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Collateral Requirements: Macroeconomic Fluctuations and Macro-Prudential Policy *

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Abstract

What are the macroeconomic implications of higher leveraged borrowing? To address this question, we develop a business cycle model with credit frictions in which firms reallocate capital among themselves through the credit market. We find that looser collateral requirements moderate the sensitivity of investment and output to changes in productivity but sharpen the response to shocks originated in the credit market. This result poses a challenge to the design of a macro-prudential policy framework that aims to mitigate pro-cyclicality in the financial market and improve macroeconomic stability. We document that, contrary to discretionary lower caps on loan-to-value ratios, time-varying caps that counter-cyclically respond to indicators of financial imbalances are successful in smoothing credit-cycles without increasing the sensitivity of the economy to real shocks. Further, countercyclical loan-to-value ratios also dampen macroeconomic volatility without reducing the size of the economy.

Keywords: *welfare analysis, reallocation of capital, loan-to value caps, penalty function.*

JEL codes:E21, E22, E 32, E44

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1 Introduction

Several papers explore the role of financial frictions as a propagation mechanism for exogenous changes in productivity, which are considered to be among the important sources of business cycle fluctuations. A common finding in this literature is that improvements in financial markets, proxied by a reduction in the degree of frictions when accessing external financing, generally dampen business cycle fluctuations.[1] Thus, academics and policy makers often concluded that developments in the credit markets, such as the adoption of higher loan-to-value (LTV) ratios and enhanced refinancing possibilities contributed to the reduction in macroeconomic volatility experienced by industrialized countries during the 1980s and 1990s, also known as the Great Moderation. The recent financial crisis proved that shocks originated in the financial sector are an important driving force of business cycle fluctuations. The significant impact of the crisis on the macro-economy called into question the conventional belief that new practices in credit markets lead to less severe business cycle fluctuations.

In order to understand how the credit market may work differently under varying shocks, we develop a business cycle model with credit frictions and analyze the role of collateral requirements as a determinant of macroeconomic fluctuations. We find that looser collateral requirements in the credit market moderate the effect of shocks generated in the real sector of the economy, such as changes in productivity, while exacerbating the effect of shocks that directly affect agents' funding conditions. Thus, we complement previous findings by showing how changes in the credit market that increased the borrowing ability of firms and households could have contributed to both the Great Moderation as well as the most recent recession. This result poses a challenge to the design of a policy framework that contributes to financial and macroeconomic stabilization while monitoring the provision of intermediation services to the wider economy. In this paper, we also address concerns about the need to monitor leverage and to mitigate pro-cyclicality in

[1] Models of the Great Moderation in the U.S. provide insight into the relationship between financial factors and business cycle fluctuations. Among others, Campbell and Hercowits (2004) document that the mortgage market deregulation of the early 1980s coincided with the decline in the volatility of output, consumption and hours worked. Using a model with collateralized household debt, they show that looser credit constraints lead to lower productivity-driven volatility. Jermann and Quadrini (2005) attribute the substantial reduction in macroeconomic volatility to the increased flexibility in the terms and uses of debt and equity financing. Justiniano and Primiceri (2006) also report that the decline in the volatility of shocks specific to the equilibrium condition of investment accounts for most of the decline in the macro volatility. Investment specific shocks can be interpreted as shocks to the relative price of investment. As highlighted by the authors, the reduction in the volatility of the relative price of investment in the data corresponds remarkably well with the timing of financial deregulation. The volatility of both variables follows a similar pattern in the last decades.

the financial system.

We extend Kiyotaki and Moore (1997) setup to a business cycle framework.[2] Credit constraints arise because lenders cannot force borrowers to repay. Thus, the physical asset is used both as a factor of production as well as loan collateral. Borrowers, limited in their capital holding by the existence of credit constraints, experience higher marginal productivity of capital. Efficient production requires the reallocation of physical capital from low productivity lenders to high productivity borrowers. Thus, in response to shocks, the credit market has an important role in reallocating capital to its efficient use. The model differs from Kiyotaki and Moore (1997) in that we use more standard assumptions about preferences and technology. Further, we assume that due to liquidation costs, borrowing is limited to a fraction of the collateral value. We also introduce changes in agents' funding conditions through temporary shocks to the valuation of the collateral asset.

A common practice in the credit friction literature is to assume that collateral constraints are always binding. In this paper we depart from this literature and investigate the role played by non-linearities and feedback effects. We address the occasionally binding nature of the borrowing constraint by using a "barrier method". This approach does not prevent agents from borrowing less than the debt limit, but does discourage them from violating the constraint.[3] We show that under the second order-approximate solution, borrowers are more prudent and, on average, consume less, buy less capital and get less credit. Further, the response to shocks strongly depends on the size and the sign of the shock. In particular, the presence of a limit to borrowing exacerbates the effects of large negative shocks.

This paper provides several insightful results. First, we show that under looser collateral requirements, the sensitivity of investment and output to productivity shocks is reduced. When the economy is hit by a negative productivity shock, borrowers decrease their capital expenditure. Since borrowers experience higher marginal productivity of capital than lenders, a decline in their capital holding reduces their share of total produc-

[2] Several papers have explored the role of collateral constraints *a la* Kiyotaki and Moore (1997) in different business cycle frameworks. See, among others, Iacoviello (2005) for the role of collateralized household debt for business cycle fluctuations, Iacoviello and Minetti (2007) for the international transmission of shocks, Calza, Monacelli, and Stracca (2011) for the transmission of monetary policy shocks and Andres and Arce (2012) for the effect of banking competition in shaping the response to different shocks.

[3] The same approach has already been used to solve models with non-negativity constraints by Preston and Roca (2007), Den Haan and Ocaktan (2009), Kim, Kollmann and Kim (2010) and Kim and Ruge-Murcia (2011).

tion and propagates the aggregate effects of the shock over time. If productive agents can contain the drop in capital through more highly leveraged borrowing, i.e. under looser collateral requirements, the effect of the shock on the aggregate economy is less sizable. Thus, fluctuations driven by productivity shocks are mitigated when the misallocation of productive resources induced by collateral constraints is less sizable. They are, however, amplified when collateral constraints are sufficiently tight to imply larger efficiency losses.

Second, credit shocks have larger and more persistent effects in economies with looser collateral requirements. When borrowers are, on average, more leveraged and the economy is hit by a sudden reduction in the availability of external funds, the drop in agent expenditure and, thus, the drop in the price of the collateral asset is larger. This reduces borrowing further. As a result, investment and aggregate production are more volatile. Looser collateral requirements exacerbate the effects of a credit crunch and at the same time dampen the impact of productivity shocks.

Since the recent financial crisis, the policy debate has focused on the design of a new macro-prudential framework intended to smooth financial cycles and their spillovers to the real economy. Among others, caps on LTV and debt-to-income ratios have been proposed to enhance the financial system's resilience, if adjusted occasionally, or to mitigate the financial cycle, if varied in a countercyclical manner in response to indicators of financial vulnerability. Relying on welfare analysis, we find that, despite the increased vulnerability to credit shocks, looser collateral requirements are socially optimal because they improve the reallocation of capital between borrowers and lenders. This implies a higher long-run level of output and social welfare. Further, we also show that LTV ratios that are varied in a countercyclical manner around a pre-established cap dampen both the severity of credit cycles as well as business cycle fluctuations driven by productivity shocks. This occurs without affecting the long-run performance of the economy. Compared to lower constant LTV ratios, countercyclical LTV ratios can mitigate procyclicality in the financial system and contribute to macroeconomic stabilization without reducing the long-run level of output. Thus, countercyclical LTV ratios are policy tools useful to address pro-cyclicality in the financial system and increase social welfare without having negative implications for the long-run performance of the economy.

This paper is related to the growing literature addressing macro-financial linkages. Several recent papers highlight credit shocks as an important source of business cycle fluctuations. Among others, Jermann and Quadrini (2011) show that financial shocks explain part of the last three economic downturns in the U.S. and have an important role in capturing the dynamics of hours worked. Khan and Thomas (2010) and Shourideh and Zetlin-Jones (2011) find that a tightening in borrowing conditions can generate a macroeconomic recession in a model with collateral constraints and heterogeneous productivity. This paper sheds light on the mechanism through which financial factors affect the transmission of shocks originated in the credit market and their implications for stabilization policies.

A number of recent papers also investigate the welfare implications of collateral requirements. Among others, Campbell and Hercowitz (2008) documents that the reduction in equity requirements on collateralized loans is not Pareto improving in a deterministic model of collateralized household debt. Nikolov (2010) investigates the optimality of capital requirements in Kiyotaki (1998)'s framework in which entrepreneurs face idiosyncratic and aggregate changes in productivity and entrepreneurial consumption is a linear function of wealth. He shows that since agents value their average consumption more than they value consumption stability, collateral requirements are not desirable. In fact, capital requirements act like a tax on highly productive entrepreneurs. Differently from them, we investigate the effects of looser collateral requirements in a stochastic economy in which collateral requirements affect aggregate production and shocks originated in the credit market are introduced as an additional source of business cycle fluctuations. The presence of credit shocks imply a non-linear relationship between the degree of collateral requirements and the unconditional volatility of consumption, investment or output. Nevertheless, the implications of looser collateral requirements for the production of high productive entrepreneurs always dominate and looser collateral requirements result to be socially optimal. Our analysis also differs from the above studies in that we investigate the desirability of time-varying macro-prudential policy, such as the use of countercyclical collateral requirements, as a policy alternative to a discretionary tightening in collateral requirements.

