Procyclical Lending Standards and Macroeconomic Fluctuations.

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Abstract

This paper uses a dynamic small open economy model of business cycles with financial frictions to explore how macroeconomic fluctuations are amplified and transmitted across borders when frictions in financial intermediation entail procyclicality in credit conditions. I find that the procyclical behavior of lending standards amplifies shocks to fundamentals beyond the effect attributable to the financial accelerator mechanism. I interpret this extra amplification in the model as resulting from the interaction of financial constraints in the lending and in the borrowing side of financial intermediation. Asset prices play a crucial role in the propagation mechanism as procyclical lending standards reinforce their "overreaction" to shocks signaled by Aiyagari and Gertler (1999). Simulation results suggest the potential for sizeable stabilization gains from "macroprudential" regulation aimed at containing the procyclical behavior of credit conditions.

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1 Introduction

The global financial crisis triggered by creditworthiness problems in the U.S. subprime mortgage market in mid-2007 has unveiled pervasive interlinkings between the financial system and the real economy, both within and across borders. The large bill due to the crisis in terms of employment, investment and output around the globe has opened the debate on the need to adjust financial regulation, in particular in its macro-prudential dimension. Changes in measured risk, the spread use of mark-to-market valuation in risk management practices and the fast innovation in financial instruments have been signaled as important factors behind the procyclical behavior of lending standards, and in particular for the relaxation of standards and the acceleration of credit growth in the period leading up to the crisis. This paper uses a dynamic stochastic general equilibrium model (DSGE hereafter) of business cycles with financial frictions to explore how the procyclical behavior of lending standards gets transmitted to asset prices and the real economy, how it affects the propagation of shocks and what are its implications in terms of macroeconomic volatility.

Asset price dynamics are placed at the core of credit cycles and macro-financial linkages. The rise in asset prices in the upturn of cycles (e.g. due an increase in productivity and profits) gets translated into increases in the net worth of borrowers. In the presence of frictions between financial intermediaries and borrowers, this also implies the rise in the value of collateral and the possibility to expand credit, resulting in procyclical lending. The role of borrowers' balance sheets (or their "creditworthiness") in amplifying or generating cycles in macro models has been amply studied in the literature (e.g. Bernanke and Gertler 1989, Kiyotaki and Moore 1997 and Aiyagari and Gertler 1999). However, fluctuations in asset prices also affect the asset side of financial intermediaries' balance sheets, and hence their creditworthiness. Although the financial dynamics of their balance sheet expansions and contractions, the implication in terms of lending standards and the link with the business cycle have been receiving increasing attention in the empirical literature,[1] the role of leverage cycles in macro models has been much less explored. The main contribution of this paper is to explore how business cycles are amplified and transmitted within the economy and across borders when frictions in financial intermediation entail procyclicality in lending standards.[2]

The macroeconomic implications of changes in the value of assets held by financial intermediaries depend on whether they adjust the liabilities side of their balance sheets and on the reaction of their creditors. Under a passive attitude, a negative relationship between the market value of their assets and the leverage ratio (i.e. the ratio of assets to own capital) would emerge, as it is the traditional finding for households, and there would be little effects in terms of aggregate credit or other macro variables. However, this seems not to be the usual behavior of financial intermediaries. According to evidence in Adrian and Shin (2010) financial institutions manage actively their balance sheets in response to changes in prices and measured risk: commercial banks show almost constant leverage ratios over the cycle and market-based financial institutions (e.g. investment banks, hedge funds, etc.) display "procyclical" leverage, in the sense that during expansions both assets and leverage rise. This is consistent with the extended use of value-at-risk rules (VaR hereafter) by institutions and regulators, and with maximizing the return on equity in the context of an implicit maximum leverage permitted by creditors.[3] In this context, when asset prices are rising and measured risk is decreasing, financial intermediaries find themselves with excess capital. The way of adjusting, consistent with maximizing return on equity and VaR rules, is by expanding their

[1] See for example Bayoumi and Melander (2008), Adrian and Shin (2010) and Adrian *et al.* (2010a).

[2] Along this paper, "lending standards" refer to any of the various non-price terms specified in a line of credit or loan, such as collateral requirements, covenants, loan limits, etc. In the models outlined later, lending standards refer more precisely to the degree pledgeability of collateral (or "collateral price" as referred in Kiyotaki and Moore 2002).

[3] See Adrian and Shin (2008b) for a theory of financial leverage as a function of the shift in the risks inherent un the underlying environment.

balance sheets: on their liabilities side, issuing more sort-term debt and, on the assets side, expanding credit, that is, searching for potential borrowers. With good borrowers already served, the expansion of balance sheets of the financial sector as a whole is only possible by relaxing lending standards (e.g. requiring less collateral) and extending credit to projects that were previously denied access. In the downswing, the opposite happens.[4]. On aggregate, this balance sheet management by individual financial institutions contributes to the procyclical behavior of lending standards and credit. Other factors signaled in the literature as inducing procyclicality in lending standards include incentive problems, herd behavior, accounting rules, etc.[5] In turn, this cyclical behavior of credit standards has aggregate effects on asset prices and on macroeconomic aggregates (Brunnermeier *et al.* 2009 and Adrian *et al.* 2010a), and on international capital flows (Shin 2009).

To explore the implications of cycles in lending standards I use a dynamic one-good small open economy model in which domestic agents face time-varying collateral constraints that limit their ability to leverage foreign debt on domestic asset holdings. The presence of financial frictions is a crucial ingredient: In a Modigliani-Miller world leverage would be irrelevant. Although I do not model the financial intermediation sector explicitly, the constraint linking borrowers and creditors in the model suggests frictions at both ends of financial intermediation: As in Bernanke and Gertler (1989), Kiyotaki and Moore (1997) and Aiyagari and Gertler (1999), limited enforcement caps the amount that intermediaries are willing to lend to a fraction of the market value of borrowers's assets. But differently from those models, the fraction imposing a ceiling on the leverage ratio of ultimate borrowers is not fixed but varies over the cycle. I interpret those variations as tightening (easing) in lending stan-

[4]The same cyclical behavior emerges as creditors of financial intermediaries change the implicit maximum leverage permitted due to, for example, changes in measured risk. As creditors reduce "haircuts" on instruments such as repurchase agreements ("repos"), financial institutions face a rise in the implicit maximum leverage permitted in collateralized borrowing (among institutions or with ultimate non-financial creditors).

[5]See for instance Borio *et al.* (2001) and Jiménez and Saurina (2006).

dards due for instance to contractions (expansions) of aggregate balance sheets of financial intermediaries, that is, to variations in financial market liquidity. The purpose of allowing the tightness of collateral constraints to vary over time is to combine, in a simple way, a credit supply channel as sketched in Adrian and Shin (2009) with the borrower's creditworthiness channel in Bernanke and Gertler (1989) and Kiyotaki and Moore (1997). I find that the procyclical behavior of lending standards amplifies shocks to fundamentals beyond the effect attributable to the financial accelerator mechanism. I interpret this extra amplification as resulting from the interaction of financial constraints in the lending and in the borrowing side of financial intermediation. The propagation mechanism operates through asset prices: procyclical lending standards reinforce the "overreaction" of asset prices to shocks signaled by Aiyagari and Gertler (1999). Moreover, the amplification effect is found to be bigger the more leveraged the economy is on average.

While there seems to be a consensus on the fact that financial systems are inherently subject to cycles, it is not yet clear how policymakers and regulators should intervene to mitigate these cyclical effects. In policy circles, the main focus is placed on reforming financial regulation and on coordinating micro-prudential (i.e. institution-level) regulation with macro-prudential (i.e. system-wide) regulation.[6] Some of the proposed modifications include changes to mark-to-market procedures, the implementation of countercyclical capital charges and longer horizons for loan loss provisions. Understanding better the macro-financial linkages in the economy, within and across countries, is crucial for this discussion. Although the model used in this paper is highly stylized, it contributes to the policy debate by exploring what can be the stabilizing effects of implementing policies aimed at lowering the degree of procyclicality in lending standards. In this sense, the results from the model simulations suggest the potential for sizable gains in terms of macroeconomic volatil-

[6] See for example Borio *et al.* (2001) and Brunnermeier *et al.* (2009).

ity from introducing some "macro-prudential" regulation that reduces the procyclicality of credit standards. For instance, a reduction in the correlation of the loan-to-value ratio with output from 0.45 to 0.25 in the model is associated with a drop in the volatility or real consumption of approximately one fourth. Also, the procyclical behavior of lending standards is found to contribute significantly to the persistence of business fluctuations.

