determined as we vary the capital requirements ratio. This is the benchmark set of results for the Greek calibration, which were also presented in Balfoussia and Papageorgiou (2016). The key intuition of the model is that there is a humped shaped steady-state relationship between capital requirements and social welfare, implying a trade-off between the two (see Figure 1). The optimal capital requirement that maximizes welfare is around 9.5.

In Figures 6 - 10 we explore the steady state effects of capping the loan-to-value ratio. More specifically, we keep the loan-to-value ratio constant in the steady state, and we vary the level of capital requirements. We do that for five different values of the loan-to-value ratio, namely 0.5, 0.6, 0.65, 0.68 and 0.7162. The latter is the value of the loan-to-value ratio in the benchmark calibration described in the previous section. Figure 6 plots the level of the intertemporal social welfare (in utils).[7] The line denoted "baseline" tracks social welfare for different values of capital requirements under the benchmark value of the loan-to-value ratio, i.e. 0.7162. It thus corresponds to Figure 1 – though not exactly, as in Figure 1 the loan-to-value ratio is endogenously determined at all levels of capital requirements and thus

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[6] In this case, the loan-to-value ratio, x_{t+1}^{m}, is treated as a choice variable in the maximization problem of the borrowing households and we substitute Equation (30) that refers to the macroprudential policy rule with the first order condition with respect to x_{t+1}^{m}. For details see Clerc et al., (2015) and Balfoussia and Papageorgiou (2016). Recall that the implied long-run value for x^{m} is the same as the one used in the benchmark calibration as described in the previous section. Following e.g. Lucas (1990), the social welfare is calculated by computing the permanent consumption subsidy that is required in each period so as to make aggregate welfare under the baseline capital requirements policy equal to the welfare under alternative policies. This percentage change in consumption is defined as ζ. If $\zeta > 0$ ($\zeta < 0$), there are welfare gains (losses) relative to the baseline policy. In particular, the reported social welfare gains/losses are a weighted average of the welfare gains/losses of the patient and impatient households: $\zeta \equiv \frac{c_0^s}{c_0^s+c_t^m}\zeta^s + \frac{c_0^m}{c_0^s+c_t^m}\zeta^m$, where c_0^s and c_0^m denote respectively the steady-state consumption of the patient and impatient dynasties under the baseline policy.

[7] The reported social welfare is computed as a weighted average of the utility of the patient and impatient households: $V \equiv \frac{c_0^s}{c_0^s+c_t^m}V^s + \frac{c_0^m}{c_0^s+c_t^m}V^m$, where c_0^s and c_0^m denote respectively the steady-state consumption of the patient and impatient dynasties, and $V_t^j = u_t^j + \beta^j E_t V_{t+1}^j$, where u_t^j is period t utility, $j = s, m$.

varies, *albeit* minutely. Each of the other lines depicts social welfare for a range of binding loan-to-value ratio limits, i.e. for values lower than 0.7162. A first observation is that all curves peak at essentially the same level of capital requirements. In other words, the level of the loan-to-value ratio –whether chosen optimally or not– does not impact on the optimal level of capital requirements. Moreover, restrictions on the loan-to-value ratio are always welfare worsening, whether capital requirements have been chosen optimally or not.

Figures 7-10 present the corresponding steady-state impact on the other model variables. The average probability of bank default –and thus the deposit spread or deposit premium requested by depositors– is essentially unaffected by the imposition of a loan-to-value ratio cap. This reflects the fact that bank default in the steady state is driven primarily by the idiosyncratic risk shocks that hit banks. Depositors acknowledge this and as a result the deposit insurance cost barely declines with tighter loan-to-value ratio restrictions. Conversely, total credit does decline with tighter restrictions. This decline reflects almost exclusively a reduction in mortgages. For a 50% loan-to value-ratio limit mortgages decline by roughly 30%, while commercial loans decline only marginally, i.e. by less than 1%. Correspondingly, household default declines drastically and, for a 50% loan-to value-ratio limit, is essentially eliminated, while the rate of default of entrepreneurs remains unaffected. Indeed, it seems that even a 60% ratio can all but eliminate mortgage default. Moreover, this comes at a relatively modest cost, i.e. with a decline in the volume of total credit of the order of 10%. The reduction in mortgage credit remains however more substantial, approximately 20%.

At the macro level, a loan-to-value ratio cap leads to lower investment. The bulk of the decline in investment comes from residential investment. Notably, this decline is substantially smaller than the corresponding decline in mortgage loans. Total deposits however decline substantially, implying that savings households now find it optimal to hold smaller deposits and now invest relatively more in housing. Correspondingly, the equity of mortgage-lending banks also declines. This reflects the fact that bankers are now faced with a lower return on mortgages and thus a lower return on the bank equity invested in mortgage-lending banks. As a result, they chose to reduce the latter and to only sustain the level of bank equity invested in firm-lending banks.[8]

Finally, the loan-to-value ratio cap leads to lower output in the steady state. The permanent effect on GDP from imposing a loan-to-value ratio limit of 60% (as compared to the households' optimal choice of 71.62%) is 45% of a single year's GDP.[9] In other words, if policymakers instituted a 60% loan-to-value ratio limit (and had optimal capital requirements) then they would have to sacrifice half a single year's GDP if they wished to completely and permanently eliminate default in the mortgage market.

Moving on to Figures 11-15, we vary the loan-to-value ratio limit and explore the steady state properties for six different values of the capital requirements ratio, i.e. 0.08, 0.09, 0.1, 0.11, 0.12 and 0.13, to detect possible non-linearities. The line denoted "optimal" depicts social welfare for different loan-to-value ratios, ranging from 0.5 to the baseline value, and for capital requirements fixed at their optimal level, i.e. $\phi^F = 0.095$. The other lines plot the same information for other levels of capital requirements. As expected, welfare increases monotonically and almost linearly, as the loan-to-value ratio limit approaches its unconstrained calibrated value. Moreover, the hump-shaped relationship between welfare and capital requirements seen in Figure 1 remains irrespective of the loan-to-value ratio. In Figure 12, households' default remains very close to zero for all loan-to-value ratios, except those which are in the neighborhood of the unconstrained value. It is notable that there are very limited spill-over effects on other markets and agents. For instance, business loans and investment decline following the tightening of the loan-to-value ratio limit but the effect is small. All macro variables, with the exception of consumption, improve monotonically in response to an easing of a binding loan-to-value ratio, with residential investment the only one presenting some curvature as the loan-to-value ratio approaches its unconstrained equilibrium value. Thus, within the context of this model, there is no tradeoff between capital requirements and the

[8] The qualitative effects are consistent with previous findings in the relevant literature; see e.g. Lozej and Rannenberg (2017).

[9] The output loss reported is computed as the percentage deviation of GDP between the two steady states divided by a real interest rate equal to 5%.

loan-to-value ratio, a binding loan-to-value ratio limit being *ceteris paribus* always welfare reducing.

5. Impulse response analysis

We now examine the dynamic responses of the economy to exogenous shocks when the LTV ratio reacts endogenously to the percentage deviation of mortgage loans from their steady-state level according to the macroprudential policy rule described earlier (see Equation 30).[10] In particular, if mortgage loans are above their long run value, the loan-to-value ratio limit adjusts positively –i.e. it increases, to accommodate the higher lending till it dissipates– and vice versa. Within this setup, we examine the dynamic responses of the system to temporary total factor productivity and bank risk shocks under two alternative parameterisations, where the feedback coefficient z in equation of the macroprudential policy rule is set equal to either 0.15 or 0.25, which constitute a tighter and looser policy rule, respectively.

A temporary positive shock to total factor productivity leads to an increase in aggregate demand and output. Households incur a positive wealth effect which induces them to increase current consumption. The increase in the marginal productivity of capital boosts investment demand and thus the price of both housing and capital. Given that, in the model, these assets constitute collateral against which loans have been pledged, this increase in asset prices leads to decreased rates of default for both households and entrepreneurs who now find that it is their optimal strategy to repay their loans. As a result, banks' equity capital also increases. The implications are twofold. Firstly, total credit increases, generating a positive second order feedback effect on GDP. Secondly, the rate of bank defaults decreases, pushing down the cost of deposit funding. This feeds into lending rates, further boosting both total credit and collateral valuations. This leads to even fewer borrower defaults, setting a virtuous circle in motion.

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[10] In doing so, we set the target for the LTV ratio to 0.68, which is lower than the calibrated value of 0.7162 that corresponds to the LTV ratio chosen by households, in order to study the case in which the macroprudential authorities impose restrictions on household borrowing.

Figures 16-17 present the dynamic responses of the system under the two aforementioned parameterisations. We use a dashed line to plot the dynamic effect of the shock for a low feedback coefficient and a solid line to plot the dynamic effect of the same shock for a high feedback coefficient. We find that under the higher feedback coefficient the positive impact of a temporary positive shock to total factor productivity is greater than under the lower one. GDP, investment and even consumption increase by more and for longer periods. So do financial variables such as credit and the same goes for default rates for which the reduction is higher and more persistent. Intuitively, following a positive shock, a higher value of the feedback coefficient, i.e. a loan-to-value policy rule which is more procyclical with regard to debt, induces larger and more persistent fluctuations of the loan-to-value ratio around its target level of 0.68. This reflects a magnification mechanism. A larger feedback coefficient, i.e. a more accommodative policy, makes any initial increase in debt (as a result of a shock) induce a relatively larger increase in the loan-to-value ratio limit, which then supports a higher increase in debt and so on, until the effect of the shock has dissipated. The existence of such a magnification mechanism implies that a higher feedback coefficient makes the response of the economy to shocks not only more procyclical but also longer lived, contributing to greater macroeconomic instability, most notably in the medium term. Thus, allowing more flexibility around a binding loan-to-value ratio limit renders the economy relatively more vulnerable to external shocks.

Similar conclusions apply in the case in which the economy is hit by negative bank risk shocks. As can be seen in Figures 18-19, the immediate effect of a negative bank risk shock is an increase in bank defaults. This is propagated via the net worth channel, depressing bankers' net worth and thus restricting total credit to the economy and reducing output through both consumption and investment. Tighter restrictions on the loan-to-value ratio (i.e. when $z = 0.15$) have a buffering effect on bank defaults and mitigate the adverse effects on GDP.

6. Conclusion

We have studied the effects of a loan-to-value ratio instrument in an economy where bank capital requirements are selected optimally in order to deter excessive risk taking. In such an economy, a binding limit on the loan-to-value ratio in the mortgage market leads to lower credit and lower default rates in that market, while leaving other sectors and agents largely unaffected. Indeed, a sufficiently low loan-to-value ratio can eliminate default, with only a modest decline in total credit. The reduction in mortgage credit is more substantial and loan-to-value ratio cap also leads to lower levels of investment and output.

In addition, the results suggest that tight restrictions on the loan-to-value ratio have a buffering effect on the real economy, acting to smooth the effects of exogenous shocks. Nonetheless, and in spite of its positive contribution to macroeconomic stability, use of the loan to value ratio is not welfare improving. It seems that once capital requirements have been set to their optimal level in order to contain excessive leverage by banks, any further restrictions on lending practices could result in lower welfare.