More recently, Bianchi and Mendoza (2011) and Jeanne and Korinek (2011) study time-varying macro-prudential policy in models of the credit cycle. In particular, Bianchi and Mendoza (2011) show that in a model in which asset prices determine debt dynamics, Pigouvian taxes (cyclical taxes on debt) may replicate the constraint-efficient allocation. Jeanne and Korinek (2011) show that, when the interaction between debt accumulation and asset prices contributes to exacerbate booms and busts, it is optimal to impose a Pigouvian tax to prevent over-borrowing. Further, the optimal macro-prudential tax on debt responds to changes in parameters values in a non-trivial way. Unlike these previous contributions, we draw implications for the use of the LTV ratio as an alternative macro-prudential measure to monitor leverage and thus, dampen the magnitude of the financial cycle.[4]

Layout. The paper proceeds as follows. Section 2 describes the model, while section 3 discusses the solution method. Section 4 documents the model's dynamics and section 5 presents the relationship between credit market size and business cycle volatility. Section 6 describes the policy implications and section 7 summarizes the conclusions of the study.

2 The Model

Consider a stochastic discrete-time economy populated by two types of households that trade two kinds of goods: a durable asset and a non-durable commodity. The durable asset, k, is reproducible and depreciates at the rate of δ. The commodity good, c, is produced using the durable asset and cannot be stored. At time *t,* there are two competitive markets in the economy: the asset market, in which one unit of the durable asset can be exchanged for q_t units of the consumption good, and the credit market. We assume ex-ante heterogeneous agents: a continuum of *patient entrepreneurs* (denoted by 1) of unit mass n_1, and a continuum of *impatient entrepreneurs* (denoted by 2) of unit mass n_2. To impose the existence of credit flows in this economy, we follow Kiyotaki and Moore (1997) and assume that the two groups have different subjective discount factors. Agents of type i ($i = 1, 2$) maximize their expected lifetime utility as given by

$$\max_{\{c_{it},k_{it},b_{it}\}} E_t \sum_{t=0}^{\infty} \beta_i^t U\left(c_{it}\ \right),$$

with $\beta_1 > \beta_2$ s.t.

$$c_{it} + q_t(k_{it} - (1-\delta)\, k_{it-1}) = F_{it} + \frac{b_{it}}{R_t} - b_{it-1}, \tag{1}$$

where q_t is the relative price of capital, b_{it} is the borrowing, R_t is the real rate and F_{it} is the total production at the individual level.

Unlike Kiyotaki and Moore (1997), we assume that agents have the same concave production technology.[5] We also allow for reproducible capital and assume that each

[4] The main reason for considering the role of LTV ratio policies is that the LTV ratio is a tool already available in the economy. As emphasized by Geanakoplos and Pedersen (2011): "Leverage and the asset level can be monitored by recording margin requirements, or, equivalently, loan-to-value ratios. This provides a model-free measure that can be directly observed, in contrast to other measures of systemic risk that require complex estimations [...] Margin requirements and down-payments are not just abstract terms in our model. They are negotiated every day in a variety of markets."

[5] Kiyotaki and Moore (1997) assume that agents are risk-neutral and, apart from using different

agent is able to produce both consumption and investment goods. For simplicity, we assume that both types of production are identical.[6] Thus,

$$F_{it} = y_{it} + q_t h_{it}, \tag{2}$$

where y_{it} and h_{it} represent, respectively, the technology for producing consumption goods and capital goods:

$$y_{it} = Z_t \left(k_{it-1}^{c}\right)^{\alpha_i^y} \qquad h_{it} = Z_t \left(k_{it-1}^{h}\right)^{\alpha_i^h}, \tag{3}$$

with k_{it-1}^{j} ($j = c, h$) being the stock of capital used as an input of production in each of the two sectors and Z_t is an aggregate productivity shock. Agents' capital stock evolves according to

$$k_{it} = (1 - \delta)\, k_{it-1} + h_{it}. \tag{4}$$

We follow Kiyotaki and Moore (1997) in assuming that the technology is specific to each producer and that only the household that initiated a particular type of production has the skills necessary to complete it. Thus, if agent i decides not to put effort into production between t and $t + 1$, there would be no production outcome at $t + 1$, but the agent would still hold the asset k_{it}. The agents cannot pre-commit to produce and, moreover, they are free to walk away from the production and debt contracts between t and $t + 1$. Lenders know that if the borrower abandons its production and debt obligations, he will still hold his assets. This prompts creditors to protect themselves by taking the borrowers' assets as collateral. We assume that the repossession of the borrower's assets is subject to a transaction cost proportional to the expected value of the collateral, $[(1 - \gamma) E_t q_{t+1} k_{it} (1 - \delta)]$. The fraction γ should not exceed one and is treated as exogenous to the model.[7] Thus, agents cannot borrow more than the expected value of next period assets

$$b_{it} \leq \gamma E_t \left[\xi_t q_{t+1} k_{it} (1 - \delta)\right]. \tag{5}$$

discount factors, they also differ in their production technologies. In the model presented here, we follow most of the business cycle literature and assume that both groups of agents have a concave utility function and are generally identical.

[6] Assuming that each agent produces both goods, we avoid creating a rental market for capital and make the model directly comparable to Kiyotaki and Moore (1997). The assumption of decreasing returns in the production of investments goods is equivalent to assuming convex adjustment costs for investments.

[7] Djankov, Hart, McLiesh and Shleifer (2008) show that debt enforcement procedures around the world are significantly inefficient. Worldwide, an average of 48 percent of an insolvent firm's value is lost in debt enforcement. Thus, limiting the amount lent to a fraction of the value of the collateralized asset turns out to be a reasonable assumption.

As emphasized by Geanakoplos (2011) the LTV can change dramatically and its rapid change can be a crucial source of crashes. We introduce changes in agents funding conditions through ξ_t, i.e., a temporary shock to the valuation of the collateral asset.[8] We refer to these as "credit shocks".[9]

In order to investigate the relationship between collateral requirements and aggregate production we rely on a model that features collateral requirements on entrepreneurial loans. As already highlighted by Liu, Wang and Zha (2011) and Berger and Udell (1990), commercial mortgages are, indeed, an important fraction of business loans. In the U.S. about 70 percent of commercial and industrial loans are secured by collateral assets. In the following, we extend Kiyotaki and Moore (1997) setup to a business cycle framework.[10]

2.1 Agents ' optimal choices

Step 1: Optimal Allocation of Capital. We divide the agents' problem into two steps. First, in any given period, each agent allocates the existing capital to the production of either consumption or investment goods by solving,

$$\max_{k^c_{it-1}} \; Z_t \left\{ \left(k^c_{it-1}\right)^{\alpha} + q_t \left(k_{it-1} - k^c_{it-1}\right)^{\alpha} \right\}.$$

This leads to the first-order condition,

$$\left(k^c_{it-1}\right)^{\alpha-1} = q_t \left[\left(k_{it-1} - k^c_{it-1}\right)\right]^{\alpha-1}. \tag{6}$$

The relative price of capital equals the ratio of the marginal productivity of capital in the two sectors. The amount of capital allocated to each type of production as a fraction of the total capital owned by each agent can be expressed as follows,

$$k^c_{it-1} = \theta_t k_{it-1}, \tag{7}$$

[8] An exogenous change in the valuation of the collateral asset could reflect an endogenous variation in the access to credit generated by a credit supply shock originated in the banking sector (not modelled in the present framework) or as a shock to lenders' expectations about the price of the collateral asset. In both cases, the shock is indipendent from the borrowers' decisions.

[9] Several other authors highlight the role of collateral shocks as an important source of business cycle fluctuations. Among others, Liu, Wang and Zha (2011) argue that collateral shocks explain a non-negligible fraction of fluctuations in output, business investment and hours worked. Khan and Thomas (2010) and Shourideh and Zetlin-Jones (2011) find that a tightening in borrowing constraints can generate a macroeconomic recession in a model with collateral constraints and heterogeneous productivity. Jermann and Quadrini (2011) show that shocks to the enforcement constraint of firms explain part of the last three economic downturns in the U.S. and have an important role in capturing the dynamics of hours worked.

[10] For other business cycle models of collateralized entrepreneurial debt, see also, Kiyotaki (1998), Iacoviello and Minetti (2006), Khan and Thomas (2010), Buera and Moll (2011), Shourideh and Zetlin-Jones (2011), Liu, Wang and Zha (2011).

where $\theta_t = \frac{(q_t)^{\frac{1}{\alpha-1}}}{1+(q_t)^{\frac{1}{\alpha-1}}}$. The allocation of existing capital between the two production processes depends on the current relative price of capital q_t. The total production of each individual can be expressed as

$$F_{it} = k_{it-1}^{\alpha} Z_t \left[\theta_t^{\alpha} + q_t \left[(1-\theta_t)\right]^{\alpha}\right]. \tag{8}$$

Step 2: Utility Maximization. It is possible to simplify the maximization problem, obtaining

$$\max_{\{c_{it},k_{it},b_{it}\}} E_t \sum_{t=0}^{\infty} \beta_i^t U\left(c_{it}\right)$$

s.t. the *budget constraint,*

$$c_{it} + q_t(k_{it} - (1-\delta)\, k_{it-1}) = k_{it-1}^{\alpha} Z_t \left\{\theta_t^{\alpha} + q_t \left[(1-\theta_t)\right]^{\alpha}\right\} + \frac{b_{it}}{R_t} - b_{it-1},$$

and the *borrowing constraint*,

$$b_{it} \le \gamma E_t \left[\xi_t q_{t+1} k_{it} \left(1-\delta\right)\right].$$

The agents' optimal choices are then characterized by

$$\frac{u_{c_{i,t}}}{R_t} \ge \beta_i E_t u_{c_{i,t+1}} \tag{9}$$

and

$$q_t - \beta_i E_t \frac{u_{c_{i,t+1}}}{u_{c_{i,t}}} q_{t+1}\left(1-\delta\right) \ge \beta_i E_t \frac{u_{c_{i,t+1}}}{u_{c_{i,t}}} \left(F_{k_{i,t+1}}\right), \tag{10}$$

where $F_{k_{i,t+1}}$ is the marginal product of capital. The first equation relates the marginal benefit of borrowing to its marginal cost, while the second shows that the opportunity cost of holding one unit of capital, $\left[q_t - \beta_i E_t \frac{U_{c_{i,t+1}}}{U_{c_{i,t}}} q_{t+1}\left(1-\delta\right)\right]$, is greater than or equal to the expected discounted marginal product of capital.