This paper is related to a recent macroeconomic literature with financial frictions incorporating perturbations that originate in the financial sector of the economy. Benk *et al.* (2005) introduce credit shocks in a monetary business cycle model with a cash-in-advance constraint and suggest that these shocks contributed significantly to US GDP movements. Kiyotaki and Moore (2008) interpret variations to the amount of equity holdings that entrepreneurs can resell as liquidity shocks and study how these affect aggregate output and asset prices in a monetary model. Focusing on the cyclical properties of firms' equity and debt payouts, Jermann and Quadrini (2009) use a model in which the firms' ability to borrow is limited by enforcement constraints and the tightness of the friction is subject to random disturbances, which are interpreted as shocks affecting directly the financial sector of the economy. Gruss and Sgherri (2009) also introduce fluctuations in the tightness of borrowing limits but on households debt and in the context of a two-country two-good model. Similar to this paper, the focus is on the procyclical behavior of leverage limits and its effect on the volatility of macroeconomic aggregates and external imbalances. In this paper the model is kept very parsimonious as it is meant mainly to explore the transmission mechanism. As in all the mentioned studies, the model treats financial intermediaries largely as a veil. Gertler and Kiyotaki (2010), instead, incorporate financial intermediaries explicitly and assumes that the quality of their assets follows an exogenous process to introduce fluctuations in their balance sheets. The model assumes a financial friction between intermediaries (inter-bank market) and with depositors, but the relationship with ultimate non-financial borrowers is frictionless.

Table 1: Simulation Results, HP Filtered Series.

Correlation TFP and LTV:	$\rho_{(A,\varphi)}$	0	0.4	0.8
a) Standard Deviations				
Lending Standards	$std(\varphi)$	2.32%	2.32%	2.32%
Output	$std(y)$	5.10%	5.68%	6.16%
Consumption	$std(c)$	3.07%	3.58%	4.01%
Investment	$std(i)$	106%	114%	122%
Asset Price	$std(q)$	2.35%	2.74%	3.06%
b) Cross-Correlations with Output				
Lending Standards	$corr(\varphi,y)$	0.25	0.36	0.45
Asset Price	$corr(q,y)$	0.47	0.55	0.60
Consumption	$corr(c,y)$	0.50	0.58	0.63
Trade balance to GDP	$corr(nx/y,y)$	0.38	0.31	0.26
c) Cross-Correlations with Asset Prices				
Lending Standards	$corr(\varphi,q)$	0.81	0.88	0.94
Consumption	$corr(c,q)$	0.99	0.99	0.99
Trade balance to GDP	$corr(nx/y,q)$	−0.44	−0.42	−0.41

Notes: All parameters as shown in 6. The long-run LTV ratio $\bar{\varphi}$ is 0.5. The series are filtered using the Hodrick-Prescott filter and a smoothing parameter equal to 100.

Instead, I interpret the presence of collateral constraints with cyclical tightening of margins in the model as deriving form frictions at both ends of financial intermediation, as suggested in Adrian and Shin (2010).

The structure of the paper is as follows. 2 reviews the empirical evidence on the cyclical behavior of lending standards and the link with business cycles. 3 develops a small open economy model with procyclical lending standards and 4 shows the results of several numerical experiments aimed at exploring the implications of such behavior of lending standards on asset prices and real variables. 5 draws conclusions and highlights lines for future research.

2 Empirical Evidence on Lending Standards

In this section I review evidence from the empirical literature on the procyclical behavior of credit conditions and its implications for asst prices and macroeconomic variables, for different countries and periods. Several empirical studies have been looking into the cyclical behavior of capital buffers of financial institutions, aggregate liquidity and lending standards, and their relationship with aggregate fluctuations. There seems to be conclusive evidence that credit conditions not only vary over the cycle but also behave procyclically and that this behavior has aggregate implications for asset prices and real activity. One explanation for that cyclical behavior relies on information asymmetries between borrowers and lenders.[7] Other many studies identify changes in aggregate credit conditions with balance sheet management by financial intermediaries, due for instance to the prescriptions of internal risk-management models, to risk-sensitive capital regulations (e.g. prescriptions in Basel II) or to the use of backward-looking loan-loss provision practices.[8]

Adrian and Shin (2009) make emphasis on the fact that a substantial fraction of the financial system is composed of highly leveraged intermediaries that fund themselves using market instruments, such as repurchase agreements ("repos" and "reverse repos") and that hold assets that are marked-to-market and are then very sensitive to variations in asset prices and in measured risk. They argue that the procyclical behavior of the financial system is then due to frictions in the supply of credit. Adrian and Shin (2010) document that financial intermediaries manage their balance sheets actively in such a way that their leverage ratio is procyclical, i.e. high during booms and low during busts. Specifically, instead of adjusting

[7]In a setting where banks obtain private information about their clients' creditworthiness, Dell'Ariccia and Marquez (2006) show that banks may loosen lending standards when information asymmetries vis-à-vis other banks are low.

[8]See Borio *et al.* (2001) for a discussion of the role of risk measurement by individual institutions and its implications for systemic risk and aggregate conditions.

equity, they react to changes in asset prices that affect their net worth and to changes in measured risk by issuing more short-term debt and accumulating more assets. This is consistent with their models of risk and in particular with the use of VaR rules, which dictate adjusting exposures continuously so that the probability of default is kept constant. Indeed, Adrian and Shin (2010) show evidence suggesting that measures of VaR explain shifts in total assets, leverage and key components on the liability side of the balance sheet, such as stock of repos. Adrian and Shin (2008a, 2009) find that the procyclicality of leverage is much clearer for market-based intermediaries (such as security dealers and brokers) than for the case of commercial banks and highlight the importance of those institutions and, more broadly, of the "shadow banking" (including asset-backed securities issuers, finance companies and funding corporations), in conveying information on the credit conditions ruling in the economy.

Ayuso *et al.* (2004) find a significant negative relationship between business cycle and banks' capital buffers in Spain from 1986 to 2000. Given that they focus their attention on voluntary capital buffers, they argue that the cyclical pattern is due to factors which are beyond the inherent features of risk-sensitive bank capital regulation, such as Basel II. Also for the Spanish economy but using loan-by-loan information from 1984 to 2002, Jiménez and Saurina (2006) show that collateral requirements are relaxed during boom periods while the opposite happens during recessions. Asea and Blomberg (1998) look at the contract terms of loans granted by U.S. banks from 1977 to 1993 and find that there is a systematic tendency for lending standards to vary over the business cycle: during the upswing of the cycle the risk premia banks charge on loans decreases, loan size increases and the probability of requiring higher collateral decreases; the opposite occurs during the downswing of the cycle.

Adrian and Shin (2008a) and Adrian *et al.* (2010a) provide evidence that the procyclical behavior of financial intermediaries' leverage has an impact on aggregate financial conditions and in real economic outcomes, especially on components of GDP that are particularly sensitive to credit supply. Adrian *et al.* (2010a) highlight the relevance of asset prices and the market risk premia in the transmission mechanism. Consistent with this evidence and using data from the U.S., Bayoumi and Melander (2008) document that during periods when the capital-asset ratio is increasing there is a net easing of lending standards (i.e. an increase in credit supply given borrower characteristics). They also find that a tightening of loan standards causes the quantity of credit effectively to decline. Lown and Morgan (2006) use survey data on credit standards from U.S. banks and find that commercial credit standards are highly significant in predicting commercial bank loans, real GDP and inventory investment. Their variance decomposition results indicate that innovations in lending standards account for nearly a third of the error variance in output at 1 year horizon, more than the fraction attributable directly to the federal funds rate.

There is evidence of procyclicality in financial conditions also in studies using cross country data. For example, Mendoza and Terrones (2008) have examined the dynamics of both macro aggregates and firm-specific financial indicators during "credit boom" episodes. Using cross-country data for 48 industrial and emerging countries from 1960 to 2006, they find that credit booms are associated with periods of economic expansion, rising equity and housing prices, and widening external deficits. Evidence of procyclicality also shows up from firm level data: the credit boom—and the macroeconomic upswing that accompany them—coincide with higher leverage, firm value and use of external financing by firms. Bank data too appear consistent with procyclical lending standards: ratios of capital adequacy and non-performing loans seem to decrease during credit booms.