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Tables and Figures

Table 1. Calibrated parameters

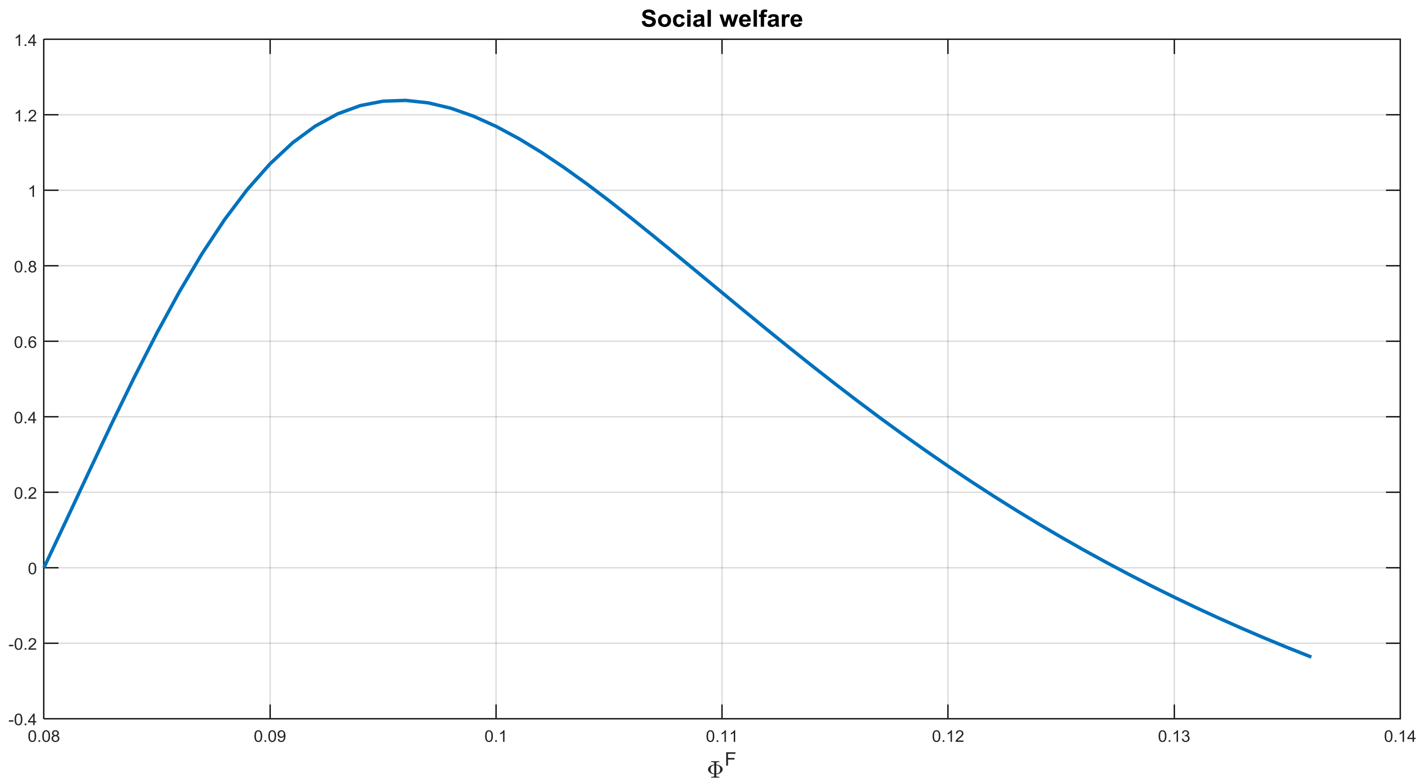
Description	Parameter	Value
Patient Household Discount Factor	β^s	0.992
Impatient Household Discount Factor	β^m	0.98
Patient Household Utility Weight of Housing	υ^m	0.25
Impatient Household Utility Weight of Housing	υ^s	0.25
Patient Household Marginal Disutility of Labor	φ^s	1
Impatient Household Marginal Disutility of Labor	φ^m	1
Inverse of Frisch Elasticity of Labor	η	0.2
Depositor Cost of Bank Default	γ	0.242
Variance of Household Idiosyncratic Shocks	σ_m^2	0.1
Household Bankruptcy Cost	μ^m	0.3
Dividend Payout of Entrepreneurs	χ^e	0.06
Variance of Entrepreneurial Risk Shock	σ_e^2	0.5
Entrepreneur Bankruptcy Cost	μ^e	0.3
Capital Requirement for Mortgage Loans	$\overline{\phi}^H$	0.04
Capital Requirement for Corporate Loans	$\overline{\phi}^F$	0.08
Mortgage Bank Bankruptcy Cost	μ^H	0.3
Corporate Bank Bankruptcy Cost	μ^F	0.3
Capital Share in Production	α	0.4
Capital Depreciation Rate	δ	0.025
Capital Adjustment Cost Parameter	ξ^K	2
Housing Depreciation Rate	δ^H	0.015
Housing Adjustment Cost Parameter	ξ^H	2
Shocks Persistence	ρ	0.9
Dividend Payout of Bankers	χ^b	0.06
Variance of Mortgage Bank Risk Shock	σ_H^2	0.01669
Variance of Corporate Bank Risk Shock	σ_F^2	0.0339
Reference value of the loan-to-value ratio	$\bar{x}_0^m$	0.7162

Table 2. Long run solution

Description	Data averages	Long run solution
Total consumption over GDP	0.64	0.5426
Investment (related to the capital good production) /over GDP	0.145	0.1386
Investment in housing/over GDP	0.084	0.0791
The premium required by the depositor in order to deposit his money in the risky bank	0.55	0.50
Borrowing spread for entrepreneurs	2.74	1.7243
Borrowing spread for households	1.25	0.8617
Debt of entrepreneurs over debt of households	1.226	1.2514
Debt-to-GDP ratio of entrepreneurs (annualized)	0.491	0.5031
Debt-to-GDP ratio of borrowers (annualized)	0.421	0.4021
Default rate - mortgages	-	0.34
Default rate - entrepreneurs	-	13.86
Default rate - firm lending banks	-	2.04
Default rate - mortgage lending banks	-	2.06