Heterogeneity in the discount factors ensures that in equilibrium, patient households lend and impatient households borrow. Patient households' demand for capital is determined by the point at which the opportunity cost of holding capital equals its marginal product. Thus, the asset price equation derived from the model can be expressed as

$$q_t = E_t \sum_{j=0}^{\infty} \beta_1^j \frac{u_{c1,t+1}}{u_{c1,t}} \left(1-\delta\right)^j F_{k1,t+j}, \tag{11}$$

where $\beta_1^j \frac{u_{c1,t+1}}{u_{c1,t}}$ is the stochastic discount factor or *pricing kernel.* Agents' demand for capital is such that the marginal productivity of capital, $F_{k1,t+j}$, discounted by $\beta_1^j \frac{u_{c1,t+1}}{u_{c1,t}}$, is equal to the relative price of capital. Thus, movements in the real interest rate – i.e. the inverse of the *pricing kernel* – and the productivity of capital experienced by the lenders, determine the behavior of the relative price of capital.

In contrast, borrowers' marginal product of capital differs from its market price. For impatient agents, the marginal benefit of borrowing is always greater than the marginal cost:

$$\frac{U_{c_{i,t}}}{R_t} - \mu_{2,t} = \beta_i E_t U_{c_{i,t+1}}. \tag{12}$$

Since the borrowers internalize the effect of their capital stock on their financial constraints, their marginal benefit of holding one unit of capital is given by both its marginal product and by the marginal benefit of being allowed to borrow more:

$$q_t - \beta_2 E_t \frac{U_{c_{2,t+1}}}{U_{c_{2,t}}} q_{t+1}(1-\delta) = \beta_2 E_t \frac{U_{c_{2,t+1}}}{U_{c_{2,t}}} \left(F_{k_{2,t+1}}\right) + \gamma E_t q_{t+1} \frac{\mu_{2,t}}{U_{c_{2,t}}}. \tag{13}$$

Collateral constraints alter the future revenue by an additional unit of capital for the borrowers. Holding an extra unit of capital relaxes the credit constraint and increases the shadow price of capital. This additional return encourages borrowers to accumulate capital even though they discount the revenues more heavily than lenders. As long as the marginal product of capital differs from its market price, borrowers have an incentive to change capital stock.[11]

Aggregate Conditions. The total stock of capital k_t is given by

$$k_t = n_1 k_{1t} + n_2 k_{2t}. \tag{14}$$

The following conditions also hold:

$$y_t = n_1 y_{1t} + n_2 y_{2t} = n_1 c_{1t} + n_2 c_{2t}, \tag{15}$$

$$n_1 b_{1t} = -n_2 b_{2t}. \tag{16}$$

Steady State. It is possible to show that, in the steady state, the borrowing constraint is always binding.[12] Moreover, the allocation under credit constraints reduces the level of capital held by the borrowers

$$\frac{k_1}{k_2} = \left[\frac{\beta_1}{\beta_2} \frac{1 - \beta_2(1-\delta) - \gamma(\beta_1 - \beta_2)}{1 - \beta_1(1-\delta)}\right]^{\frac{1}{1-\alpha}} > 1 \tag{17}$$

[11] The price of capital is higher than the frictionless marginal Tobin's Q for the borrowers.

[12] Consider the Euler equation for the impatient household. In the deterministic steady state:

$$\mu_2 = (\beta_1 - \beta_2) U_{c_2} > 0,$$

where μ_2 is the Lagrange multiplier associated with the borrowing constraint.

as long as $\gamma \leq 1$ and $\beta_1 > \beta_2$. Relative to the lenders, the borrowers experience higher marginal productivity of capital and produce a lower fraction of aggregate output. Efficient production requires the reallocation of physical capital from low productivity lenders to high productivity borrowers. Consequently, the credit market has an important role in reallocating capital to its efficient use in response to shocks.

3 Solution Method

It is common to solve models with collateral constraints by assuming that the constraint is always binding in a neighborhood of the steady state.[13] We take an alternative approach and address the occasionally binding nature of the borrowing constraint by using a "barrier method".[14] That is, we solve an equivalent version of the model in which higher borrowing is feasible but it is too costly to exceed the limit. The inequality constraint is replaced by a differentiable penalty function, $P(k_{it}, b_{it})$, that enters the utility function of the agents

$$U(c_{it}) = \frac{c_{it}^{1-\varphi}}{1-\varphi} - P(k_{it}, b_{it}).$$

The function

$$P(k_{it}, b_{it}) = \frac{\kappa_1}{\kappa_0} e^{[-\kappa_0(\gamma E_t[\xi_t q_{t+1} k_{it}] - b_{it})]} \tag{18}$$

is decreasing in the difference between b_{it} and the endogenous limit, $\gamma E_t \left[\xi_t q_{t+1} k_{it}\right]$. Unlike a constraint that is always binding, the penalty function does not prevent impatient agents from borrowing less than the debt limit in a neighborhood of the steady state. However, it does discourage them from violating the debt limit. The penalty term, κ_0, discourages the agents from violating the constraint such that large values of κ_0 ensure that the agents' indebtedness does not exceed the limit.[15] In equilibrium, the derivative of the penalty function w.r.t. b_{it} replaces the shadow price of the borrowing constraint, μ_2. We can set κ_1 such that the two versions of the model have the same deterministic steady state.[16]

[13] See, among others, Campbell and Hercowitz (2004), Iacoviello (2005), Monacelli (2009), Iacoviello and Neri (2010), Sterk (2010), Calza, Monacelli, and Stracca (2010), Andres and Arce (2012).

[14] For the use of "barrier methods", see Judd (1998). This approach has already been used to solve models with non-negativity constraints by Preston and Roca (2007), Den Haan and Ocaktan (2009), Kim, Kollmann and Kim (2010) and Kim and Ruge-Murcia (2011).

[15] We set the penalty term, κ_0, equal to 100.

[16] This occurs when $\kappa_1 = \mu_2$.

The agents' optimal choices of borrowing and capital, together with the equilibrium conditions, represent a non-linear dynamic stochastic system of equations. To capture the non-linearity induced by the asymmetric penalty function, we solve for the recursive law of motion by relying on a second order approximation.[17]

Figure 1 shows the policy functions for borrowers' capital, consumption and credit as a function of the beginning of the period capital stock, level of indebtedness and the size of the shocks. To construct this plot, we assign standard values to preference and technology parameters. The model's period is one quarter. The productivity parameter, α, is set to 0.4, the capital depreciation rate, δ, equals 0.025 and the utility parameter φ is equal to 2.2. The discount factor of patient households, β_1, equals 0.99, such that the average annual rate of return is approximately 4 percent. We choose a fraction of borrowers equal to fifty percent of the population. The baseline choice for the borrowers' discount factor, β_2, is 0.95. These values are in the ballpark of estimated values reported by previous literature and are commonly used in models with collateral constraints.[18] For an illustrative purpose, we set the parameters related to the liquidation cost of the collateral asset, γ, equal to 0.85.[19] Regarding the aggregate productivity shock, we assume an AR process with 0.9 persistence. We set the standard deviation of both shocks and persistence of the credit shock such that the unconditional standard deviation of the relative price of capital to debt predicted by the model matches those computed from the data.[20]

The policy functions are obtained using first- and second-order polynomial approximation. Due to the introduction of uncertainty, under the second-order approximation borrowers are more prudent and on average consume less, buy less capital and get less credit than under the first order approximate solution. Further, the second-order approximate solution implies a non-linear relationship between the model's endogenous

[17] See Schimitt-Grohe and Uribe (2004), Kim, Kim, Schaumburg and Sims (2008), Ruge-Murcia (2010) and Lombardo (2010) for studies of the second-order polynomial approximation in details.

[18] See among others, Campbell and Hercowitz (2005), Iacoviello (2005), Iacoviello and Minetti (2007), Iacoviello (2008), Iacoviello and Neri (2010), Sterk (2010).

[19] According to Djankov, Hart, McLiesh and Shleifer (2008) an average of 48 percent of a firm's value is lost in debt enforcement worldwide. In OECD countries, around 24 percent of a firm's value is lost in debt enforcement, while about 14 percent is lost in the U.S. The parameter γ, in the model could also be interpreted as the maximum LTV ratio. Iacoviello (2005) using limited information methods, estimates a business cycle model for the U.S. economy and report a LTV ratio of 89 percent for the entrepreneurial real estate and 55 percent for the household real estate.

[20] Using U.S. aggregate data over the 1995:1-2005:4 period, we calculate a standard deviation of the relative price of investment to business debt of about 30 per cent. For the model to match this relative standard deviation we need to calibrate the persistence of the credit shock to 0.5 and the standard deviation of the productivity and credit shock to 1 and 0.8 per cent, respectively.

variables and state variables. Thus, the response to shocks strongly depends on the size and the sign of the shock. In particular, the presence of a limit to borrowing exacerbates the effect of large negative shocks. Notice that the first-order approximate solution of the model with the penalty function is equal to the solution of the model with always binding collateral constraints.

4 Economic and Financial Downturns

In the following section, we analyze the effects of a negative aggregate productivity shock as well as a credit crunch. We assume that the economy is at the steady-state level at time zero and then is hit by each of the two shocks, separately. We set the parameters of the model equal to the values reported in the previous section.