Gruss and Sgherri (2009) also present evidence on the behavior of firms' leverage, using data from 16 advanced and 12 emerging European economies over the period from January 1999 until April 2008. The evidence from that sample confirms, first, that firms' leverage ratios vary substantially over the cycle. Next, and relying on financial condition indices constructed by means of country-specific vector autoregression models and corresponding impulse responses functions, they find that changes in financial conditions account for a large fraction of the variation in GDP growth, especially in the emerging countries in the sample. Also, a higher degree of procyclicality in firms' leverage is found to be associated with higher volatility in private investment. Finally, evidence in Gruss and Sgherri (2009) suggest that changes in firms' borrowing tend to be more sensitive to changes in asset prices in those economies where firms leverage co-moves more closely with the business cycle, which can be interpreted as economies where the financial frictions are stronger.

Although evidence of procyclicality on lending conditions is also found for periods excluding the recent financial crisis,[9] the explosive growth in securitization that modified the model of financial intermediaries from "risk warehousing" to "originating and distributing" has been signaled as a factor accentuating relaxation of standards in the last credit cycle. Keys *et al.* (2010) find that securitization practices in the U.S. subprime market did adversely affect the screening standards of lenders: loans more likely to be securitized default 20% more than similar risk profile loans with lower likelihood of securitization. Mian and Sufi (2009) use detailed ZIP code-level data from the U.S. and argue that the rise in securitization of subprime mortgages represented an outward shift in mortgage credit by lenders, which came along with the relaxation of earlier credit-rationing constraints.

Regarding the international implications of financial factors, some authors claim that the

[9]For example Adrian *et al.* (2010a) repeat their estimations with data up to the crisis and the results are similar. Other studies, such as Bayoumi and Melander (2008) and Lown and Morgan (2006), use data prior to the crisis.

expansion of financial intermediaries' balance sheets and the growing use of securitization had a significant impact on international capital flows. Shin (2009) argue that the increased leverage of the financial system in the U.S., fueled by securitization, exacerbated global imbalances. He shows evidence that foreign central banks have been a particularly important funding source for residential mortgage lending in the United States. Shin (2009) argues that the fact that the greatest increase in foreign holdings of U.S. debt securities has been on asset-backed securities issued by private label securitization vehicles suggests an alternative "supply push" perspective to global imbalance that complements the "savings glut" hypothesis.[10]

3 A Small Open Economy Model

In this section I use a production small open economy model with financial frictions, similar to the one in Kocherlakota (2000), to analyze how the amplification of business cycles is affected when lending standards vary over the cycle. Output is produced using a constant returns to scale technology, using a durable good in fix supply (for example, land or real estate) and a durable good in variable supply (that I call capital). The economy is populated by a continuum of identical, infinitely-lived and self-employed firm-households, with preferences described by:

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \ln c_t \ , \quad 0 < \beta < 1 \tag{1}$$

where c_t denotes consumption and β is the subjective discount factor. The budget constraint faced by the representative agent is:

$$c_t + q_t\,(L_{t+1} - L_t) + (1+r)d_t + k_{t+1} - (1-\delta)k_t = d_{t+1} + y_t \ , \tag{2}$$

[10] See, for example, Caballero *et al.* (2008).

where L_t denotes the individual holdings of the asset in fixed supply (land), q_t is its relative price in terms of the consumption good, k_t denotes holdings of capital and δ its depreciation rate per period. Output (GDP) is given by $y_t = A_t k_t^{\alpha} L_t^{1-\alpha}$ where A_t is stochastic total factor productivity (TFP) and $0 < \alpha < 1$. Financial markets are incomplete: d_{t+1} is the amount of non-contingent debt issued at t and r is the real interest rate the economy faces in international markets, taken as given by individual agents and assumed constant for simplicity. As will be clear later, the values assumed for β and r will imply that the small open economy is relatively impatient in comparison to international markets.

In the production function land is combined with another durable good (capital) instead of labor, so that agents have an additional instrument, besides debt, that is subject to financial frictions, to transfer resources across periods.[11] However and in order to focus on the main transmission mechanisms, the model is kept as parsimonious as possible, so it does not include capital adjustment costs.

Financial frictions. The world credit market is assumed to be imperfect: Due to an inability to commit to repayment, agents in the small open economy need to guarantee their debt by offering the domestic assets as collateral. The collateral credit constraint takes the form of the margin requirement proposed by Aiyagari and Gertler (1999) and used in a small open economy context by Kocherlakota (2000) and Mendoza (2010), among others. As in Kocherlakota (2000), Iacoviello (2005) and Mendoza and Smith (2006), the asset used for collateral is in fix supply. Specifically, the endogenous credit constraint that agents face is given by:

$$d_{t+1} \leq \varphi_t q_t L_{t+1} \tag{3}$$

[11] Production is similar then to Kocherlakota (2000) but relaxing the full depreciation assumption.

where φ_t determines the maximum amount that can be borrowed for a given value of collateral at time t, imposing a ceiling on the loan-to-value ratio ("LTV ratio" hereafter). The maximum leverage of the borrower, that is, the ratio of assets to net worth, is given by $1/(1-\varphi_t)$. The "collateral price" of the asset is a fraction of the market price of the asset, as in Kiyotaki and Moore (1997, 2002), but here it is assumed to be time varying.

Evidence in Adrian and Shin (2010) and Adrian *et al.* (2010a) suggests the presence of financial frictions in the funding side of financial intermediation; that is, between financial intermediaries and between financial institutions and ultimate non-financial lenders. According to the authors, changes in underlying conditions such as measured risk, asset prices, the opportunity cost of funds, etc. translate into variations in their ability to leverage their liabilities into assets and ultimately into changes in the aggregate supply of credit. Shifts in the size of financial intermediaries' balance sheets and in aggregate credit supply come along with changes in the quality of the marginal credits, implying variations in lending standards (Bayoumi and Melander 2008).

I integrate this friction in the model, in an admittedly crude way, by allowing the ceiling on the leverage ratio of borrowers $1/(1-\varphi_t)$ to vary over time. In this sense, an increase in φ_t implies a higher allowed leverage for the borrower: lenders would allow more borrowing for any given value of collateral. What I am trying to capture in a simple way is an exogenous force, possibly correlated with the business cycle, that affects credit supply for any given level of net worth of borrowers. As a starting point, I simply assume that TFP and the LTV ratio jointly follow a first-order bivariate autoregressive process in the neighborhood of the constant unconditional mean ($\bar{A}$ and $\bar{\varphi}$). In this sense, the approach is similar to other models that introduce shocks that are interpreted as originated in the financial sector, such as Kiyotaki and Moore (2008) and Jermann and Quadrini (2009), among others. More precisely, I assume:

$$\begin{pmatrix} ln(A_t) - ln(\bar{A}) \\ ln(\varphi_t) - ln(\bar{\varphi}) \end{pmatrix} = \begin{pmatrix} \rho_A & 0 \\ 0 & \rho_\varphi \end{pmatrix} \begin{pmatrix} ln(A_{t-1}) - ln(\bar{A}) \\ ln(\varphi_{t-1}) - ln(\bar{\varphi}) \end{pmatrix} + \begin{pmatrix} \varepsilon_{A,t} \\ \varepsilon_{\varphi,t} \end{pmatrix}, \tag{4}$$

where the vector of shocks $\varepsilon_t = (\varepsilon_{A,t}, \varepsilon_{\varphi,t})'$ follows a bivariate normal distribution with zero mean and contemporaneous variance-covariance matrix V, given by:

$$V = \begin{pmatrix} \sigma_A^2 & cov(A,\varphi) \\ cov(A,\varphi) & \sigma_\varphi^2 \end{pmatrix}. \tag{5}$$

Equilibrium Given initial values of debt, capital and land holdings, the representative Household-Firm problem is to choose sequences $\{c_t, k_{t+1}, d_{t+1}, L_{t+1}\}$, taking q_t, φ_t, A_t and r as given, in order to maximize (1), subject to equations (2) and (3). Land is assumed to be in aggregate fixed supply and normalized to one. Imposing this market clearing condition and letting μ_t be the multiplier on the borrowing constraint, the optimality conditions for the representative agent's problem include:

$$U_{c,t} = \beta E_t U_{c,t+1}(1+r) + \mu_t \tag{6}$$

$$U_{c,t} = \beta E_t U_{c,t+1}\left[\alpha A_{t+1} k_{t+1}^{\alpha-1} + (1-\delta)\right] \tag{7}$$

$$q_t\left[U_{c,t} - \varphi_t \mu_t\right] = \beta E_t U_{c,t+1}\left[q_{t+1} + (1-\alpha) A_{t+1} k_{t+1}^{\alpha}\right] \tag{8}$$

If the borrowing constraint were not binding, μ_t would be zero and Equation (6) would be a standard Euler equation for debt. However, given the assumptions on the subjective discount factor β and the international interest rate r, in a deterministic steady state μ is strictly greater than zero and, hence, (3) holds with equality. The extent to which this is also the case in a stochastic equilibrium (i.e. outside the steady state) mainly depends on the size of the gap between β and $1+r$ and the variance of the shocks hitting the economy. In this paper, as in Iacoviello (2005), Iacoviello and Neri (2010) and Jermann and Quadrini (2009) among others, the variability of shocks is kept "small enough" relative to the degree of impatience and the model is solved by linearizing around the steady state with a binding collateral constraint.[12]

The presence of the financial friction implies, from Equation (6), that agents in the domestic economy always face an endogenous external financing premium on the effective (i.e. shadow) real interest rate at which they borrow. This can be appreciated by rewriting (6) as:

$$1 = \beta E_t \frac{U_{c,t+1}}{U_{c,t}} \left[\frac{(1+r)}{1-\mu_t/U_{c,t}} \right]$$

As long as the economy is constrained (i.e. $\mu_t > 0$), the effective interest rate $\frac{(1+r)}{1-\mu_t/U_{c,t}}$ is higher than $(1+r)$. The higher effective interest rate reflects the fact that, at the prevailing interest rate $(1+r)$, agents in the domestic economy would like to borrow more than they are actually allowed to.