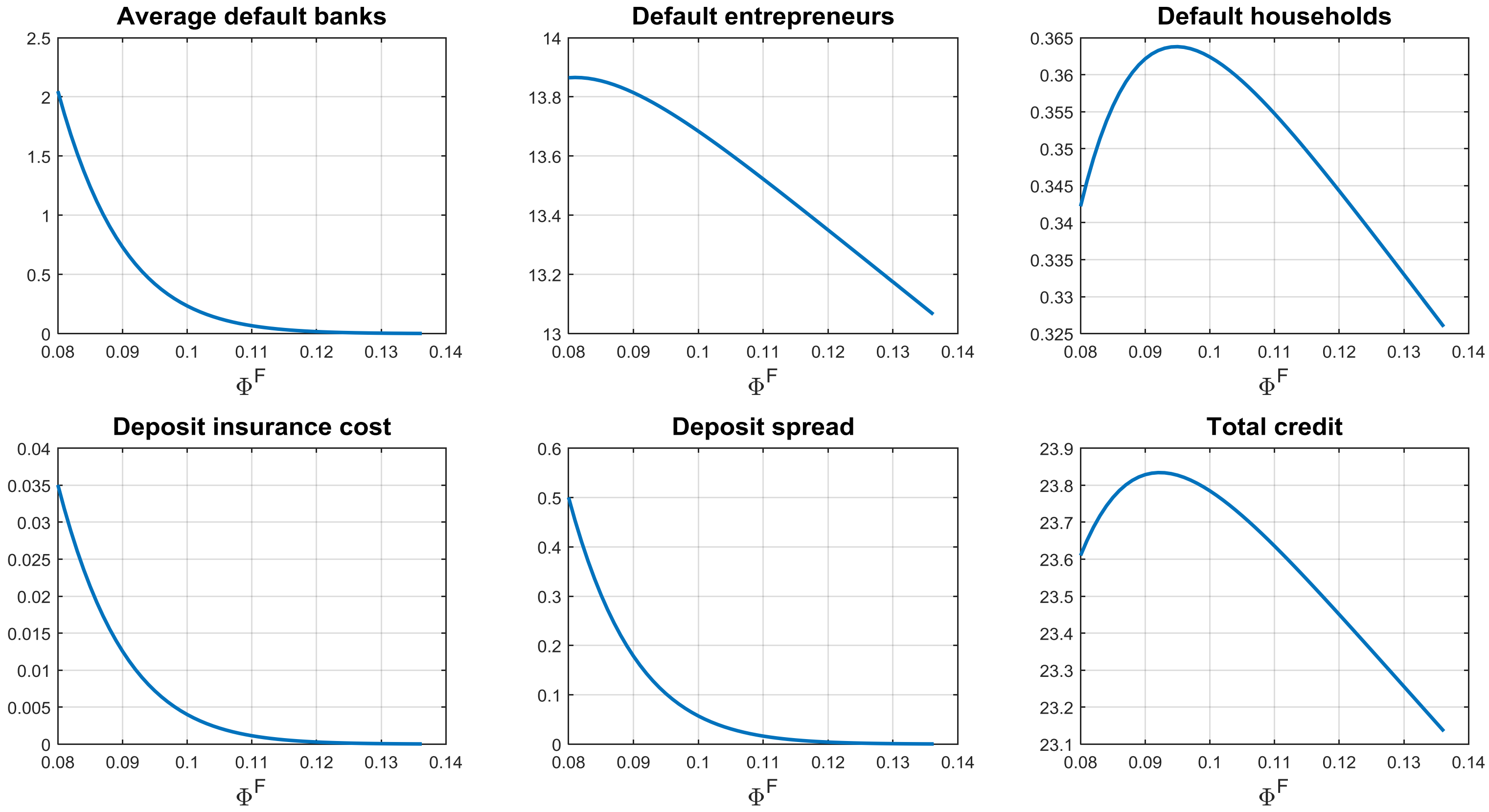
Figures

Figure 1. Steady-state welfare depending on the capital requirement



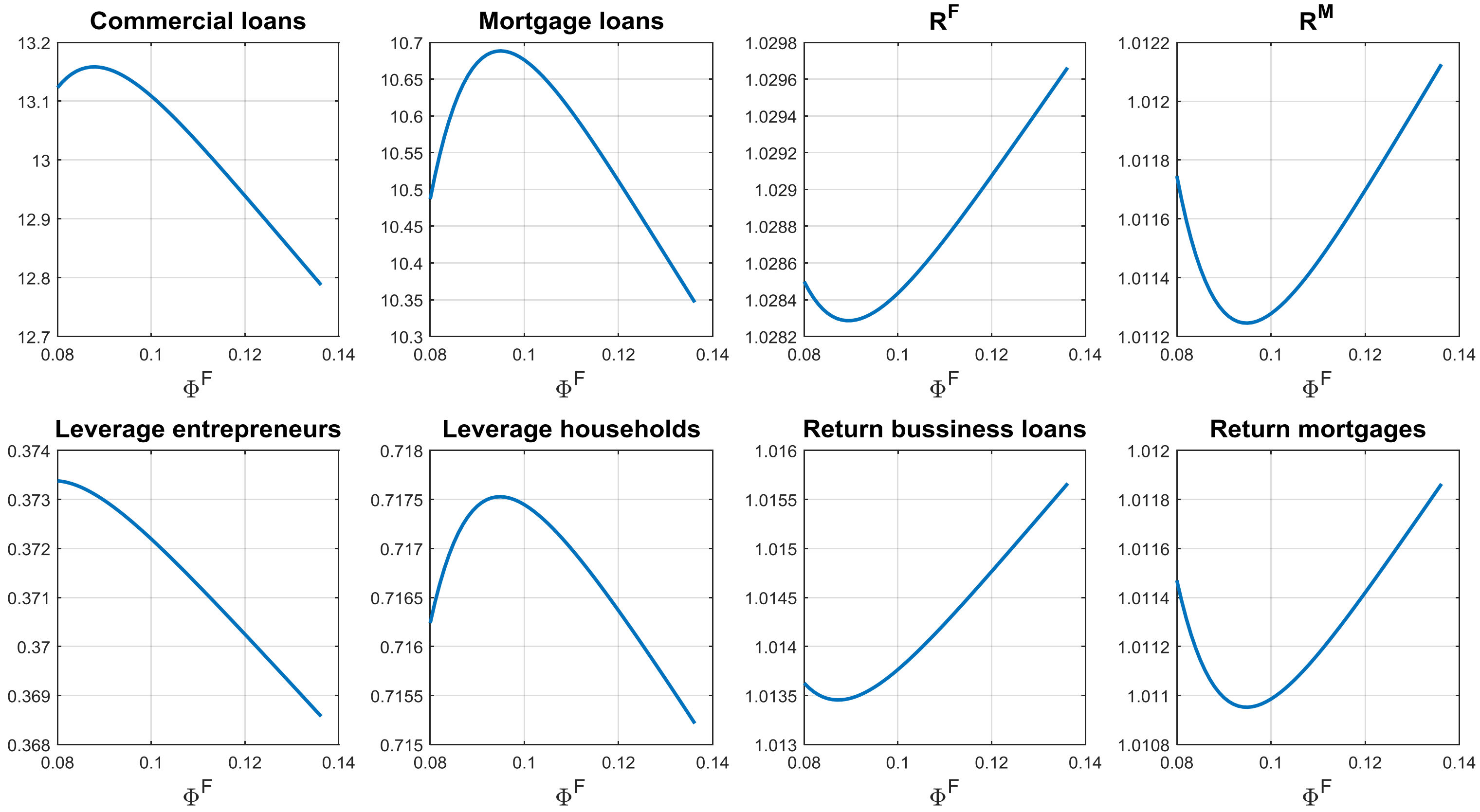
Notes: (i) The vertical axis shows the social welfare gains/losses, ζ (%), (ii) Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$.

Figure 2. Steady-state values depending on the capital requirement (I)



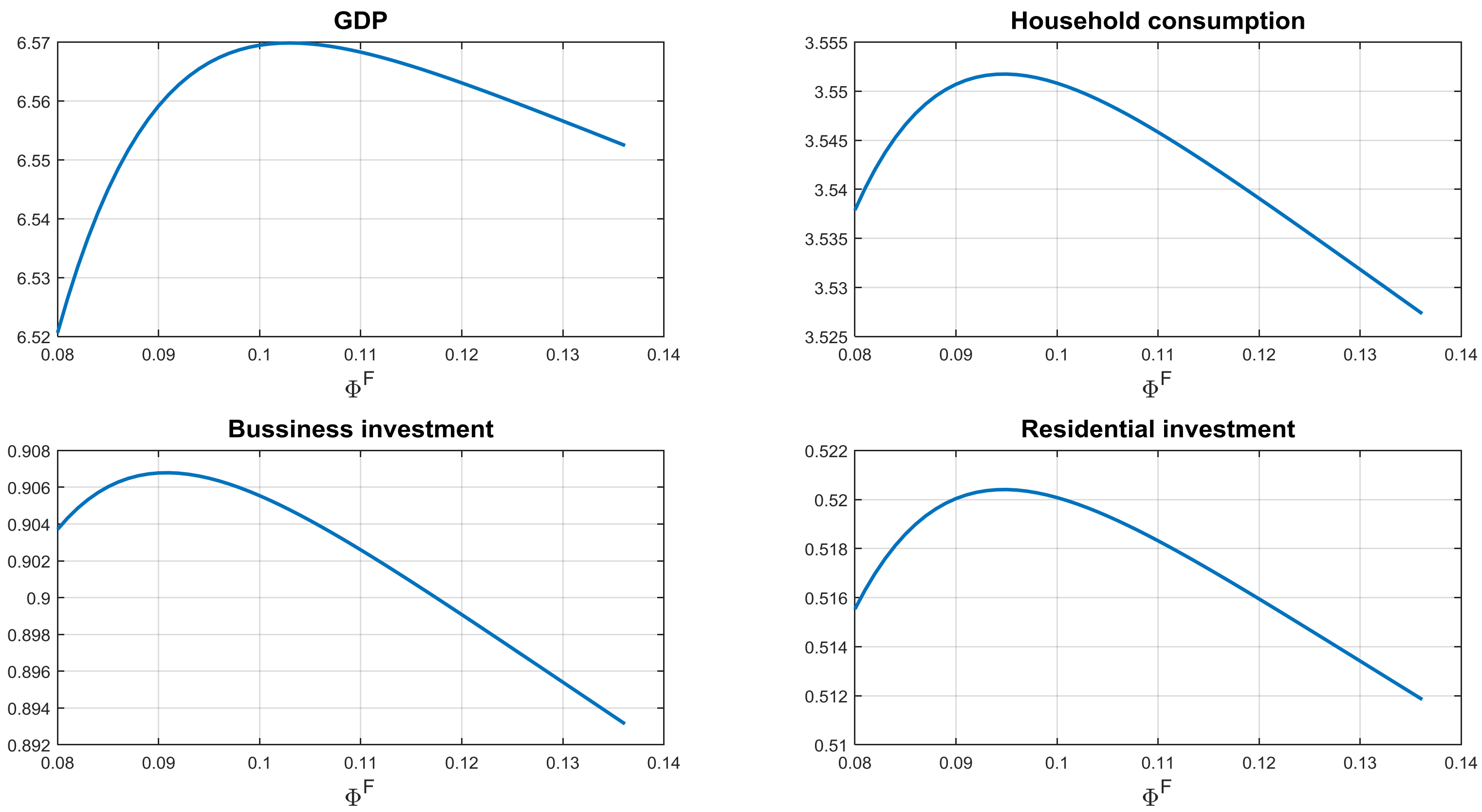
Notes: (i) The vertical axis shows steady-state values, (ii) Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$.

Figure 3. Steady-state values depending on the capital requirement (II)



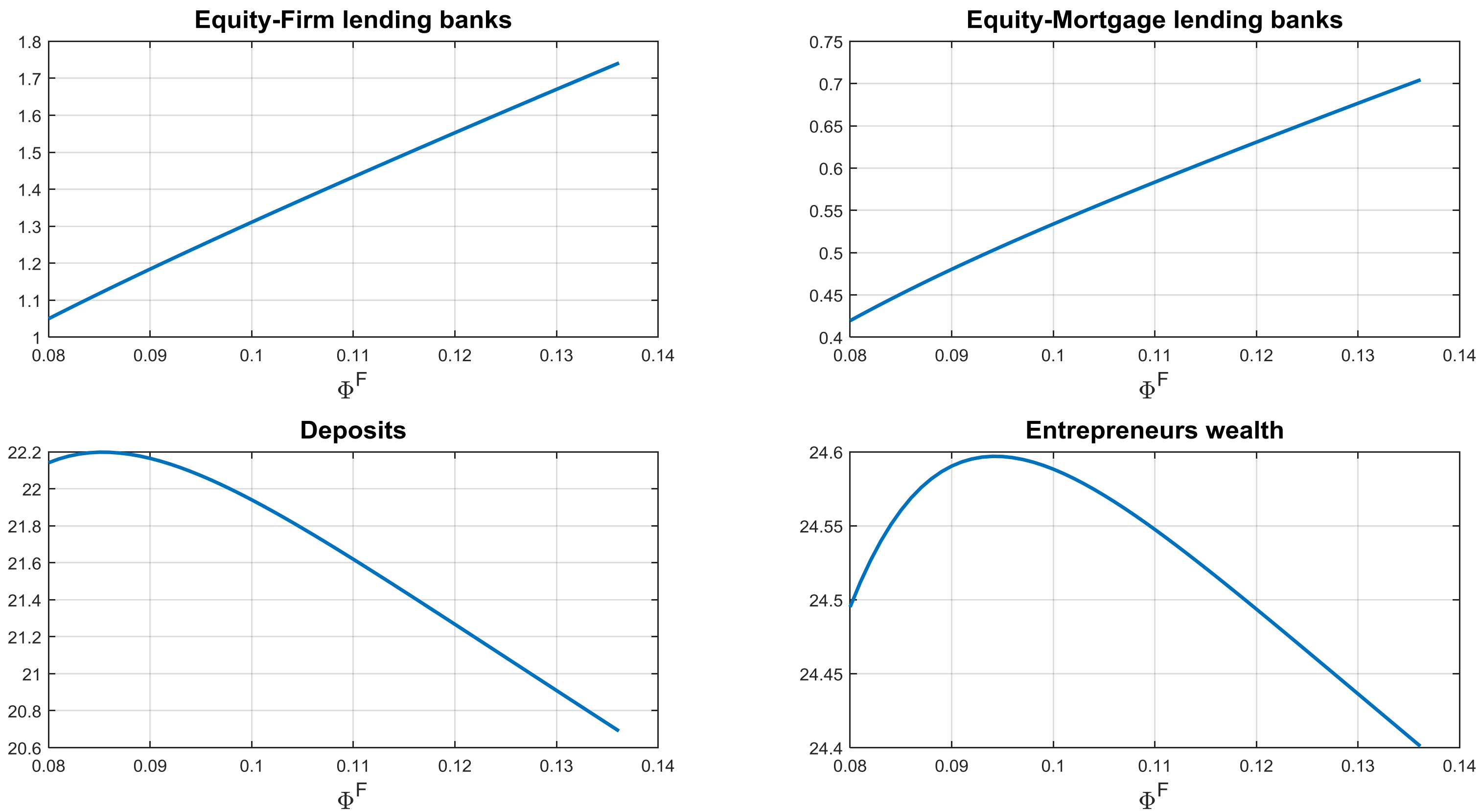
Notes: (i) The vertical axis shows steady-state values, (ii) Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$.