4.1 Productivity Shock

An exogenous change in aggregate productivity affects the decisions of all agents in a similar way. Both borrowers and lenders reduce their investment in capital. The user cost of capital declines, implying a less profitable allocation of capital as an input factor in the production of investment goods, as indicated by the increase in θ. Thus, in response to a neutral technology shock, the model generates co-movement between consumption and investment good production. The investment good production shows evidence of significant amplification, while the production of the consumption good reacts much less markedly. See Figure 2.a.

The allocation under credit constraints reduces the steady state level of capital held by the borrowers. Consequently, before the occurrence of the shock, borrowers experience higher marginal productivity and produce a lower fraction of aggregate output. The decline in their level of capital implied by the shock further reduces their share of production. In the second period, the borrowers' production is more strongly affected by the shock and displays a more severe decline. This propagates the negative effect of the shock on the aggregate economy over time. Overall, after a one percent decrease in aggregate productivity, total output decreases by approximately 1.2 percent in the first period and by even more in the second.

4.2 Credit Crunch

The model implies an asymmetric response to credit shocks. In fact, borrowers reduce their capital holding, whereas lenders' capital increases. Thus, capital is reallocated from the high productive borrowers to the less productive lenders widening the productivity gap. The asymmetric responses from borrowers' and lenders' production imply that the negative effect on aggregate output driven by the reduction in borrowers' production is dampened by the increase in lenders' production. Unlike productivity shocks, credit shocks do not generate a sudden fall in either GDP or in the relative price of capital. In contrast, due to the widening of the productivity gap, the largest effect of the shock occurs in the second period, i.e. when the new level of capital is put into production. See Figure 2.b.

Overall, after a shock that reduces the borrowers' ability to raise external funds, aggregate variables move in the same direction as in the case of a negative productivity shock. The behavior of the real interest rate offers an exception. When credit conditions become tighter, borrowers are forced to reduce their level of indebtedness. Thus, as a general equilibrium effect, lenders reduce their holding of financial assets. For the reduction in the availability of funds to be consistent with the lenders' optimality conditions for the bond's demand, the real interest rate declines. Since capital can only be used in production with a one-period lag, movements in the real interest rate determine the first-period behavior of asset prices. See Equation 11. The relative price of capital first declines and then increases. The initial decline in the relative price of capital further reduces the availability of credit by reducing the value of the collateralized asset. A one percent exogenous decline in the valuation of the collateral implies an endogenous reduction in agents' debt by six percent.

5 Are looser collateral requirements a (de)stabilization device?

In the following, we investigate the relationship between the degree of collateral requirements, macroeconomic volatility and welfare. We take into account different degrees of credit market frictions by limiting the borrowing to a fraction of the expected liquidation value of the collateral. A higher γ represents looser collateral requirements, while a lower γ represents an economy subject to a higher degree of frictions in the credit market.[21]

[21] See, among others, Aghion et al. (2003), Campbell and Hercowitz (2005), Calza, Monacelli and Stracca (2009).

5.1 Credit Frictions as a Transmission Mechanism

We examine the relationship between the volatility of the cyclical component of key macroeconomic variables and the collateral requirements in the credit market. Figure 3 shows the standard deviation of output, investment and the relative price of capital as a function of γ, conditional on each of the two shocks, separately.[22]

Our results show that productivity-driven macroeconomic volatility generally declines with respect to the degree of credit frictions. Nevertheless, while looser collateral requirements reduce the role of productivity shocks as a source of fluctuations, they also amplify the macroeconomic effects of credit shocks.

Changes in productivity have a symmetric effect on borrowers and lenders. A negative productivity shock reduces the production and investment decisions of both groups of agents. However, under a lower degree of credit frictions, borrowers can better smooth the negative effect of productivity shocks through the credit market. Thus, their demand for capital declines by a smaller margin. This dampens the decrease in the relative price of capital and makes the productivity gap react by less. Reduced variations in the relative marginal productivity of capital mean lower losses in terms of productive efficiency. This implies a dampening effect on the transmission of the shock. Thus, fluctuations driven by productivity shocks are mitigated when the misallocation of productive resources induced by collateral constraints is less sizable. In contrast, they are amplified when collateral constraints are sufficiently tight to imply larger efficiency losses. Figure 4.a reports the response of the economy to a productivity shock for γ equal 0.85 (solid line) and 0.5 (dashed line).

On the contrary, changes in credit conditions have an asymmetric effect on borrowers and lenders. A negative credit shock implies a widening of the productivity gap. This is because in economies with looser collateral requirements, borrowers are more leveraged. When the economy is hit by a shock that reduces the valuation of the collateral asset, the drop in borrowers' expenditure is more sizable. Thus, due to the reduced availability of nominal assets, lenders shift their resources to physical capital and further increase their production. Larger variations in the misallocation of resources imply feedback effects and make the economy more responsive to the shock. See Figure 4.b.

[22] Regarding the credit shock, we considered variations in the valuation of the collateral asset by one percent. This means that the borrowers' ability to raise external funds changes by more in economies with higher LTV ratios. In order to avoid concerns related to the fact that the larger volatility recorded in economies with higher γ might be entirely driven by larger shocks, in Figure 3 we report the elasticity to the change in the loan to value ratio implied by the valuation shock. This is measured as the standard deviation of macroeconomic variables relative to the change in the LTV ratio implied by the shock.

Summarizing, in an economy with credit frictions heterogeneity in the production sector, the degree of collateral requirements is key to the transmission of the shocks. In fact, it affects the degree of inefficiency in directing resources from less to more productive agents and viceversa. Movements in the productivity gap, as induced by changes in the allocation of capital between borrowers and lenders, affect the amplification and endogenous persistence of the shocks: larger variations in the misallocation of resources make the economy more responsive to the shock. This happens for low values of γ in the case of productivity shocks and for high values of γ in the case of credit shocks.

5.2 Welfare Implications

Our findings suggest that looser collateral requirements increase the vulnerability of the economy to shocks originated in the credit market. Thus, monitoring leverage through margin requirements turns out to be relevant. In order to draw meaningful conclusions about the macroeconomic implications of alternative LTV ratios, we compare them on the bases of welfare criteria. In this way, we avoid any *a priori* conjecture on the optimality of reducing volatility of same particular variables, such as output or credit.

We assume that the policy objective function can be summarized in a social welfare function that assigns social weights to the welfare of the individual agents, V_t^i,

$$\tilde{V}_t \equiv \left[(1-\beta_1)V_{1t} + (1-\beta_2)V_{2t}\right], \tag{19}$$

where the weights on households' welfare, β_1 and β_2 are such that, given a constant consumption stream, the borrowers and the lenders achieve the same level of utility and, thus, contribute equally to social welfare.[23] The individual welfare of each agent is measured by the conditional expectations of lifetime utility as of time t.[24] To compute the optimal LTV ratio, we evaluate ex-ante optimal policy, i.e., policy that is not dependent on a particular realization of the shocks. Given the difficulty in identifying the source of fluctuations, we find it more interesting to characterize optimal LTV policy under a mixture of shocks. All welfare results and simulations are based on shocks originated in both the production sector and in the credit market.[25]

[23] See also Mendicino and Pescatori (2008) and Rubio (2010).

[24] Thus, $V_{it} \equiv \max E_t \left[\sum_{j=0}^{\infty} (\beta_i)^j U(c_{i,t+j})\right]$. At the optimum $V_{it} = U(c_{i,t}) + \beta_i E_t V_{i,t+j}$,where $V_{it} = \{V_{1t}, V_{2t}\}$ denotes the welfare of the lenders and the borrowers, respectively. Thus, we augment the set of equilibrium conditions of the model with two equations in two unknowns V_{1t} and V_{2t}.

[25] Calza, Monacelli and Stracca (2011) show that in a model featuring collateralized household debt, the response of all variables to a monetary policy shock, i.e., an i.i.d shock to a standard Taylor-type rule, is amplifieded by a smaller down-payment rate (the inverse of the LTV ratio). It is plausible to believe

Figure 5.a shows social welfare w.r.t. alternative values for γ. In order to understand this result, we distinguish between the *level* and the *volatility effect* of alternative LTV ratio policies. The *level effect* refers to the implied stochastic mean of consumption, i.e., the arguments of the welfare function, and other aggregate variables.[26] The *volatility effect* refers to the implied standard deviations of the same variables. In what follows, we use the terms *standard deviation* and *volatility* interchangeably.

Interestingly, the optimality of higher LTV ratios is not necessarily related to lower volatility. Results presented in the previous section imply that lower discretionary LTV caps, as measured by lower γ, are useful in mitigating the severity of a financial bust. However, they also lead to *larger* macroeconomic responses to productivity shocks. This results in a non-linear relationship between macroeconomic volatility and the LTV ratio. The unconditional standard deviation of consumption and other aggregate variables increases in some regions of γ, while it declines in others. In particular, for γ closer to one the implied larger effect of credit shocks generally dominates and the model displays larger volatility. Thus, the relation between average consumption and volatility is non-linear.[27] Figure 5.b (bottom panel) reports the standard deviation of aggregate variables w.r.t. γ.

The welfare gains of higher LTV ratios are mainly related to the implied larger size of the economy in the stochastic environment. Figure 5.b (top panel) displays the stochastic mean of aggregate variables w.r.t. γ. Looser collateral requirements mean that borrowers have easier access to credit and buy, on average, more capital. This leads to higher levels of the price of the collateral asset which imply a further easing of collateral constraint in a self-reinforcing way. Higher levels of credit also improve the allocation of capital between the two groups of agents. The reduction in the difference between borrowers' and lenders' marginal productivity results in higher levels of output and consumption. The long run average of aggregate variables increases with γ. It is possible to show that in this economy, total output is maximized when the marginal

that the results of the paper are robust to the introduction of monetary policy shocks. In this latter case, looser collateral requirements would amplify the effect of both monetary policy and credit shocks. Since monetary policy shocks generally explain a small fraction of business cycle fluctuations, there are no reasons to expect significant changes in the results. For the quantitative effects of higher LTV ratio in the mortgage market in an estimated model of the Swedish economy featuring a rich stochastic structure see Walentin and Sellin (2010).