Finally, solving Equation (8) forward we can obtain a standard asset pricing condition for land:

$$q_t = E_t \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \Lambda_{t+i,t+1+i} \right) r^L_{t+1+j} \tag{9}$$

where $\Lambda_{t,t+1} = \beta U_{c,t+1}/(U_{c,t} - \varphi_t \mu_t)$ is the stochastic discount factor and $r^L_t = (1-\alpha) A_t k^\alpha_t$ is the marginal product of land. The valuation of the asset corresponds to the discounted flow

[12] In the quantitative exercises in the next sections I check that indeed the value of the multiplier μ_t is always positive.

of future returns.[13]

3.1 The Role of Asset Prices and Excess Returns

To understand the role of asset prices in shaping equilibrium dynamics, it is useful to derive an expression for excess returns (i.e. risk premium) in this model and explore how it is affected by the fact that the economy is financially constrained and that the tightness of the constraint (i.e. the LTV ratio) varies over time. The return on holding land is defined as $R^L_{t+1} \equiv \left(\frac{r^L_{t+1}+q_{t+1}}{q_t}\right)$. Using the Euler equations for bonds and land we can express the excess return on land holdings (relative to the real interest rate on international debt) as:

$$\mathrm{E}_t(R^L_{t+1}) - (1+r) = \frac{-cov(U_{c,t+1}, R^L_{t+1})}{\mathrm{E}_t U_{c,t+1}} + \frac{\mu_t\,(1-\varphi_t)}{\beta \mathrm{E}_t U_{c,t+1}} \tag{10}$$

If the collateral constraint is binding ($\mu_t > 0$), then there is a positive *wedge* between the equity premium in this economy and the "fundamental" one—that is, the one that would prevail in a frictionless environment. Indeed, if the collateral constraint is not binding ($\mu_t = 0$), then Equation (10) would reduce to $\frac{-cov(U_{c,t+1}, R^L_{t+1})}{\mathrm{E}_t U_{c,t+1}}$, which is the standard excess return corresponding to a frictionless asset-pricing model, the "fundamental" risk premium (Aiyagari and Gertler 1999).

In turn, the behavior of excess returns, and of the wedge to its "fundamental" expression, affects asset prices. Taking expectations on the return on land holdings R^L_{t+1} and solving for q_t and iterating forward, we obtain:

$$q_t = \mathrm{E}_t \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \frac{1}{\mathrm{E}_t(R^L_{t+1+i})} \right) r^L_{t+1+j} \tag{11}$$

[13]Note that $\Lambda_{t,t+1}$ includes both the multiplier μ_t and the LTV ratio φ_t, none of which would appear in a frictionless model.

where the sequence $\{\mathrm{E}_t(R^L_{t+1+j})\}_{j=0}^{\infty}$ is given by (10). It should thus be clear that an increase of excess returns at period t (or at any other time in the future) would increase the rate at which future dividends are discounted, thereby lowering the price of the asset at period t.

The behavior of excess returns (as well as the one of the wedge between the actual and the "fundamental" risk premium) plays an important role in the dynamics of the model. As Aiyagari and Gertler (1999) and Mendoza and Smith (2006) point out, the behavior of the equity premium is affected both directly and indirectly by the presence of financial market frictions. A binding collateral constraint in the current period affects directly the wedge between the "fundamental" and the actual equity premium, as indicated by the second term of equation (10). For example, a tighter borrowing constraint (higher μ_t) in period t originated by a drop in productivity that lowers asset prices would reinforce such a drop by pushing up the risk premium. Regarding the indirect effect, the probability that the constraint will be binding in the future affects the covariance expression in the first term of equation (10). The possibility of a tighter borrowing constraint in period $t+1$ is likely to reduce (i.e., make more negative) the covariance with the marginal utility of consumption in $t+1$. In other words, the more stringent the borrowing constraint, the bigger the drop in consumption at $t+1$ (i.e., the rise in $U_{c,t+1}$) associated with a given fall in the ex-post return on equity.

The presence of effects due to financial frictions can hence amplify fluctuations of the equity premium and, thereby, of equity prices, as it was shown by Aiyagari and Gertler (1999). What is new in this model is that this phenomenon may be potentially affected by fluctuations in lending standards (i.e. in φ_t). In the following sections I analyze how time-varying lending standards affect the reaction of asset prices and the amplification of shocks relying on numerical experiments.

3.2 Parameter Values and Solution Method

To perform numerical experiments with the model it is necessary to assign values to 10 parameters. Most of them are standard preference and technology parameters for which I use reasonably conventional values, reported in Table 6. The period in the model is a year. The parameter $\bar{A}$ is set to normalize output to one in the non-stochastic steady state. The rate of time preference is assumed to be bigger than the gross international real interest rate $(1+r<1/\beta)$. Given this assumption, in a deterministic steady state μ is strictly greater than zero and, hence, (3) holds with equality and the economy is a net debtor in international markets.

The only parameters specific to my model are the ones related to the law of motion of the LTV ratio: $\bar{\varphi}$, ρ_{φ}, σ_{φ} and $cov(A,\varphi)$—or, equivalently, the correlation between innovations to TFP and the LTV ratio, that I denote $\rho_{(A,\varphi)}$. Regarding the long-run mean of the LTV ratio ($\bar{\varphi}$), I use a range of values from 0.3 to 0.7 (see Table 6) that imply a ceiling on the leverage ratio of ultimate borrowers ranging from 1.4 to 3.3. As a reference, Calza *et al.* (2007) consider LTV ratios ranging from 50% to 90% to analyze the effect of different institutional characteristics of mortgage markets, 50% being the LTV ratio estimated for the Italian market. Jermann and Quadrini (2009) report that the average LTV ratio for nonfinancial companies over the period 1984 to 2008 is 0.46. Mendoza (2010) uses values of 0.2 and 0.3 for the LTV ratio.

The persistence parameter of the LTV ratio ρ_{φ} is set to 0.6, the same than for productivity shocks. I also report the results when shocks to TFP and to lending standards are iid. The standard deviation of innovations to the LTV ratio (σ_{φ}) is set to 5%, 2.5 times bigger than the standard deviation of innovations to productivity. The correlation of innovations to TFP and the LTV ratio, $\rho_{(A,\varphi)}$, is a key parameter for the policy experiment explained later in section 4.3. For this parameter I use a range of values from 0.8 to 0. These parameter values are overall consistent with the empirical evidence in section 2 and with estimates in Jermann and Quadrini (2009).[14]

Numerical solution technique. The methods are familiar: The model is solved by log-linearizing the equations characterizing the equilibrium around the deterministic steady state (with (3) holding with equality) and by solving the resulting system of linear difference equations to obtain the policy functions. As explained above, the parameters imply that the collateral constraint is assumed to be binding in the steady state. This implies that the amplification created by the financial friction is symmetric and is always present (like, for example, in Iacoviello 2005, Iacoviello and Neri 2010, Calza *et al.* 2007 and Jermann and Quadrini 2009).[15]

4 Quantitative Analysis

4.1 The Usual Financial Accelerator Mechanism

Before introducing fluctuations in lending standards, this section shows the response of the model when the leverage ratio does not vary over time. The amplification of shocks due to financial frictions such as in (3) when the LTV ratio is a fixed parameter has been widely analyzed in the literature (some examples include Bernanke and Gertler 1989, Kiyotaki and Moore 1997, 2002 and Kocherlakota 2000). In this section I analyze the workings of the

[14]Jermann and Quadrini (2009) estimate a first-order bivariate autoregressive process for productivity and financial shocks, where the financial shock series is constructed using a model's optimality conditions. Using quarterly data, the estimated autocorrelation parameters of the shocks are 0.93 and 0.97 respectively, the off-diagonal elements are found to be close to zero, the estimated standard deviation of financial innovations are 2.5 bigger than the one of productivity innovations and the estimated correlation of shock innovations is 0.36.