Figure 4. Steady-state values depending on the capital requirement (III)



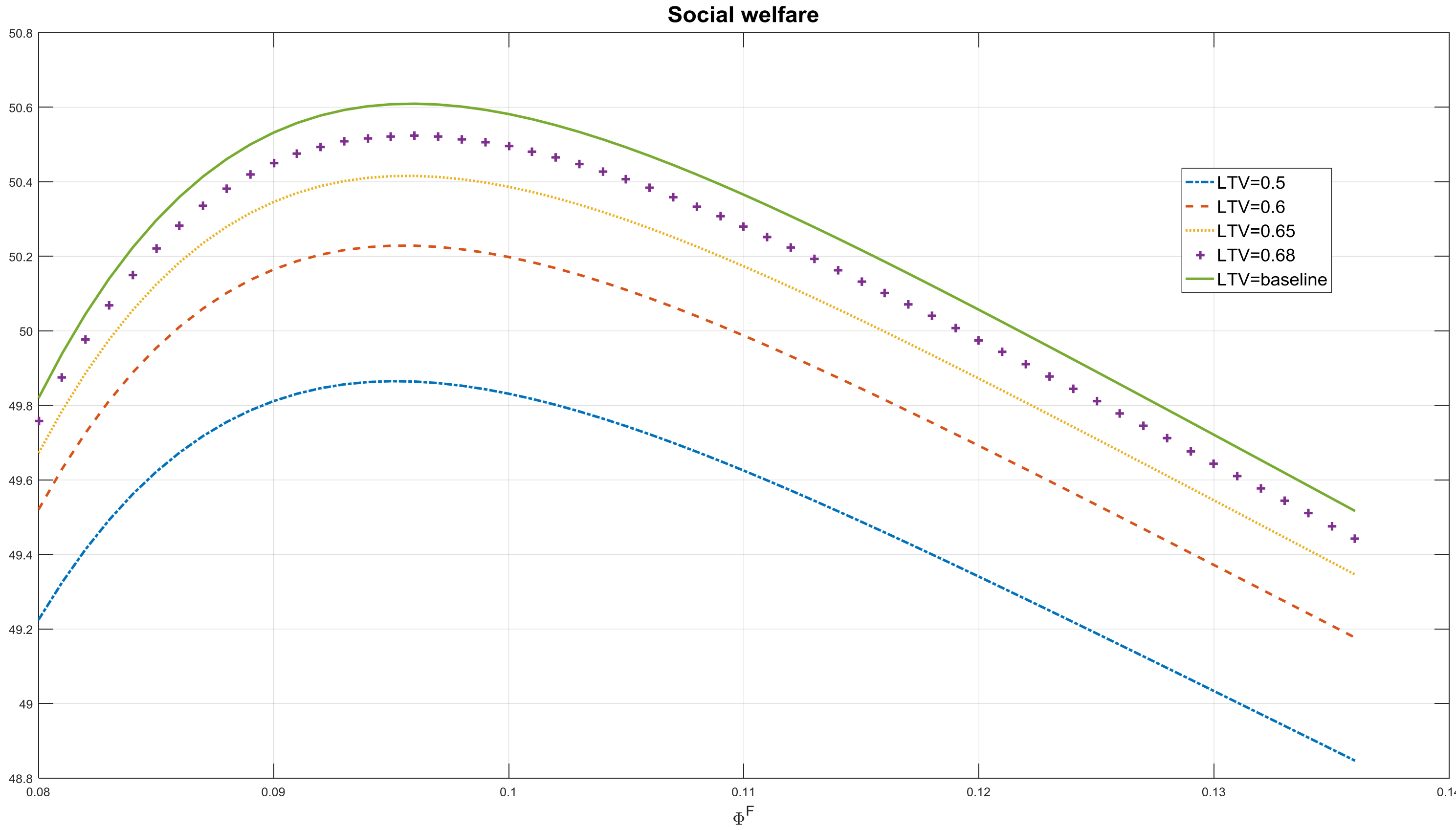
Notes: (i) The vertical axis shows steady-state values, (ii) Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$.

Figure 5. Steady-state values depending on the capital requirement (IV)



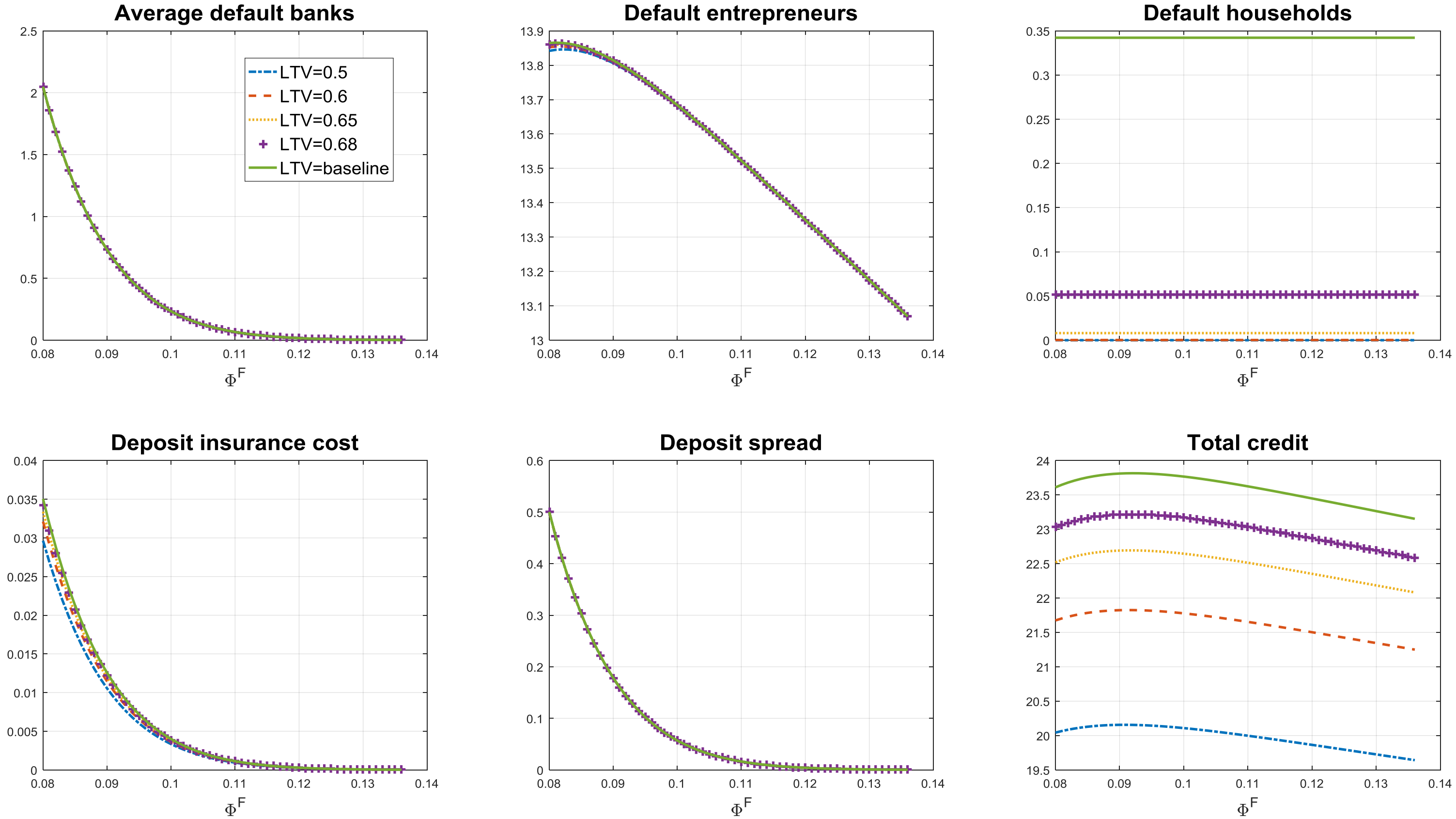
Notes: (i) The vertical axis shows steady-state values, (ii) Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$.

Figure 6. Steady state effects of capping the loan-to-value ratio (I)



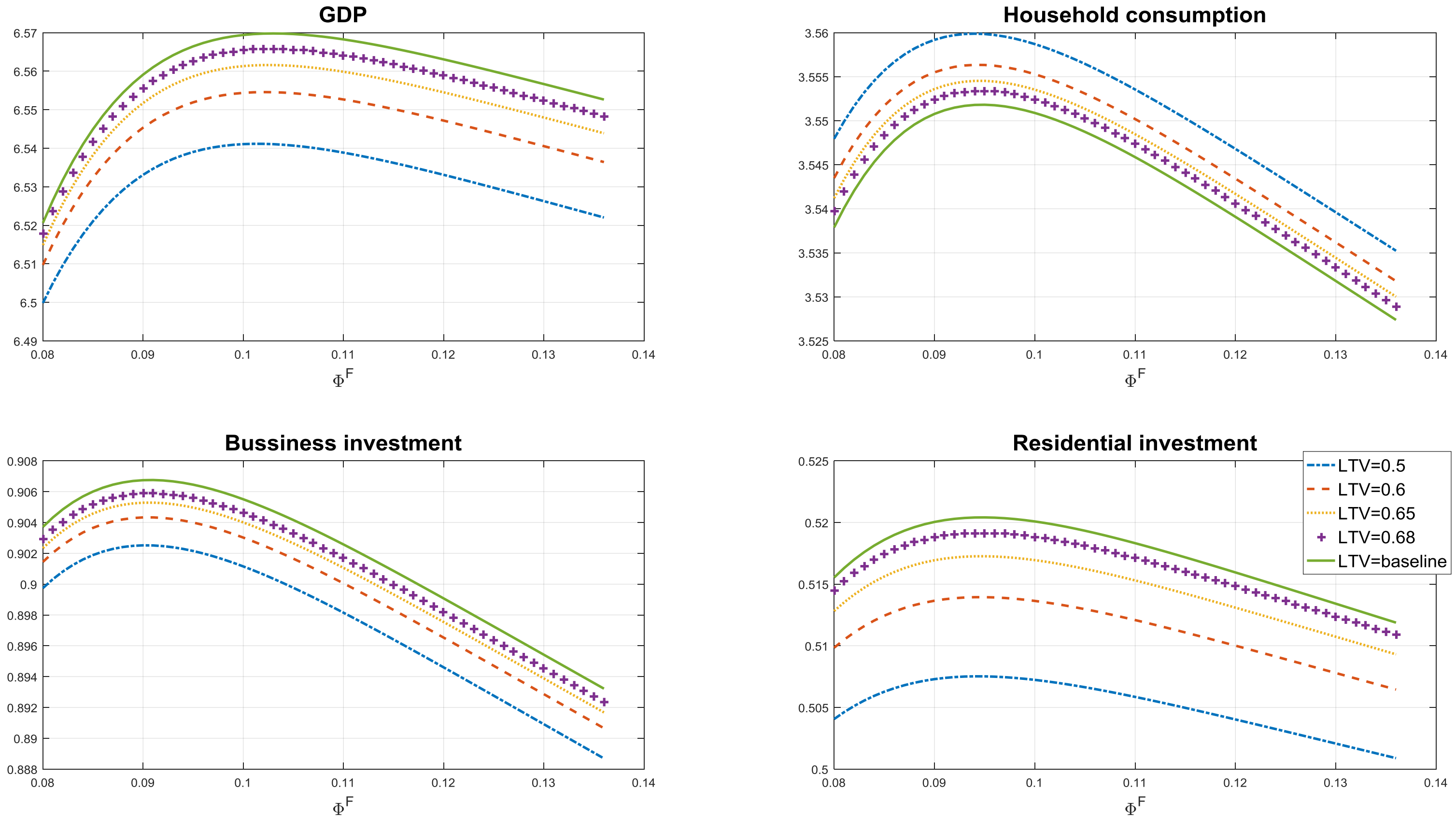
Notes: (i) The vertical axis shows the levels of social welfare V (%), (ii) Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$.