[26] Stochastic mean refers to the mean values of these variables delivered by the second order approximated simulation of the model (i.e. the stochastic steady state) under the calibrated shocks.

[27] Differently from Nikolov (2010) we depart from the linearity of entrepreneurial consumption in wealth. Allowing for non-linear feedback effects affects the link between average consumption and volatility that, in turn, becomes non-linear.

productivity of the two groups is equalized.[28] Thus, collateral requirements distort total production below the efficient level. Reducing the LTV ratio implies a higher share of production of lower firm productivity and moves the economy further away from the efficient long run equilibrium.[29] Thus, despite the larger impact of credit shocks, reducing the LTV ratio turns out to be detrimental for welfare.

6 Time-Varying LTV Caps

In the aftermath of the recent financial crises, policy-makers have broadly agreed on the need for a new regulatory framework that includes macro-prudential elements of financial stability in order to mitigate pro-cyclicality in the financial system and the spreading of financial imbalances to the real economy. At the international level, the Basel III agreement contemplates the use of a countercyclical capital buffer in order to address pro-cyclicality. Other measures have also been proposed or adopted at the national level, including the use of LTV ratios that vary in a countercyclical manner around a pre-established cap. These could help in mitigating the reduction of the provision of credit to the economy during the downturn of the financial cycle and avoid widespread financial distress.[30]

To investigate the effectiveness of time-varying LTV ratios we allow γ_t to temporarily deviate around its benchmark steady state value (γ=0.85) and to respond countercyclically to credit growth:

$$\gamma_t = \nu_\gamma \gamma_{t-1} - (1 - \nu_\gamma)\nu_b \left(b_t - b_{t-1}\right), \tag{20}$$

where ν_γ is an autoregressive parameter and ν_b is the response to credit growth. ν_b=0 corresponds to the case where the LTV ratio does not respond to credit growth.

We compute the optimal time-varying LTV ratio in the class of rules described in equation (20). We search over a [0,0.95] range for the smoothing parameter ν_γ and [0,40] for the parameters ν_b.[31] The optimal LTV rule features a strong countercyclical

[28] In the deterministic steady state, the efficient allocation occurs for γ equal 1.01, i.e. the inverse of the discount factor of the lenders.

[29] Discretionary adjustments in the LTV ratio caps have considered as useful to limit the vulnerability of the financial system to shocks. Several countries have considered reductions in LTV ratios to avoid the recurrence of asset price, and debt cycles and mitigate potential vulnerabilities in the financial system.

[30] See, "Macroprudential Policy Tools and Frameworks", BIS (2011), "Macro-prudential Instruments and Frameworks: a Stocktaking of Issues and Experiences", CGFS (2010), "The role of macro-prudential policy", Bank of England (2009), among others.

[31] The two dimensional grid is based on a 0.1 step for each parameter. For values of ν_b larger than 25 yield only marginally higher social welfare levels (improvements are related to the 6th decimal number).

response to credit growth and no response to the lagged LTV ratio, i.e. ν_b equals 40 and ν_γ equals zero. Figure 6.a shows social welfare as a function of ν_b. Allowing for the LTV ratio to respond to credit growth in a countercyclical manner is welfare improving with respect to a constant LTV ratio. Through the reduction in the level of indebtedness in the economy, a countercyclical LTV rule sizably reduces the volatility of credit to output and it also dampens the volatility of other macroeconomic variables. However, this occurs without a reduction in the stochastic mean of consumption and output. See Figure 6.b.

After a financial shock, the access to external funds decreases by less under a countercyclical LTV ratio (dotted line) than under a constant LTV ratio (solid line). The more contained drop in credit reduces the decline in borrowers' capital, and thus, the effect on the productions of this group of agents, implying smoother aggregate fluctuations. A countercyclical LTV ratio also dampens the bust in credit generated by a negative productivity shock. However, unlike lower discretionary LTV caps (dashed line), it does not imply a more sizable output's and relative price of capital's response to changes in productivity. In fact, time-varying LTV slightly mitigate the macroeconomic effect of the economic downturn induced by changes in productivity. Though, the overall effect on aggregate output is only marginal due to the fact that the dampening effect on the borrowers' production is offset by the slower recover in lenders' production. Figure 4.a-4.b compare the impulse-responses under alternative LTV policies.

Summarizing, counter-cyclical LTV caps are successful in mitigating the effects of credit shocks without amplifying the macroeconomic impact of changes in productivity. Thus, these are a policy tool useful to address pro-cyclicality in the financial system and increase social welfare without having negative implications for the long-run performance of the economy.

7 Concluding Remarks

Studying the determinants of business cycle fluctuations is crucial for understanding the dynamics of modern economies. The aim of this paper is to examine how collateral requirements are related to business cycle fluctuations. In particular, we shed light on the mechanism trough which financial factors affect the transmission of shocks originated in different sectors of the economy and their implications for stabilization policies. We present a model economy in which different collateral requirements, *ceteris paribus,* affect the sensitivity of output to both productivity and credit market shocks and thus output's volatility over the business cycle. Tighter collateral requirements imply larger sensitivity of output to changes in aggregate productivity, but lower variability induced by shocks originated in the credit market.

We explore the effectiveness of LTV ratio caps as macro-prudential tools aimed at financial and macroeconomic stabilization. The dampening effect on the transmission of some shocks and the amplifying effect on others make discretionary lower LTV caps ineffective in the moderation of both financial and economic downturns. In contrast, countercyclical time-varying caps are successful at dampening credit cycles without increasing the response of output and other macroeconomic variables to real shocks. Thus, countercyclical LTV rations result in a welfare improvement.

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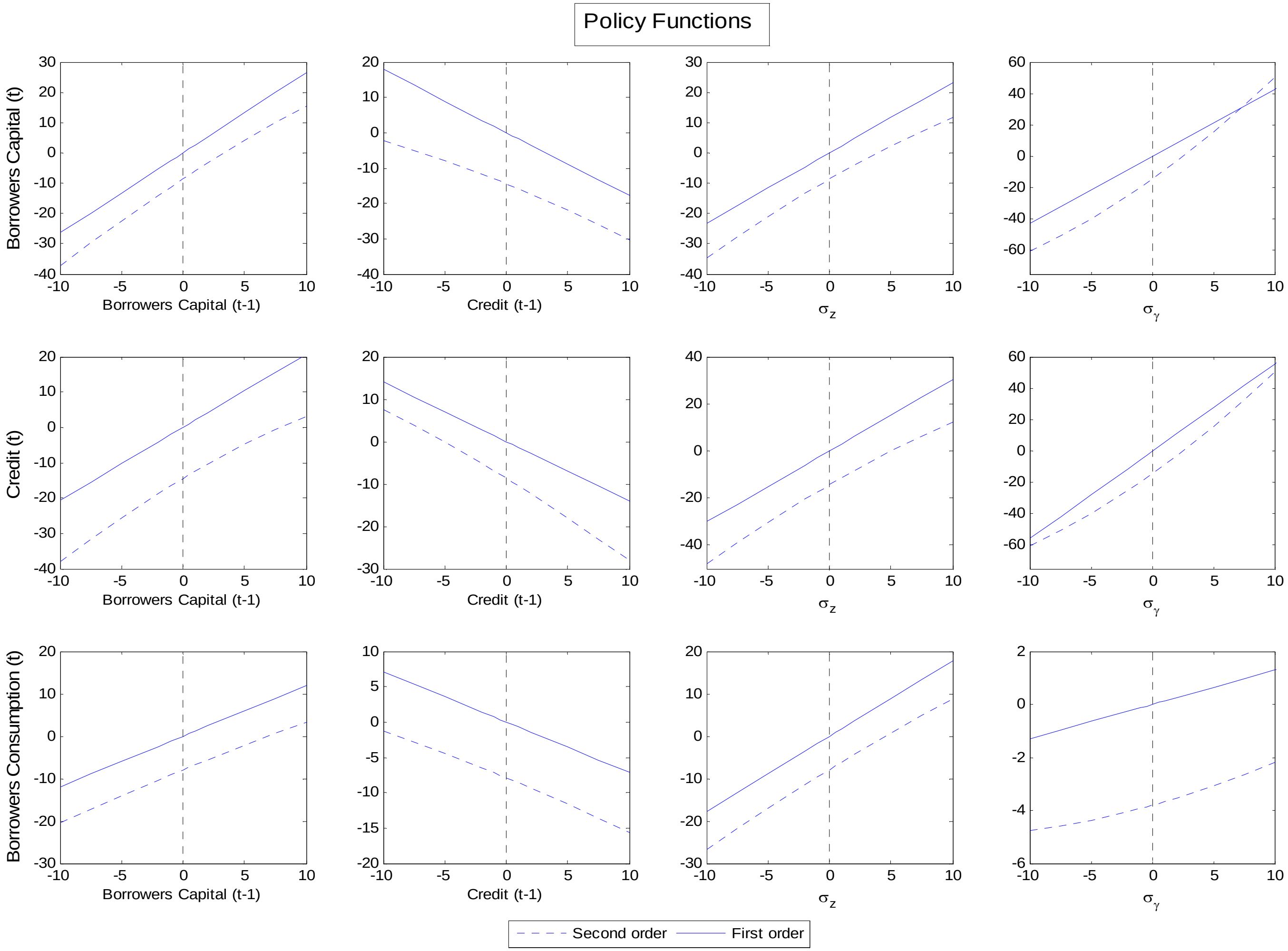

Figure 1. Policy Rules: Penalty vs Always Binding Collateral Constraint. The vertical axes measure percentage deviations from the steady state. The horizontal axes measure percentage deviations from the steady state in the first two columns, and the standard deviation of each of the two shocks in the last two columns.