[15]Note that if the focus were on the effect of occasionally-binding constraints, as it is the case in Mendoza (2010), this solution technique would probably lead to a poor approximation, as it would fail to capture the non-linear dynamics produced when the economy switches from a state in which the constraint does not bind to a state in which it binds.

financial accelerator mechanism in the context of this model.

Figure 1 shows the reaction of consumption, investment, output, debt, net exports-to-GDP and asset prices to a negative 1% productivity shock. The different lines in each plot correspond to different $\bar{\varphi}$ values, that is, different long-run averages for the LTV ratio, ranging from 0.3 to 0.7. The first result to notice is that the more leveraged the economy is (i.e. the higher $\bar{\varphi}$), the stronger the response of asset prices and real variables to the shock. The drop in debt in the period following the shock reflects the decreased ability to rollover debt due to the drop in the market value of the collateral after the productivity decline. While $\hat{d_t}$ is slightly higher than -0.2% when $\bar{\varphi} = 0.3$, it drops by almost 0.6%, three times more, when $\bar{\varphi} = 0.7$.[16] The counterpart of the sudden inability to rollover debt is the capital outflows captured by the reaction of net exports-to-GDP: The trade balance jumps up by 1% when the long-run leverage is low ($\bar{\varphi} = 0.3$), while the same shock to productivity triggers a 5% increase in net experts-to-GDP when the economy is highly leveraged ($\bar{\varphi} = 0.7$). The response on impact of consumption is of slightly less than 0.8% when the long-run LTV ratio is 0.3, but it is twice as big (1.6%) when $\bar{\varphi}$ is 0.7. The greater outflows under a high leverage setting are relatively more absorbed by investment in physical capital than by consumption: the drop in investment is around four times bigger when $\bar{\varphi} = 0.7$ than when $\bar{\varphi} = 0.3$, while this ratio for consumption is only two.[17] The drop in output reflects first the drop in productivity and then the decrease in the capital stock; $\hat{y}_t$ reaches a minimum of -1% when $\bar{\varphi} = 0.3$ and of -1.6% when $\bar{\varphi} = 0.7$.

Excess Returns and Asset Prices. In the model the negative shock to income cannot be smoothed out by borrowing because the drop in the asset price implies a reduction in the

[16] Variables with hat denote log deviations from their steady state value.

[17] The model does not include capital adjustment costs. The presence of such costs would have implied a higher cost for smoothing consumption, leading to a bigger relative drop in consumption.

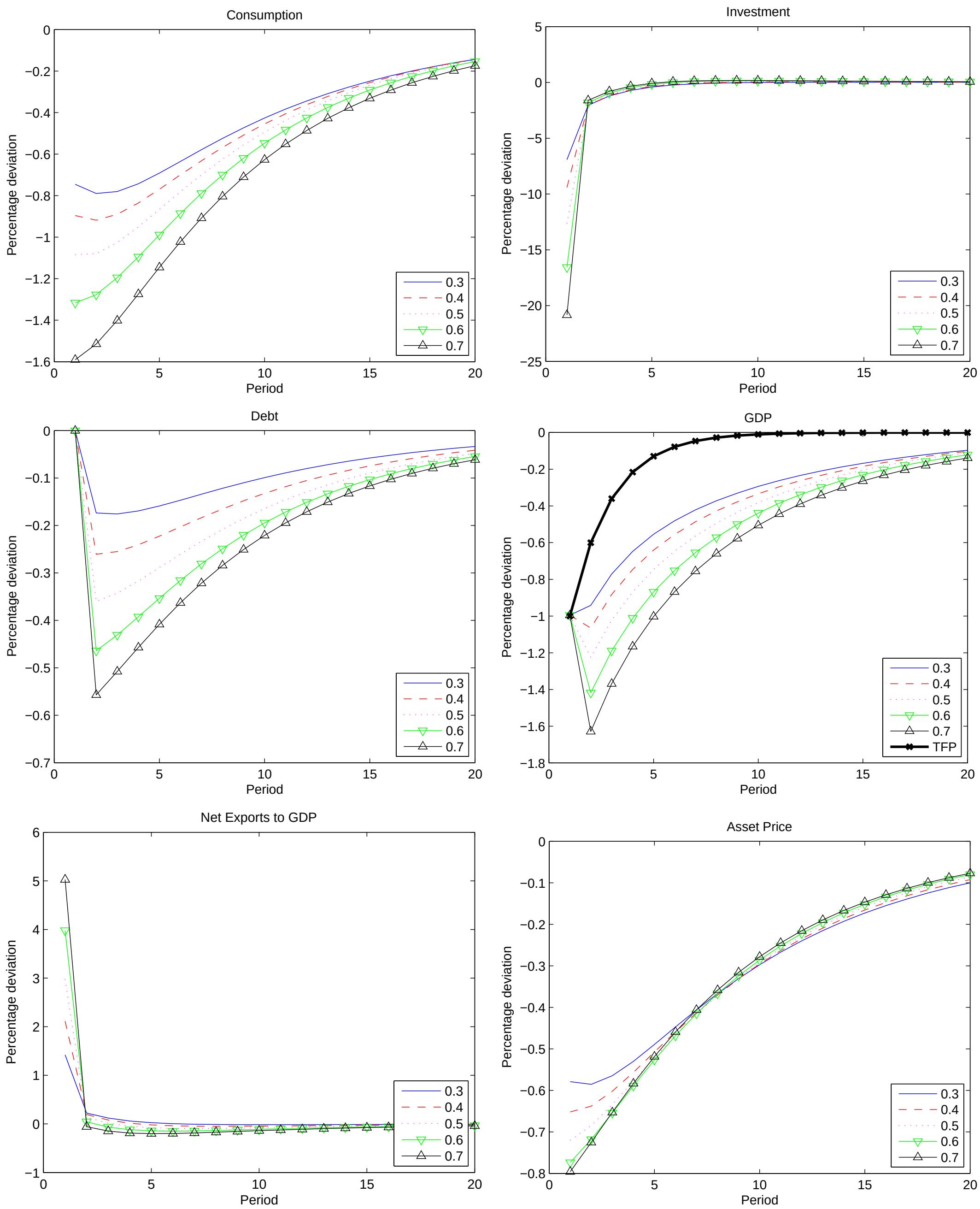

Figure 1: Impulse Responses to Productivity Shock.

Responses to a 1% negative shock to TFP under different values for the long-run LTV ratio ($\bar{\varphi}$). All the responses are expressed in percentage deviation from the steady state value, except for the net exports-to-GDP ratio that is in percentage points.

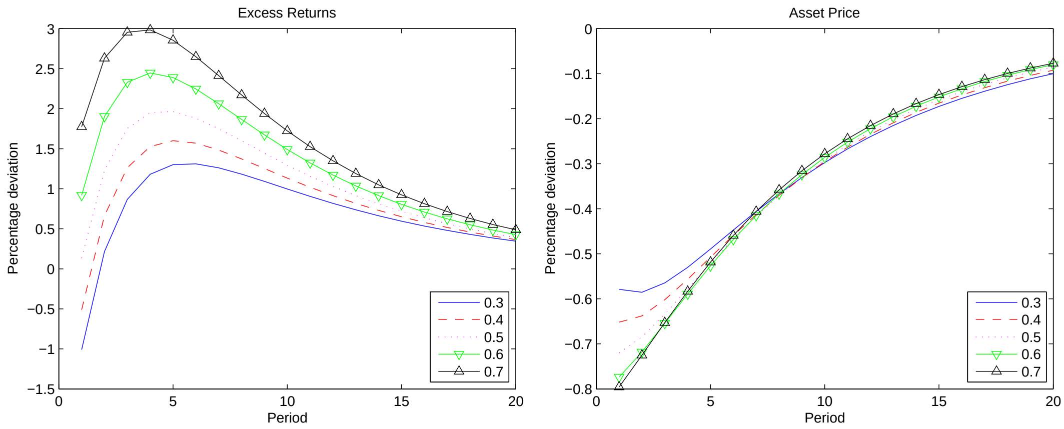

Figure 2: Excess Returns and Asset prices

Response of excess returns (equity premium) and asset prices to a 1% negative shock to TFP under different values for the long-run LTV ratio ($\bar{\varphi}$).