Figure 7: Steady state effects of capping the loan-to-value ratio (II)



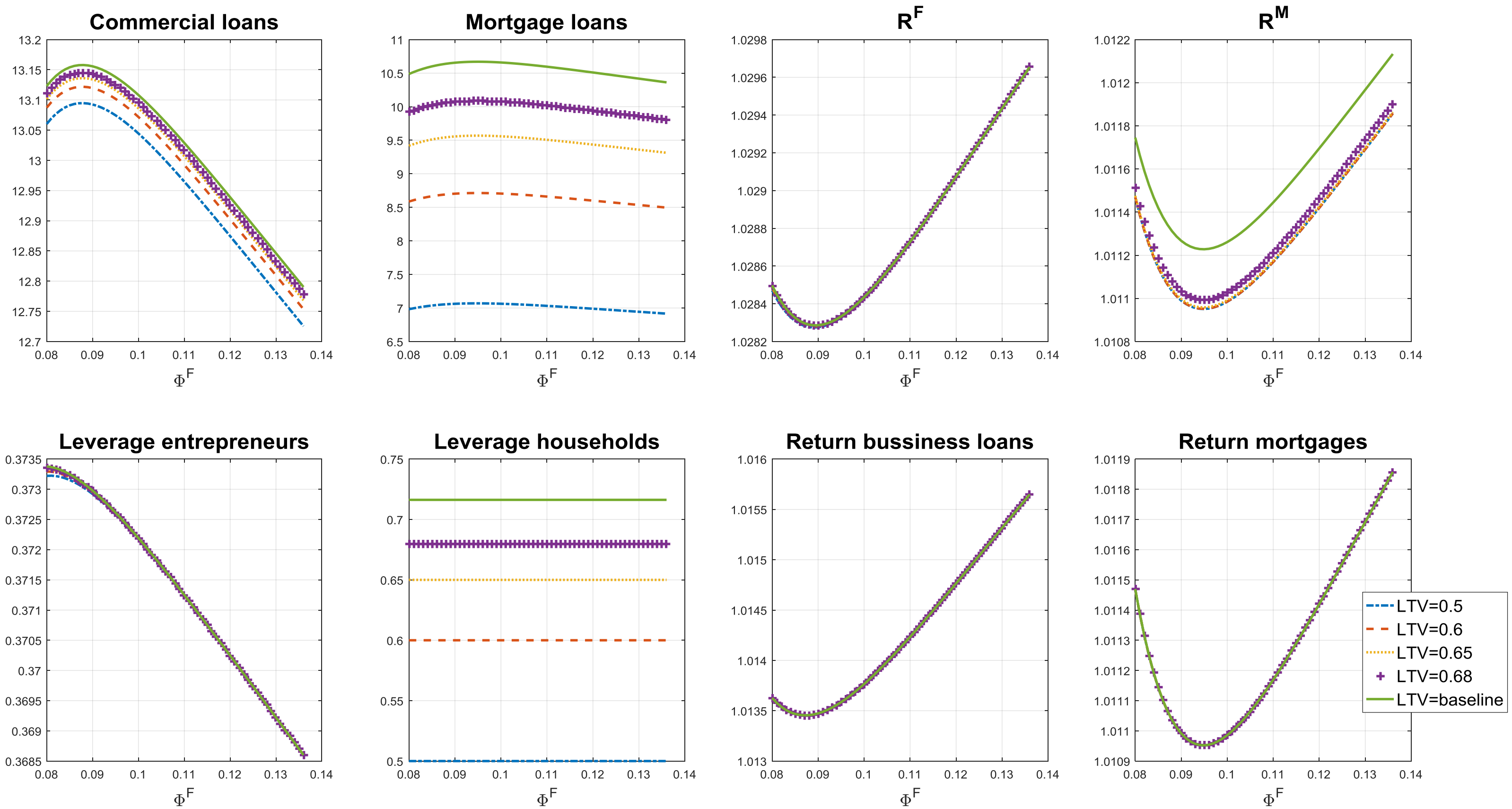
Notes: (i) The vertical axis shows steady-state values, (ii) Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$.

Figure 8: Steady state effects of capping the loan-to-value ratio (III)



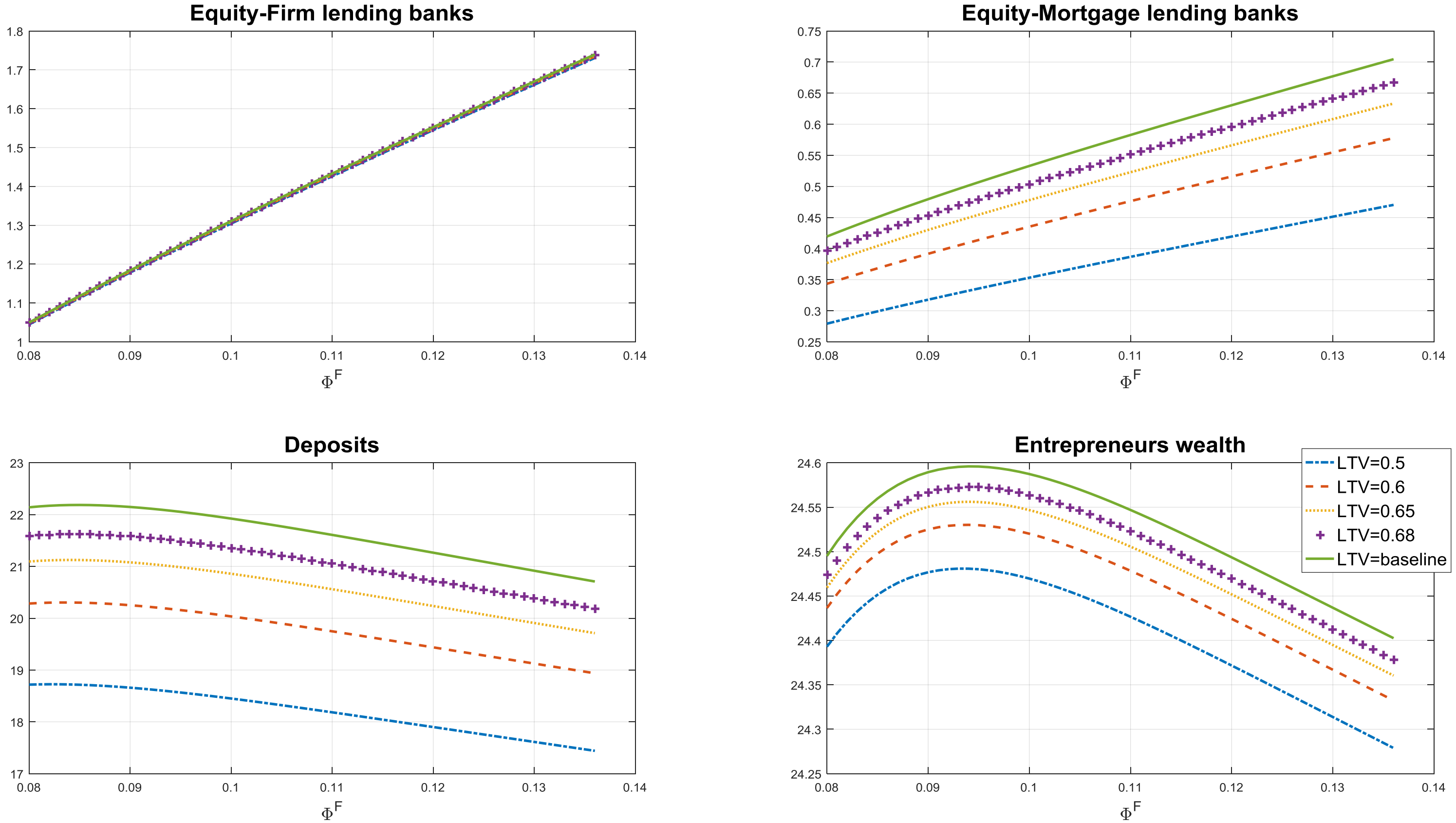
Notes: (i) The vertical axis shows steady-state values, (ii) Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$.

Figure 9: Steady state effects of capping the loan-to-value ratio (IV)



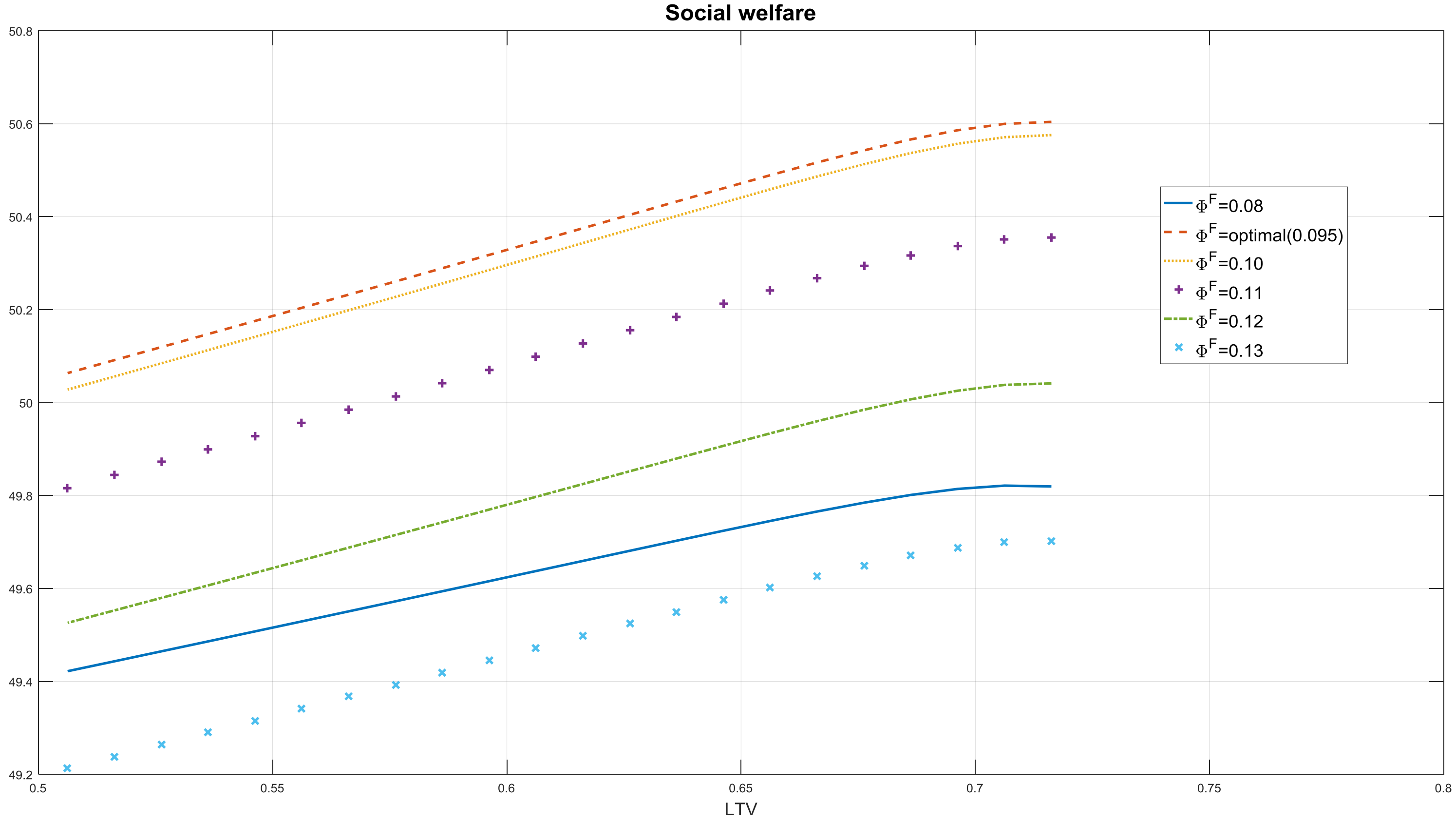
Notes: (i) The vertical axis shows steady-state values, (ii) Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$.