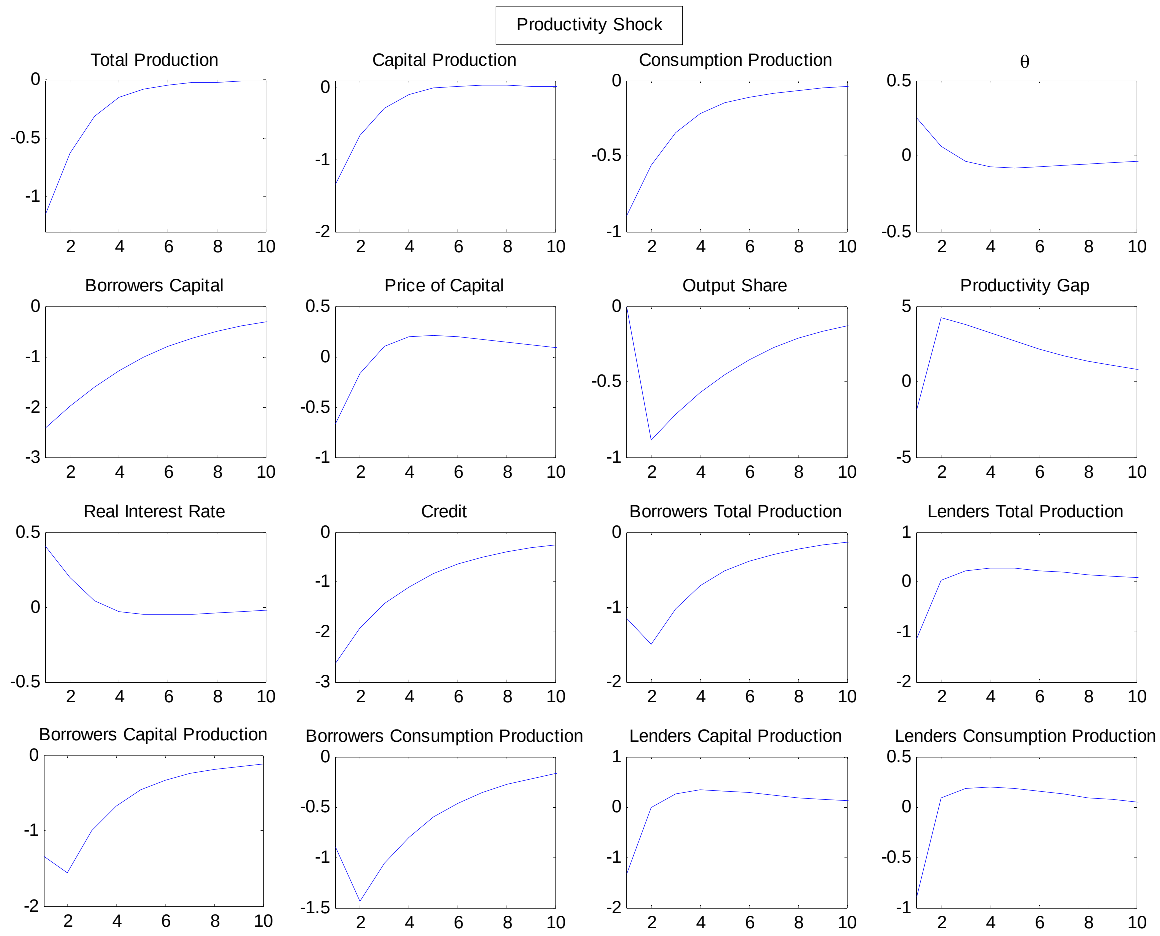

Figure 2.a Responses of the model economy to a one-period 1% decrease in aggregate productivity; γ=0.85. The vertical axes measure deviations from the steady state, while on the horizontal axes are quarters.

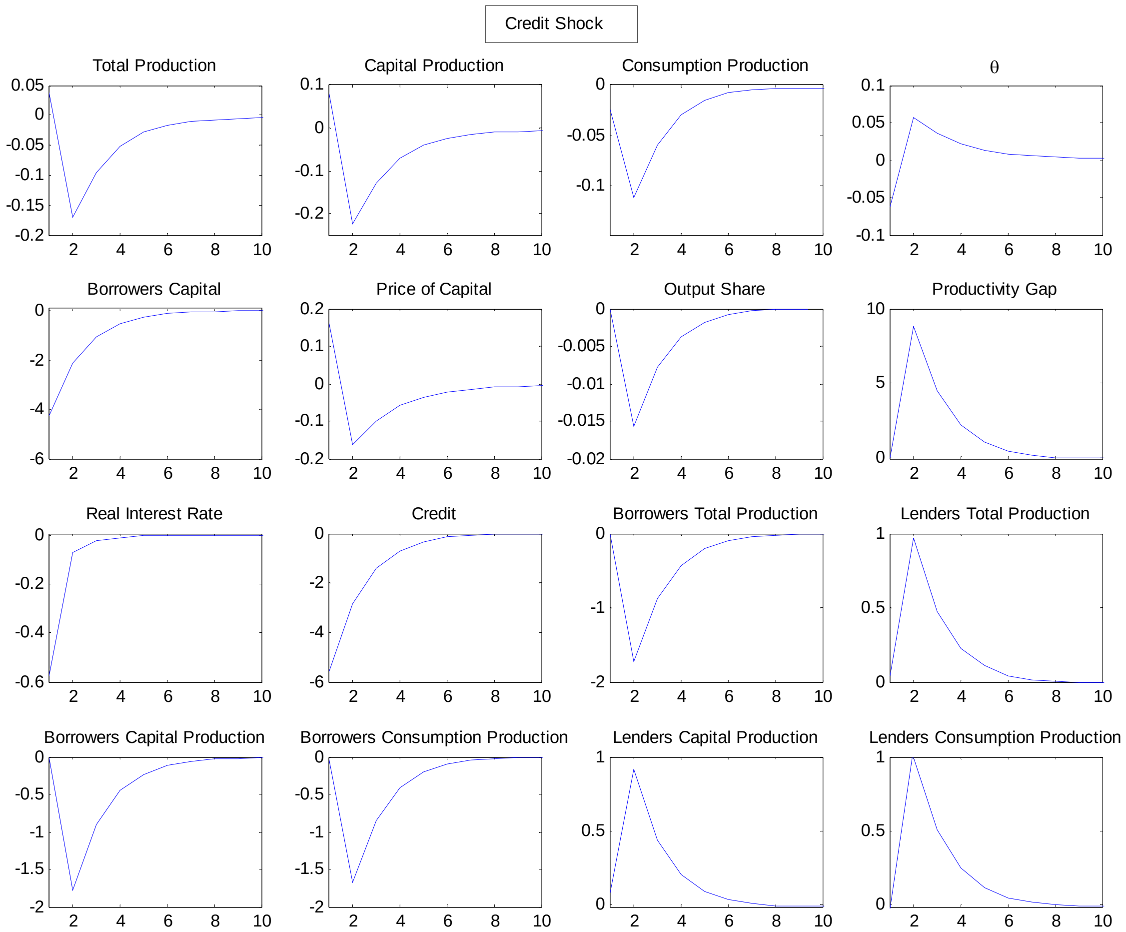

Figure 2.b Responses of the model economy to a one-period 1% decrease in the valuation of the collateral; γ=0.85. The vertical axes measure deviations from the steady state, while on the horizontal axes are quarters.