market value of the collateral and the consequent reduction in the borrowing capacity of the constrained economy. The drop in productivity affects the asset price directly because it affects actual dividends and the expected flow of future dividends (given that the shock is persistent).[18] But the shock also affects the asset price because of the financial friction in the economy. This effect, described as "overreaction" of asset prices to shocks in Aiyagari and Gertler (1999) and explained in section 3.1, can in principle have different intensities for low and high leveraged economies. Table 2 reports the steady state values of excess returns and

Table 2: Steady State Values

Loan-to-Value ($\bar{\varphi}$)	0.3	0.4	0.5	0.6	0.7
Excess Returns (%)	3.29	2.82	2.35	1.88	1.41
Asset Price	6.87	7.33	7.88	8.51	9.24

the asset price for different values of the long-run LTV ratio ($\bar{\varphi}$). The steady state level of excess returns is lower the higher $\bar{\varphi}$, while the opposite is the case for asset prices. Figure 2

[18] In section 4.4 I repeat the exercise assuming iid shocks. Interestingly, the response of asset prices to productivity shocks is very persistent even when the shock is iid.

instead depicts the reaction of excess returns and asset prices starting from the steady state when the economy is hit by a 1% negative productivity shock. The risk premium drops on impact for the two lowest values of $\bar{\varphi}$ considered, 0.3 and 0.4, while it increases for the rest. In all cases the dynamics of the risk premium lay above the steady state level after the first period. While the steady state level of excess returns is decreasing in $\bar{\varphi}$, its response to productivity shocks is stronger for higher average LTV levels. For all the values of $\bar{\varphi}$ considered, the asset price decreases on impact when productivity declines. The size of the decrease is increasing in $\bar{\varphi}$, implying that in this model the "overreaction" of asset prices is bigger the more leveraged the economy is. Given the 1% shock to TFP, the asset price drops less than 0.6% from its steady state value when LTV is 0.3 on average but it drops by 0.8% when $\bar{\varphi} = 0.7$.

4.2 The Effect of Shifts in Lending Standards

Along the previous section the LTV ratio was introduced as a constant. In this section instead I explore the response of the model to fluctuations in the LTV ratio. The empirical evidence cited in section 2 suggests that expansions (contractions) of financial intermediaries' balance sheets lead to the easing (tightening) of lending standards. Although the model is not sufficiently rich to capture precisely this phenomenon, I interpret shocks to $\hat{\varphi}_t$ as relaxation/tightening in lending standards due to frictions between the financial sector and ultimate lenders, as discussed in Adrian and Shin (2010). Fluctuations in $\hat{\varphi}_t$ can also be interpreted as shocks to balance sheets of financial intermediaries due, for example, to changes in measured risk or to changes in the risk-appetite of investors and in the maximum leverage they allow to financial intermediaries.

Figure 3 shows impulse responses to a 1% decrease in the LTV ratio, that is, a tightening in lending standards. The different lines in each plot correspond to different $\bar{\varphi}$ values. As it was the case for shocks to productivity, the responses of asset prices and real variables to the

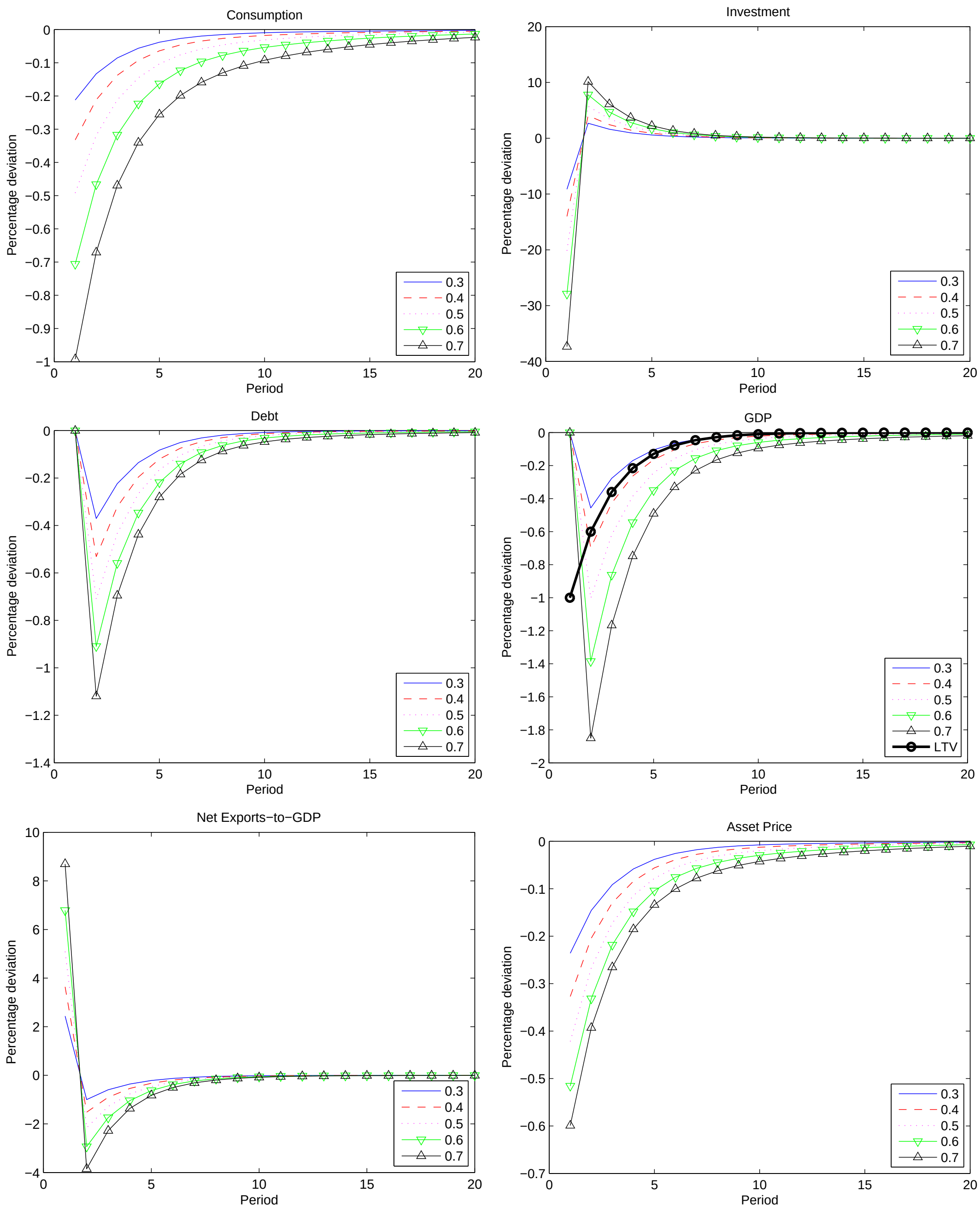

Figure 3: Impulse Responses to Lending Standards Shock.

Responses to a 1% negative shock to the LTV ratio under different values for the long-run LTV ratio ($\bar{\varphi}$). All the responses are expressed in percentage deviation from the steady state value, except for the net exports-to-GDP ratio that is in percentage points.

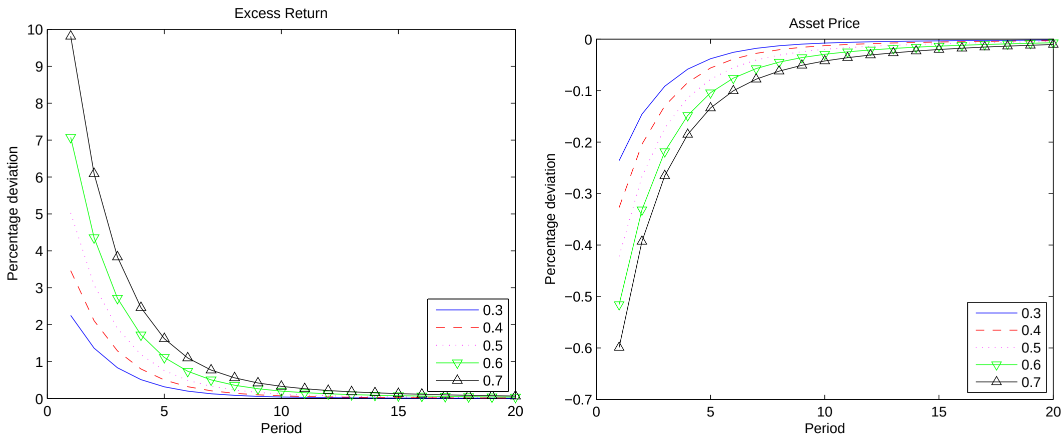

Figure 4: Excess Returns and Asset Prices

Response of excess returns (risk premium) and asset prices to a 1% negative shock to the LTV ratio under different values for the long-run LTV ratio ($\bar{\varphi}$).