Figure 10: Steady state effects of capping the loan-to-value ratio (V)



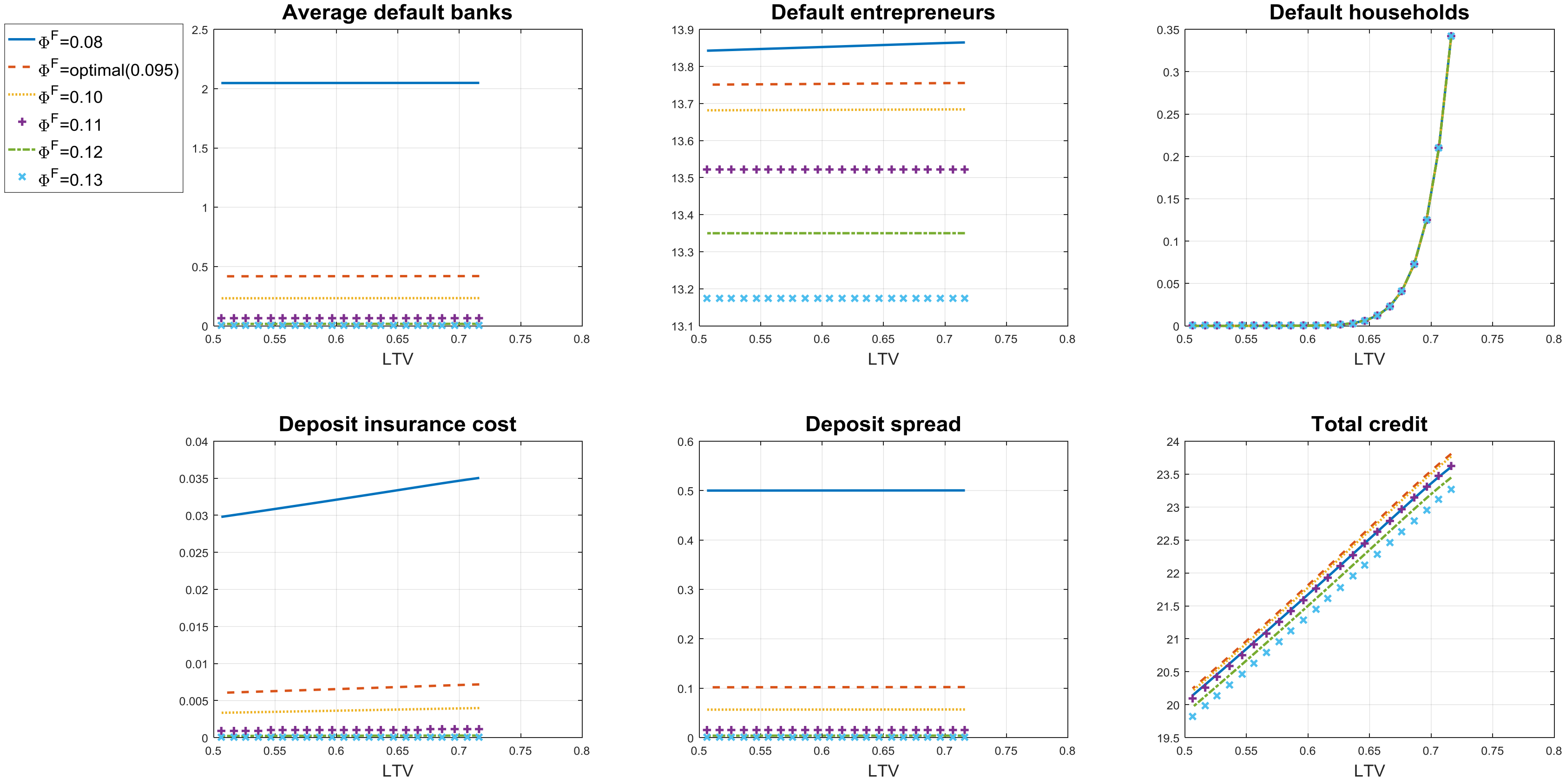
Notes: (i) The vertical axis shows steady-state values, (ii) Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$.

Figure 11: Steady state effects depending on the loan-to-value ratio (I)



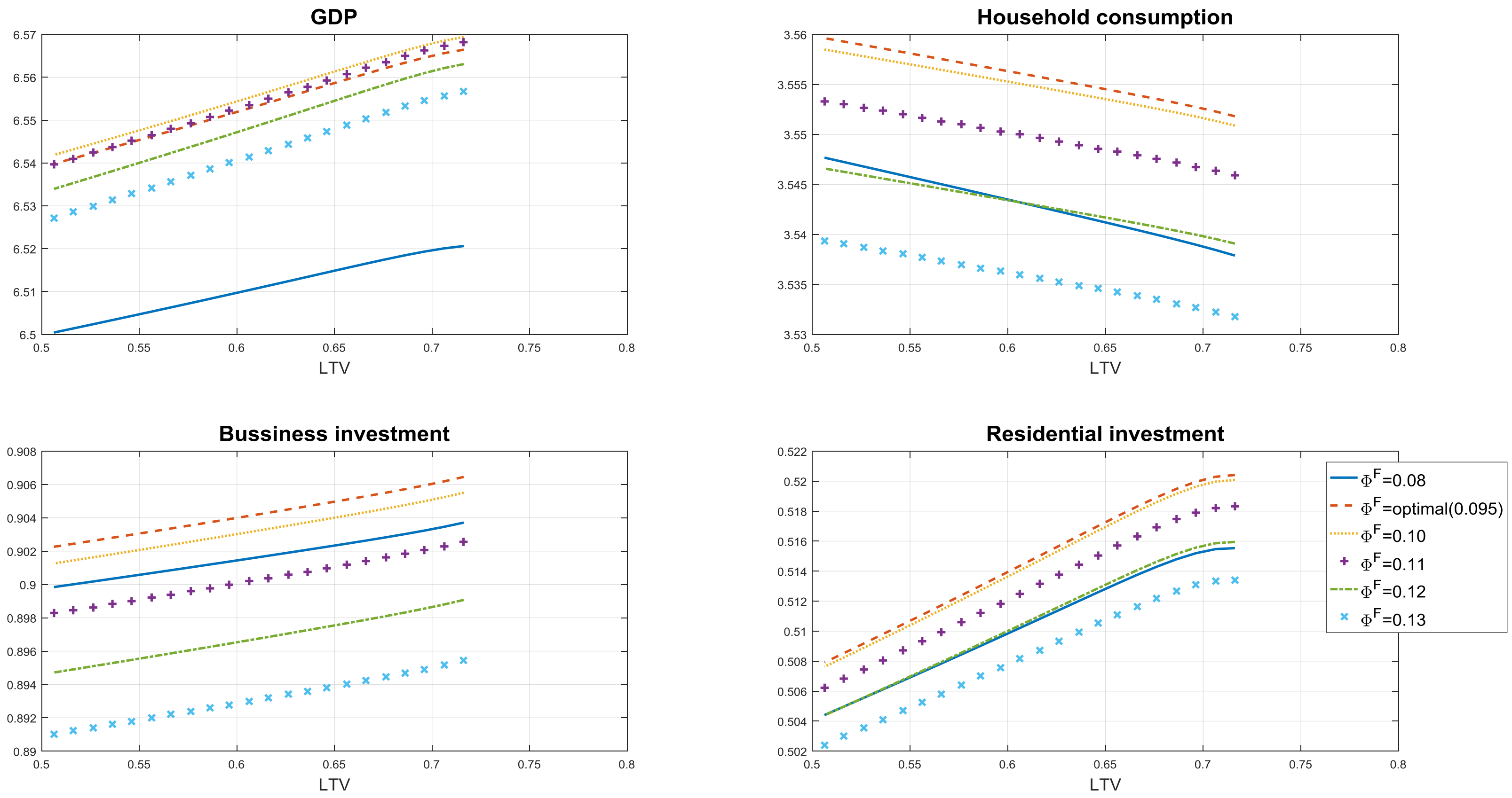
Notes: (i) The vertical axis shows the levels of social welfare V (%), (ii) The horizontal axis shows the values of the LTV ratio, (iii) $\phi^H = \phi^F / 2$.

Figure 12: Steady state effects depending on the loan-to-value ratio (II)



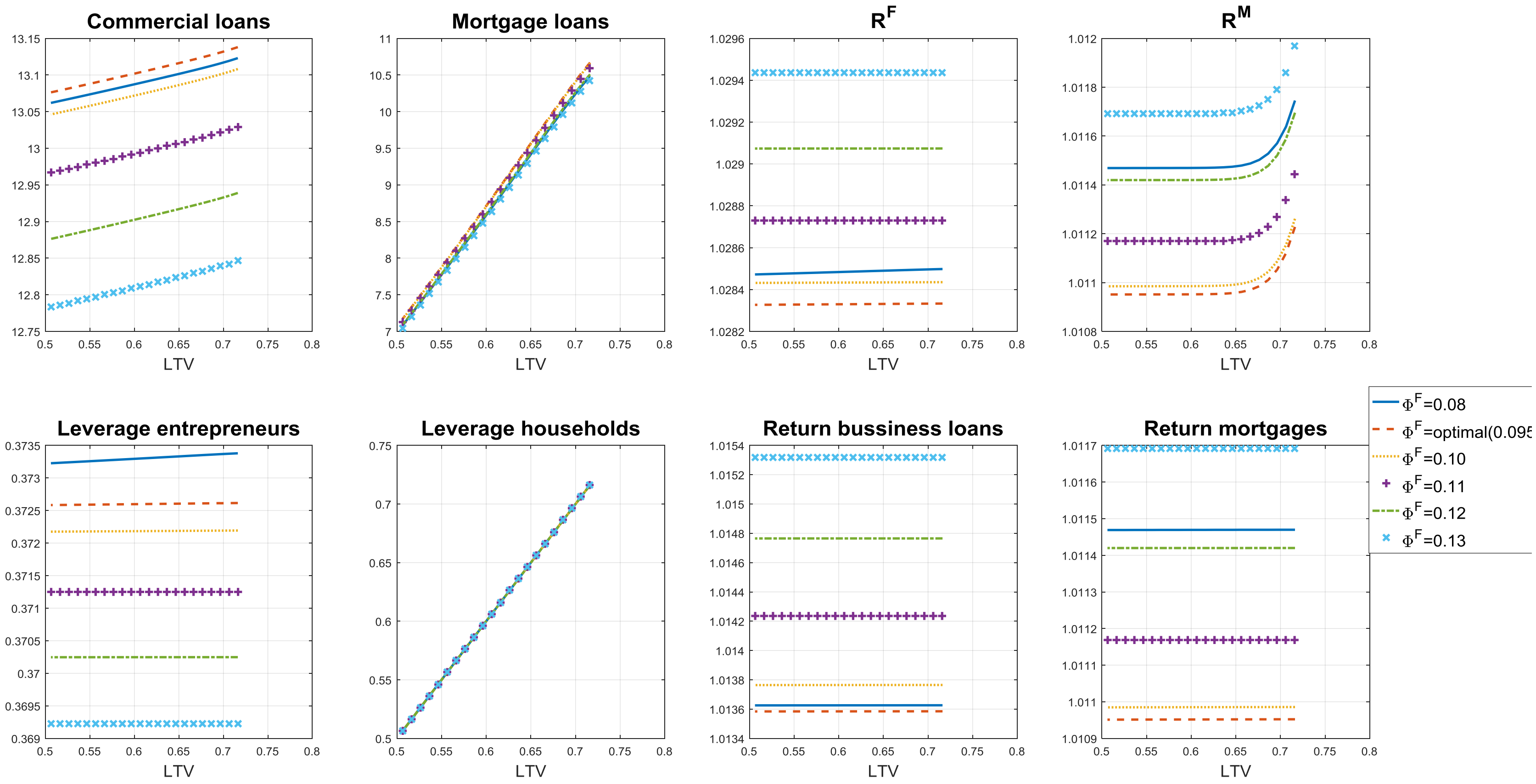
Notes: The vertical axis shows steady-state values, (ii) The horizontal axis shows the values of the LTV ratio, (iii) $\phi^H = \phi^F / 2$.