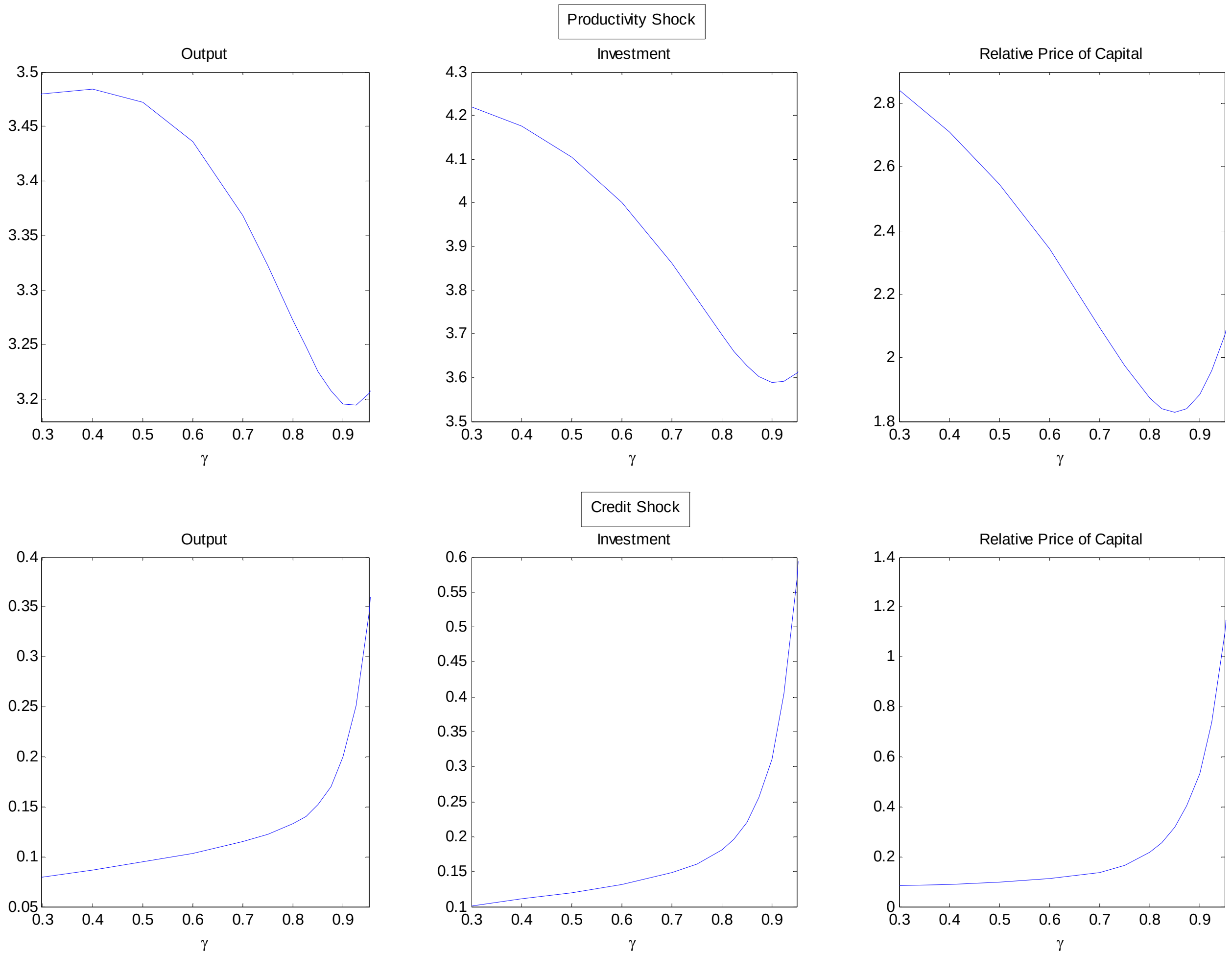

Figure 3 Standard deviations for any given value of γ, conditional on a one percent shock.

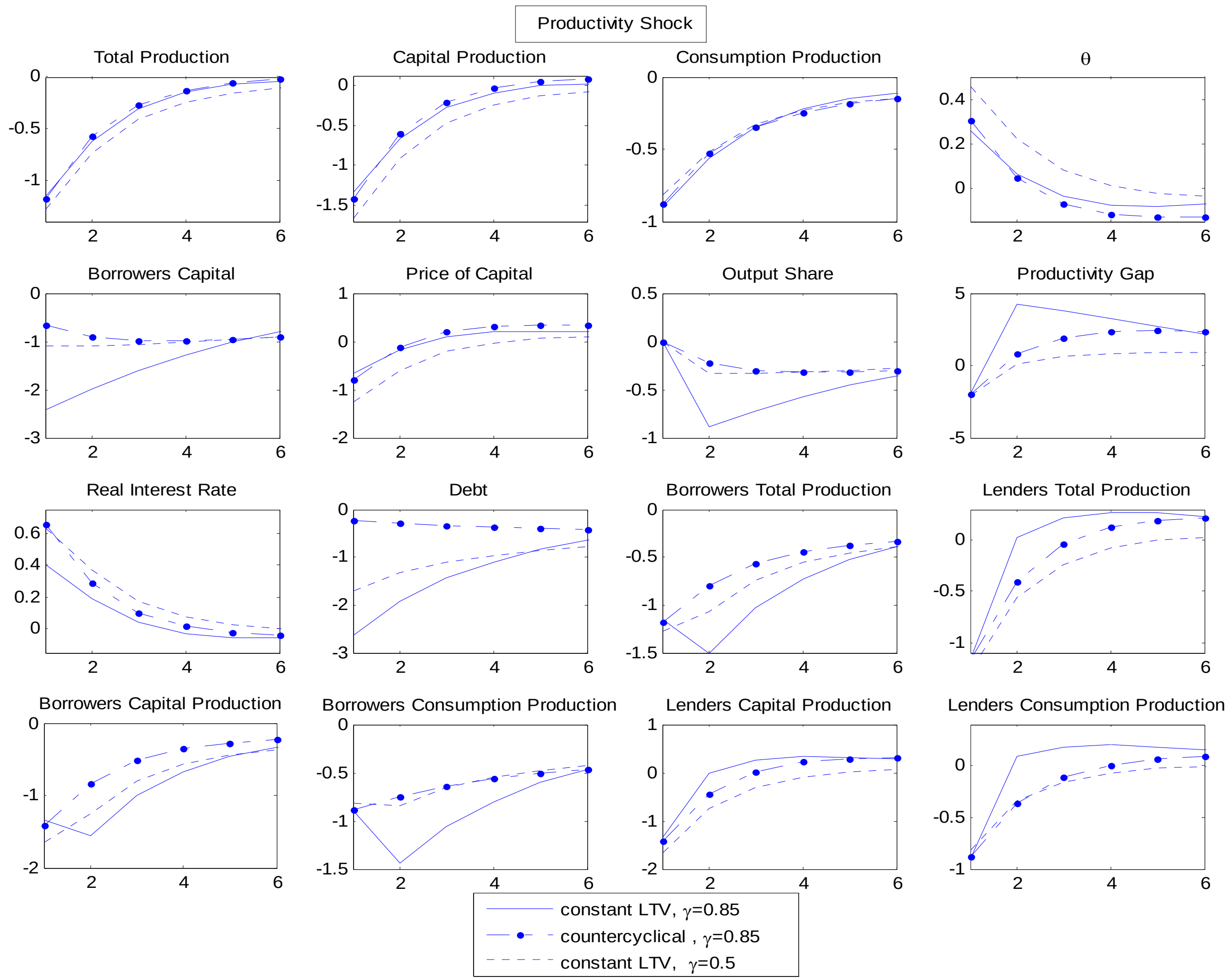

Figure 4.a Responses of the model economy to a one-period 1% increase in aggregate productivity. The vertical axes measure deviations from the steady state, while on the horizontal axes are quarters. For an illustrative purpose, in the case of the LTV that countercyclically varies around the 0.85 cap, we set v_Y equal to 0.5 and v_b to 5.

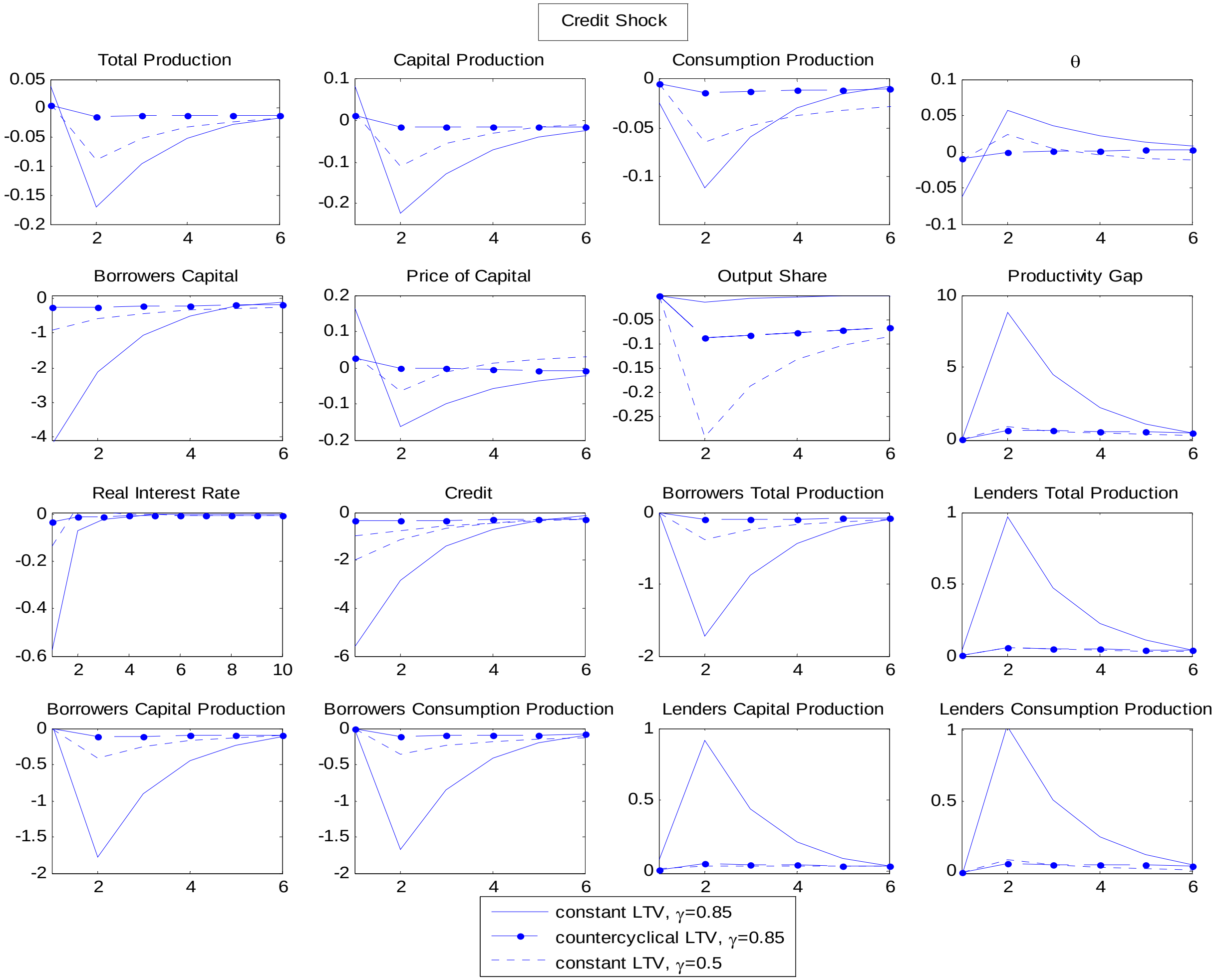

Figure 4.b Responses of the model economy to a one-period 1% decrease in the valuation of the collateral. The vertical axes measure deviations from the steady state, while on the horizontal axes are quarters. For an illustrative purpose, in the case of the LTV that countercyclically varies around the 0.85 cap, we set v_Y equal to 0.5 and v_b to 5.