shock are stronger when the LTV ratio fluctuates around a higher long-run level. The drop in debt issued reflects the combination of a lower leverage allowed by creditors (the drop in $\hat{\varphi}_t$) and the drop in the asset price triggered by the tightening of lending standards. When $\bar{\varphi} = 0.3$, the asset price drops to around 0.2% below its steady state value and $\hat{d}_t$ decreases by 0.4%. Instead, in a highly leveraged economy ($\bar{\varphi} = 0.7$) these drops are -0.6% and -1.2% respectively. The tightening in credit conditions forces agents to cut strongly on investment (between -9% and -35% depending on the mean leverage ratio) in order to smooth partly the drop in consumption (between -0.2% and -1%). The reduction in the capital stock implies a decrease in the marginal productivity of land and then a lower market value for the collateral, reinforcing the tightening of the borrowing constraint. Output is not affected on impact but only one period later, due to the reduction in the capital stock induced by a lower borrowing limit; under $\bar{\varphi} = 0.7$ GDP decreases by almost 2% with respect to its steady state value, one period after the shock.

Excess Returns and Asset Prices. Figure 4 reports the reaction of excess returns and the asset price to the shock to lending standards. When φ_t drops, the risk premium required by investors goes up and asset prices drop. The response of both excess returns and the asset price is bigger the higher the long-run leverage ratio of the economy: The rise in excess returns when $\bar{\varphi} = 0.3$ is 2%, but it is almost five times bigger, 10%, when $\bar{\varphi} = 0.7$. The associated drops in q_t are approximately 0.2% and 0.6% respectively. The responses in Figures 3 and 4 show that the predictions of this simple model to changes in lending conditions attributable to credit supply shocks is consistent with the evidence put forward by Adrian and Shin (2010) and reviewed in section 2.

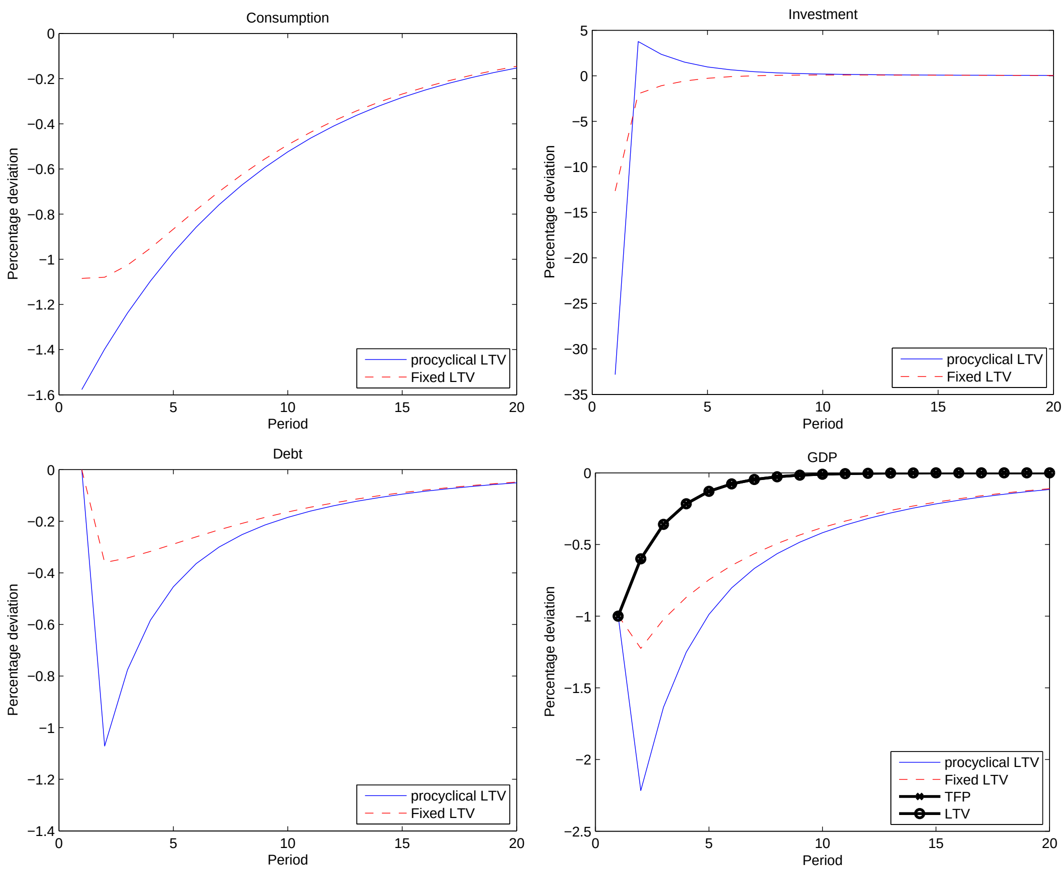

Figure 5: Impulse Responses, Procyclical Lending Standards.

The line labeled "Fixed LTV" corresponds to the responses to a 1% negative productivity shock, with φ_t constant at $\bar{\varphi} = 0.5$. The "procyclical LTV" corresponds to the responses to 1% negative shock to both TFP and the LTV ratio.

Procyclical Lending Standards. What would happen then if lending standards behaved "procyclically"? We can obtain an intuitive answer by comparing the responses of the same variables to a productivity shock on one side, and to a combination of both the productivity shock and the lending standards shock (e.g. a case in which the innovations to productivity and lending standards are perfectly correlated) on the other side. The exercise is carried for a middle value of long-run leverage: $\bar{\varphi}$ is set at 0.5, implying a leverage ratio equal to two. Figure 5 reports the responses of consumption, investment, debt and output under a "fixed LTV" ratio (i.e. only productivity shock) and "procyclical LTV" (i.e. under simultaneous productivity and lending standards shocks). The fourth graph in Figure 5 also depicts the path of $\hat{A}_t$ and $\hat{\varphi}_t$ under the "procyclical LTV" case. Both shocks are assumed to have the same persistence, so under this case lending standards are below its steady state level for exactly as long as productivity is below its long-run level.[19] Interestingly, when lending standards get tightened as productivity drops, the contraction in debt is almost three times bigger than when the LTV ratio is unchanged. Consequently, the drops in consumption and investment are much more accentuated under the procyclical LTV scenario: the decrease in investment on impact is between two and three times bigger under procyclical standards while that of consumption is about 50% bigger (-1.6% versus -1.1% under fixed LTV).

Figure 6 makes clear that the reaction of the risk premium and of asset prices is bigger under the procyclical LTV case. Aiyagari and Gertler (1999) showed that the presence of financial frictions entails an "overreaction" of asset prices to shocks to fundamentals. The results in Figure 6 show that frictions implying a procyclical behavior of the LTV ratio can further reinforce that overreaction. Indeed, the reaction of asset prices is almost twice as big under the procyclical LTV experiment than when the LTV ratio is constant. The procyclical behavior of lending standards can potentially have important consequences for the volatility

[19] As a robustness exercise, in section 4.4 I report the results under iid shocks.

of asset prices and real variables; I explore these implications in the next section.

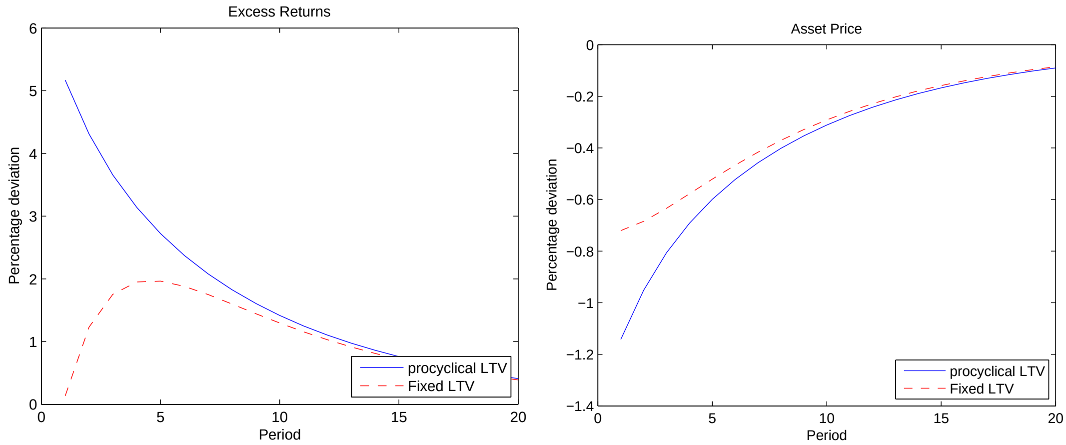

Figure 6: Amplified "Overreaction" of Asset Prices.