Figure 13: Steady state effects depending on the loan-to-value ratio (III)



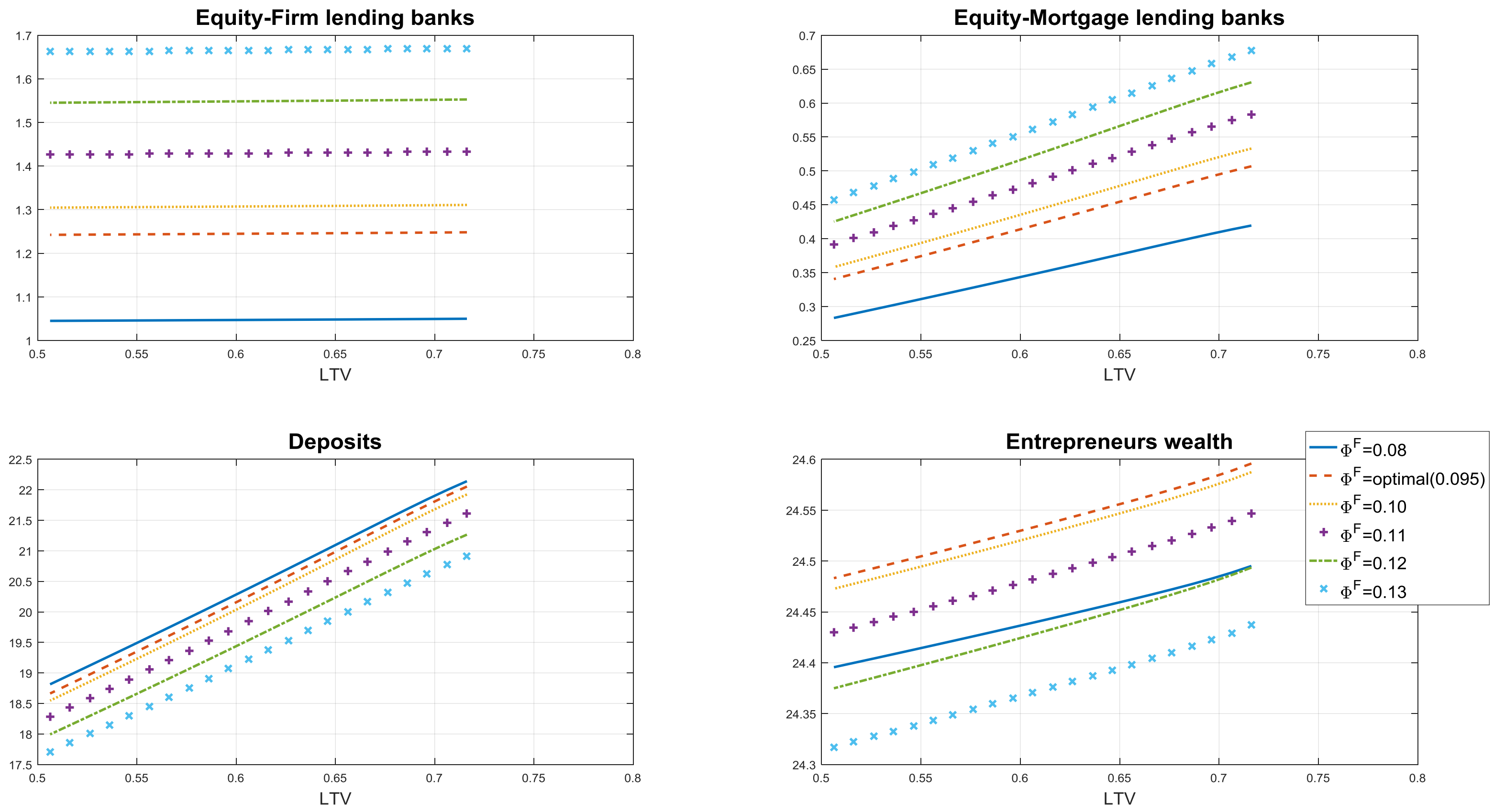
Notes: The vertical axis shows steady-state values, (ii) The horizontal axis shows the values of the LTV ratio, (iii) $\phi^H = \phi^F / 2$.

Figure 14: Steady state effects depending on the loan-to-value ratio (IV)



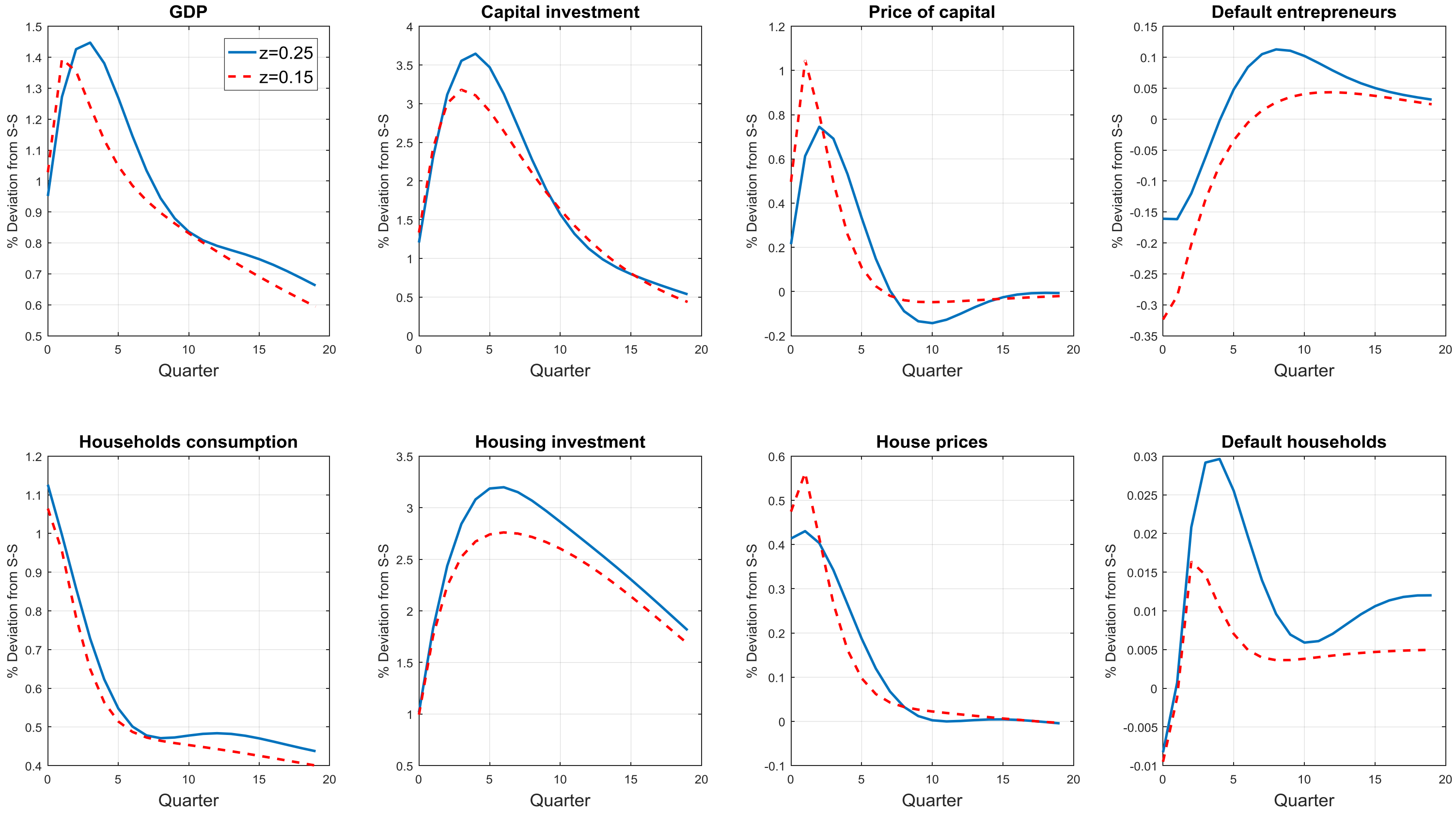
Notes: The vertical axis shows steady-state values, (ii) The horizontal axis shows the values of the LTV ratio, (iii) $\phi^H = \phi^F / 2$.