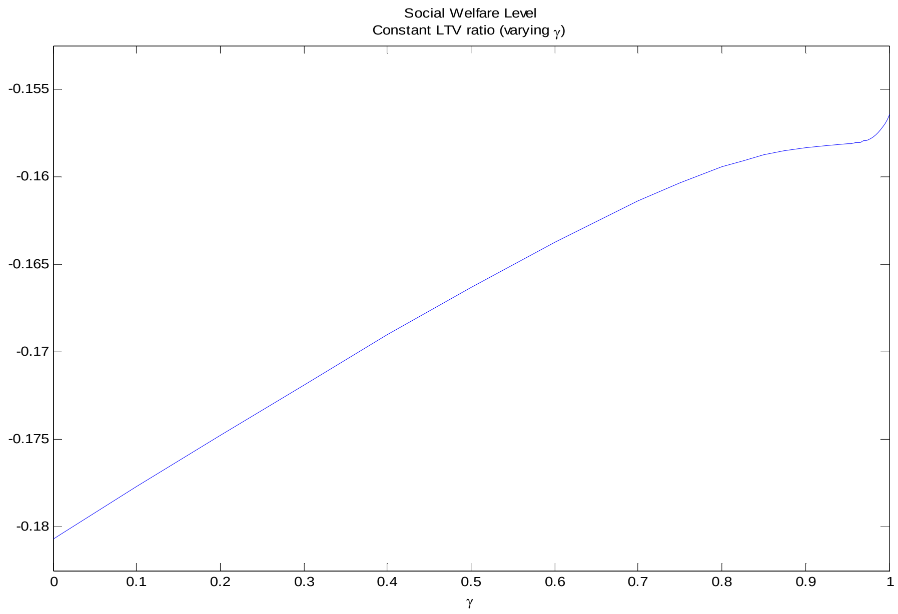

Figure 5.a. Social Welfare Level for any given value of γ.

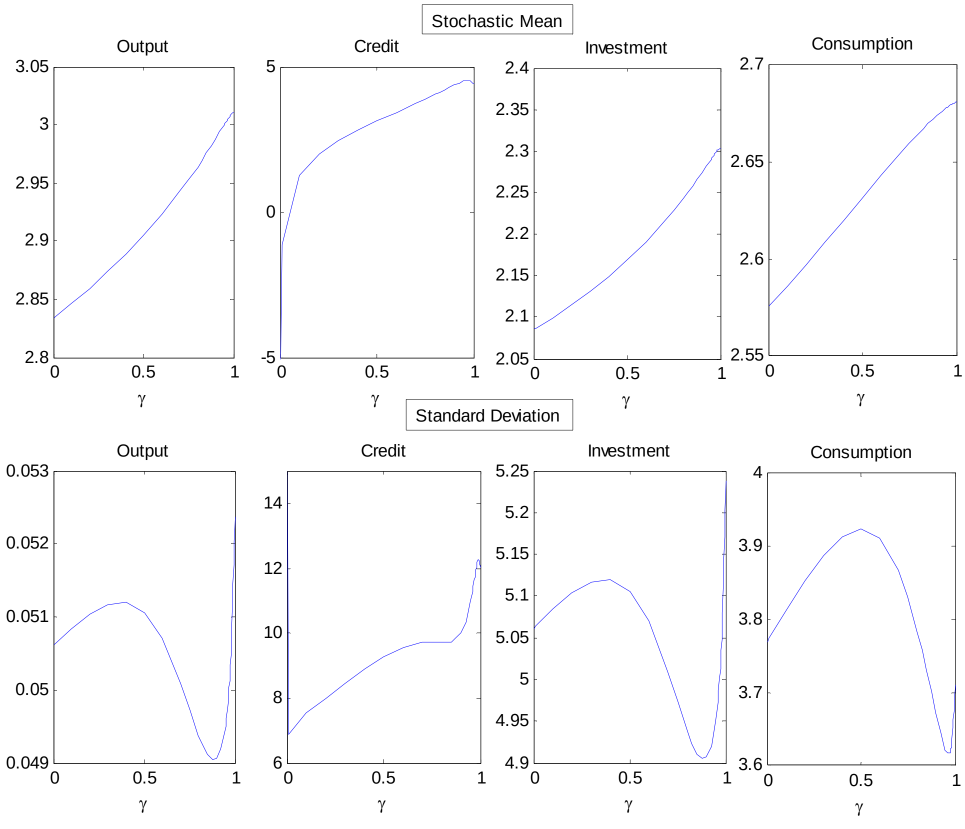

Figure 5.b. Stochastic mean and standard deviation of selected variables for any given value of γ.

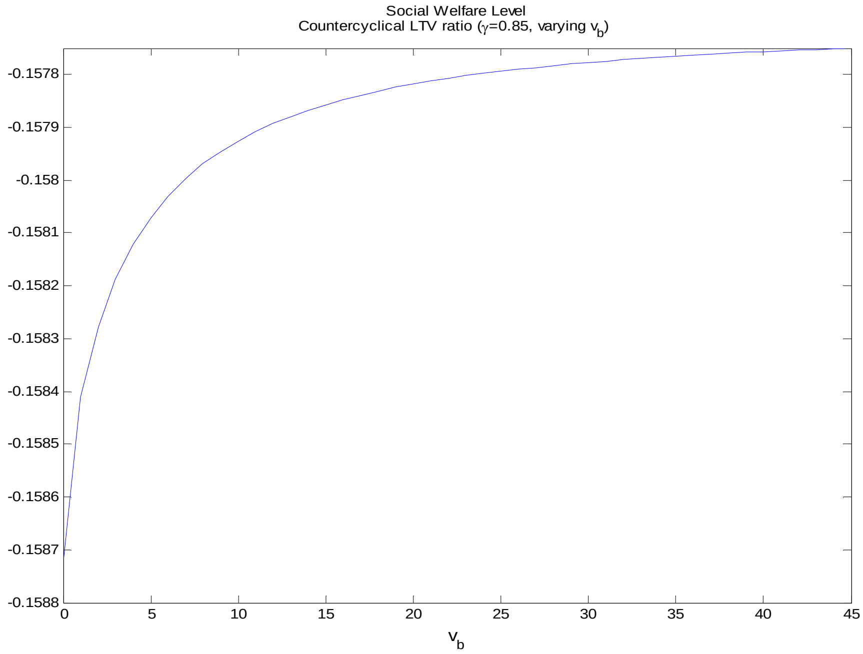

Figure6.a. Social Welfare Level for any given value of v_b.

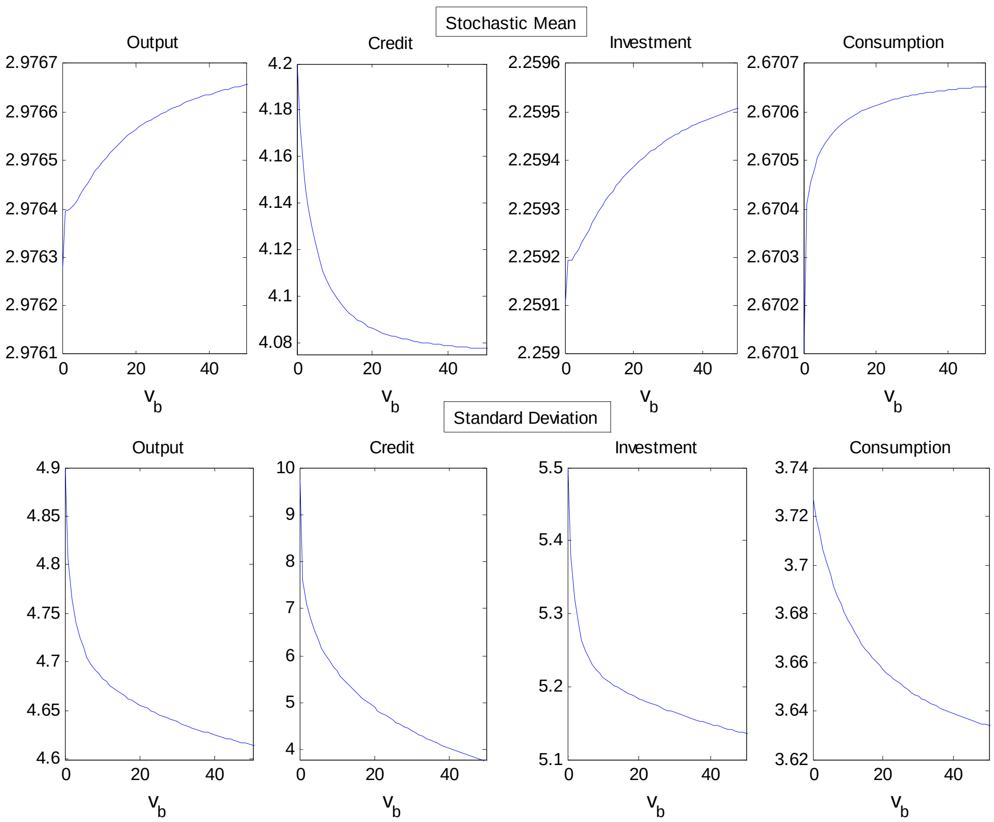

Figure 6.b. Stochastic mean and standard deviation of selected variables for any given value of v_b.

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