Figure 15: Steady state effects depending on the loan-to-value ratio (V)



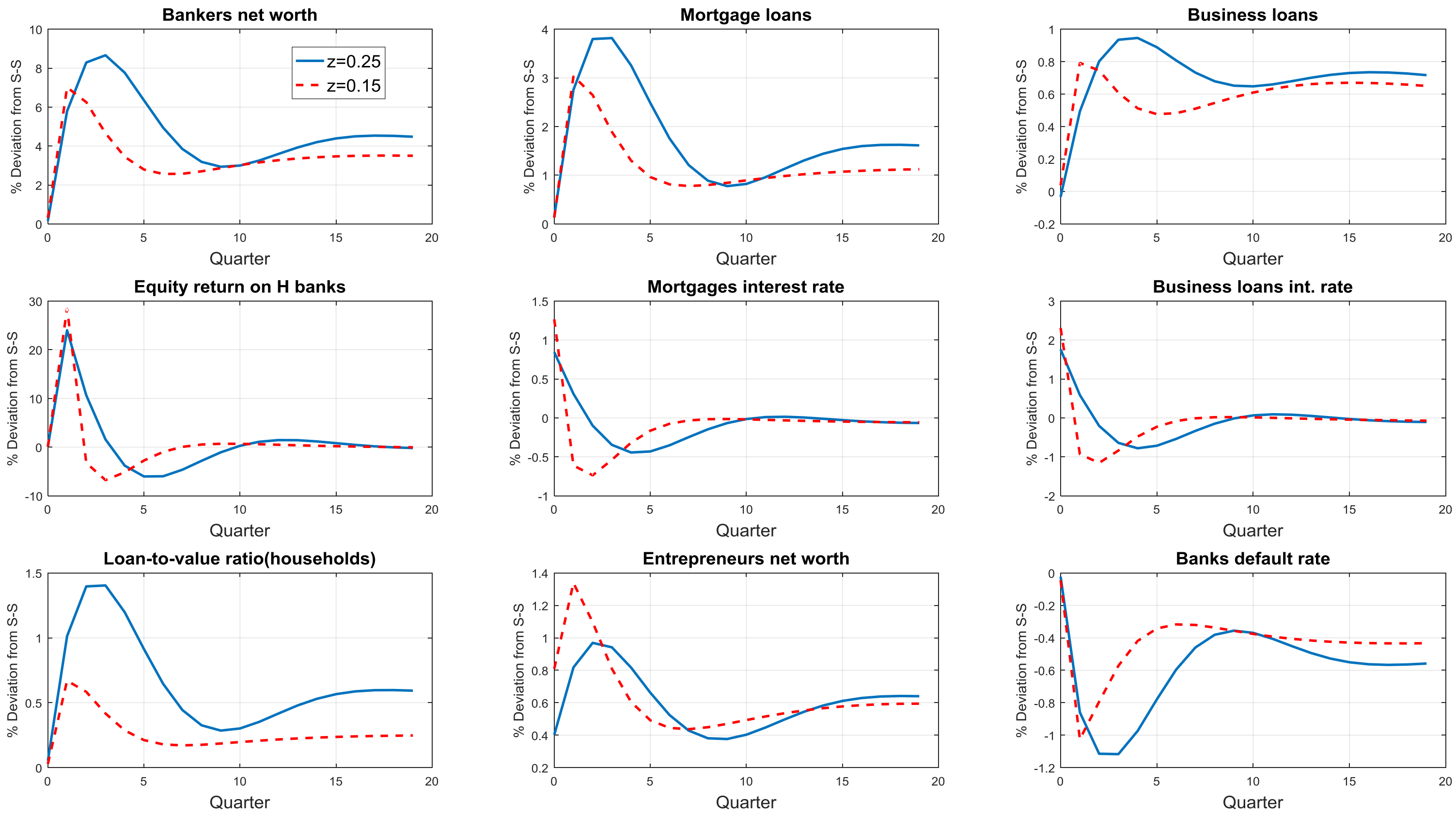
Notes: The vertical axis shows steady-state values, (ii) The horizontal axis shows the values of the LTV ratio, (iii) $\phi^H = \phi^F / 2$.

Figure 16: Impulse responses to a 1% increase in TFP (I)



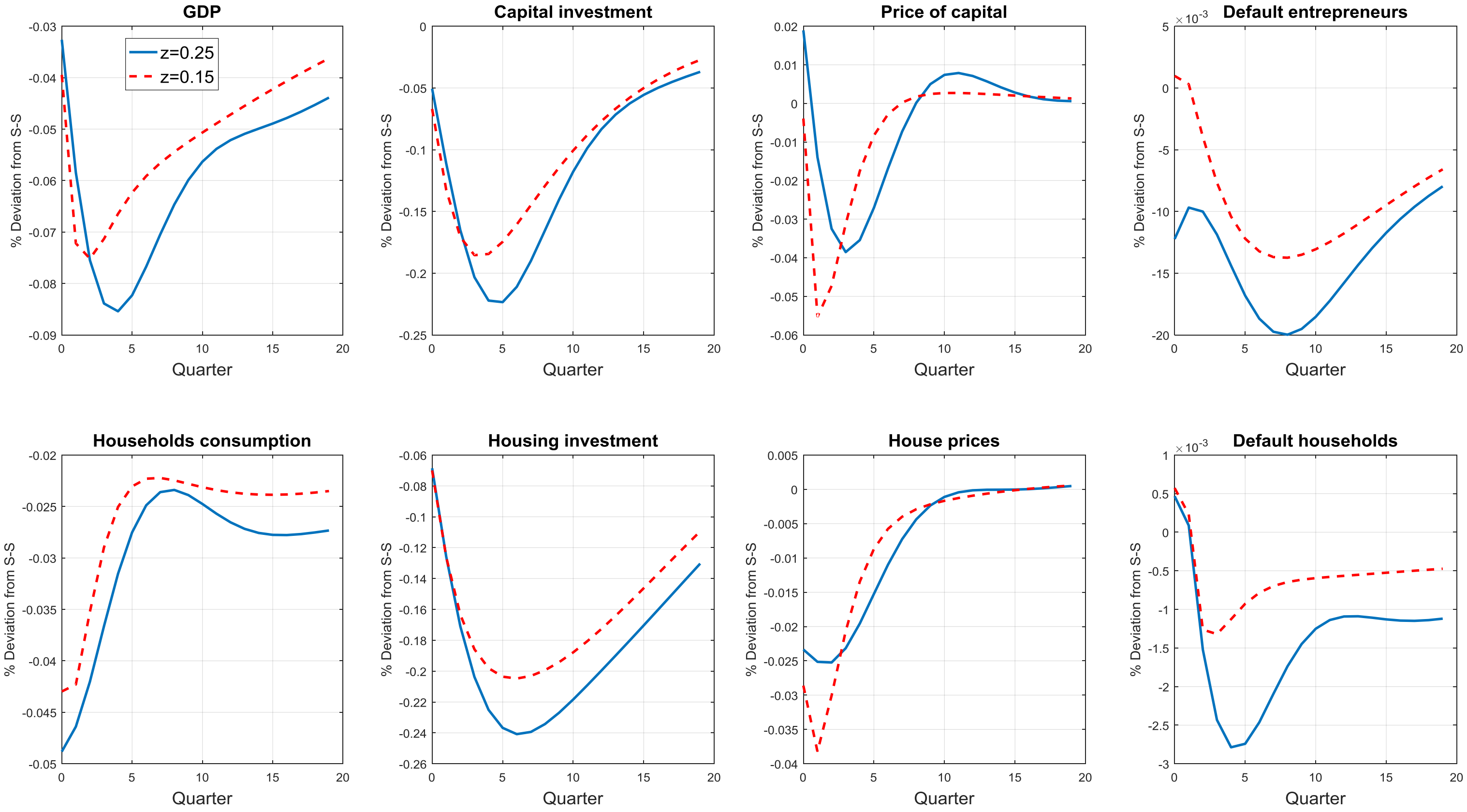
Note: All variables are expressed as percentage deviations from the steady-state.

Figure 17: Impulse responses to a 1% increase in TFP (II)



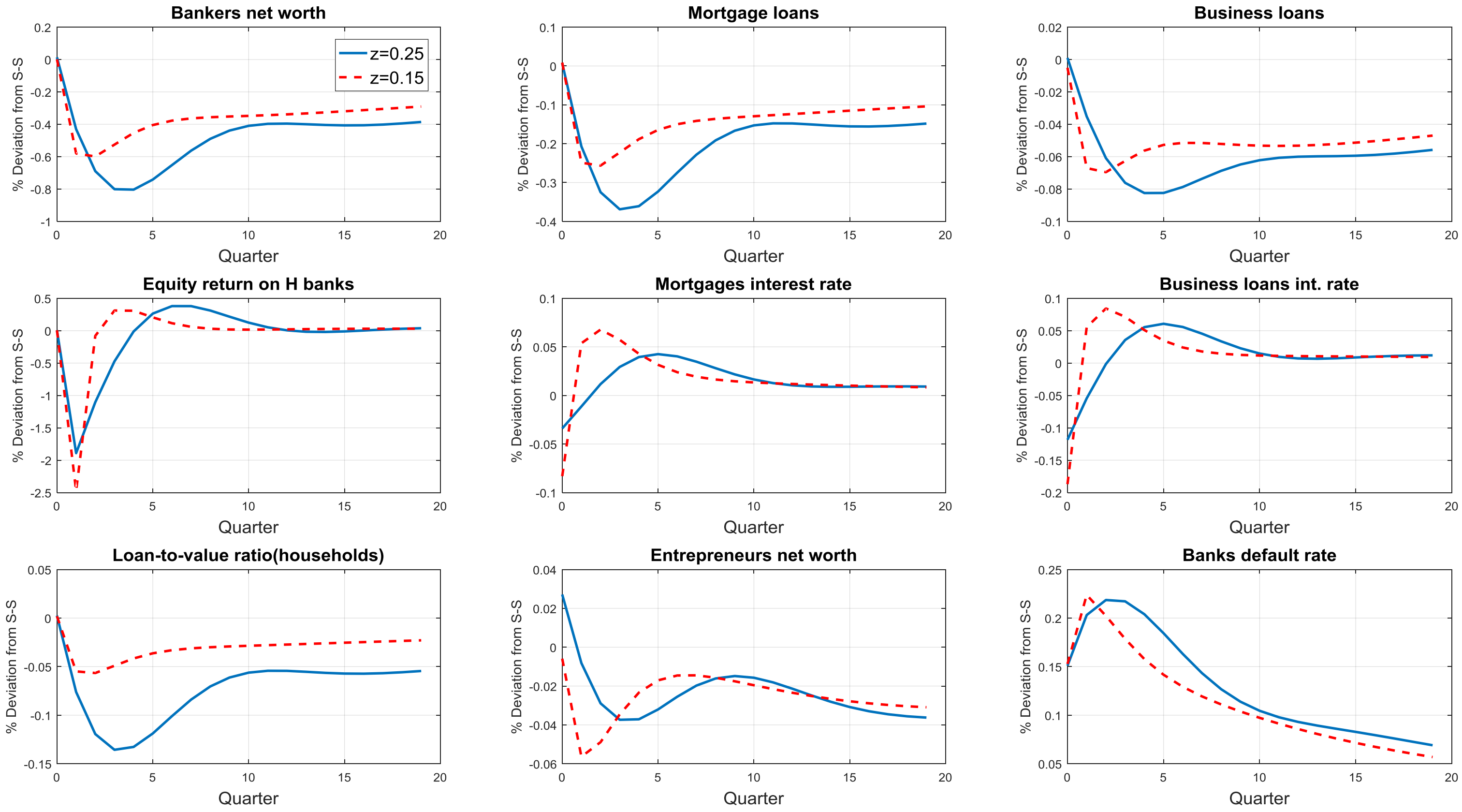
Note: All variables are expressed as percentage deviations from the steady-state.

Figure 18: Impulse responses to a 1% increase in the variance of bank risk shocks (I)



Note: All variables are expressed as percentage deviations from the steady-state.

Figure 19 Impulse responses to a 1% increase in the variance of bank risk shocks (II)



Note: All variables are expressed as percentage deviations from the steady-state.

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