The line labeled "Fixed LTV" corresponds to the responses to a 1% negative productivity shock, with φ_t constant at $\bar{\varphi} = 0.5$. The "procyclical LTV" corresponds to the responses to 1% negative shock to both TFP and the LTV ratio.

4.3 Lending Standards and Macroeconomic Volatility

In this section I analyze the impact of reducing the degree of correlation of lending standards with the business cycle on the second moments of simulated macroeconomic aggregates. The reduction in correlation can be interpreted as the implementation of macro-prudential regulation aimed at reducing procyclicality in lending standards. The nature of the experiment in this section is the following. For each combination of the five values considered for $\rho_{(A,\varphi)}$ and $\bar{\varphi}$ I simulate 1000 samples of 100 periods, each with a burn-in of 500 periods, and I compute average unconditional moments across samples.

In Table 3 I report moments for a benchmark parametrization fixing $\bar{\varphi} = 0.5$ and considering values of $\rho_{(A,\varphi)} = \{0, 0.4, 0.8\}$. Although the model has no growth, the simulated series are filtered using the Hodrick-Prescott filter to focus the attention on the business cy-

Table 3: Simulation Results, HP Filtered Series.

Correlation TFP and LTV:	$\rho_{(A,\varphi)}$	0	0.4	0.8
a) Standard Deviations				
Lending Standards	$std(\varphi)$	2.32%	2.32%	2.32%
Output	$std(y)$	5.10%	5.68%	6.16%
Consumption	$std(c)$	3.07%	3.58%	4.01%
Investment	$std(i)$	106%	114%	122%
Asset Price	$std(q)$	2.35%	2.74%	3.06%
b) Cross-Correlations with Output				
Lending Standards	$corr(\varphi, y)$	0.25	0.36	0.45
Asset Price	$corr(q, y)$	0.47	0.55	0.60
Consumption	$corr(c, y)$	0.50	0.58	0.63
Trade balance to GDP	$corr(nx/y, y)$	0.38	0.31	0.26
c) Cross-Correlations with Asset Prices				
Lending Standards	$corr(\varphi, q)$	0.81	0.88	0.94
Consumption	$corr(c, q)$	0.99	0.99	0.99
Trade balance to GDP	$corr(nx/y, q)$	−0.44	−0.42	−0.41

Notes: All parameters as shown in Table 6. The long-run LTV ratio $\bar{\varphi}$ is 0.5. The series are filtered using the Hodrick-Prescott filter and a smoothing parameter equal to 100.

cle frequency.[20] The volatility of lending standards is 2.32% irrespectively of the value of $\rho_{(A,\varphi)}$, roughly between 1/3 and 1/2 of the volatility of output. Although the correlation of innovations $\rho_{(A,\varphi)}$ ranges from 0 to 0.8, it is worth noting that the corresponding correlation of the LTV ratio with output goes only from 0.25 to 0.45. Fluctuations in φ_t have important effects in asset prices, as it was clear from the previous section. This is reflected in simulated series: The correlation of the LTV ratio with the asset price is 0.81 when $\rho_{(A,\varphi)} = 0$ and 0.94 when $\rho_{(A,\varphi)} = 0.8$.

What is the gain in terms of macro volatility from reducing $\rho_{(A,\varphi)}$ gradually from 0.8 to 0? Figures 7 and 13 provide a visual summary of this experiment. Figure 7 presents the de-

[20]As a robustness check, Table 7 reports the results corresponding to unfiltered data.

crease in volatility for consumption, investment, output, foreign debt and net exports-to-GDP ratio, each relative to its own volatility when the correlation is 0.8, for a given long-run mean of the LTV ratio ($\bar{\varphi} = 0.5$, implying a leverage ratio of borrowers of 2). The figure shows potential sizeable gains in terms of volatility of macroeconomic aggregates from reducing the procyclicality of lending standards. In this sense, reducing the correlation of lending standards with productivity from 0.8 to 0 leads to a reduction in the volatility of consumption of almost 1/4: the volatility of consumption under acyclical lending standards is about 25% lower than when $\rho_{(A,\varphi)} = 0.8$. The same exercise leads to a reduction in the volatility of output of around 17%. The biggest drop in volatility is achieved for the net export-to-GDP series, of around 30%. The gains in terms of macroeconomic volatility are significant, especially taking into account that reducing the correlation of the innovations from 0.8 to 0 implies a relatively modest reduction in the correlation between the LTV ratio and output, from 0.45 to 0.25 (see Table 3).[21] As a reference, removing the shocks to lending standards altogether reduces the standard deviation of consumption and output relative to the 0.8 correlation case by 53% and 36% respectively.

Figure 13 reports the results for the same exercise but over a range of values for $\bar{\varphi}$. For each series the value on the vertical axis corresponds to its unconditional volatility relative to the one corresponding to $\rho_{(A,\varphi)} = 0.8$ and $\bar{\varphi} = 0.7$. The first thing to note is that, for all the variables, the volatility is higher the bigger the long-run leverage is. For example, the volatility of consumption is around 70% lower when the long-run leverage ratio is 1.4 ($\bar{\varphi} = 0.3$) than when it is 3.3 ($\bar{\varphi} = 0.7$). Approximately the same ratio holds for output. In the case of asset prices, the unconditional volatility when ($\bar{\varphi} = 0.3$) is about half of the one under ($\bar{\varphi} = 0.7$). The most sensible variable in terms of unconditional volatility under different long-run leverage ratios is the trade balance: the volatility is several times higher when

[21] In the case of unfiltered series the correlation between the LTV ratio and output decreases from 0.65 to 0.45 when $\rho_{(A,\varphi)}$ is lowered from 0.8 to 0.

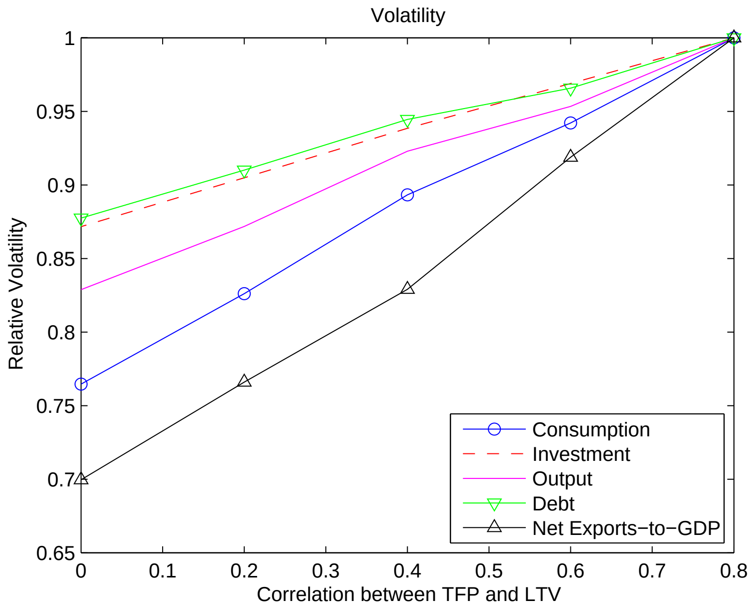

Figure 7: Stabilization Gains from Reducing Procyclicality of φ_t.

Each plot corresponds to the volatility of the series under different degrees of correlation ($\rho_{(A,\varphi)}$), relative to its own volatility when $\rho_{(A,\varphi)} = 0.8$. The long-run mean of the LTV ratio ($\bar{\varphi}$) is 0.5 in all cases. All series have been filtered using the Hodrick-Prescott filter.

$\bar{\varphi}$ takes the maximum value.

The second result is that, for all the variables and for all long-run values of LTV ($\bar{\varphi}$), a reduction of the correlation $\rho_{(A,\varphi)}$ always entails a reduction in volatility. Whether the slope is steeper for different cuts over the $\bar{\varphi}$ dimension is hard to assess in the surface graphs. Figure 8 makes this comparison clearer for two variables: consumption and the trade balance to output ratio. The result is mixed: While for the case of consumption the gain in volatility from reducing the procyclicality of lending standards is roughly equivalent for different values of $\bar{\varphi}$, in the case of the trade balance the reduction is much more accentuated the higher the mean leverage of the economy.

Overall, the results in this section suggest that policies aimed at smoothing the procycli-

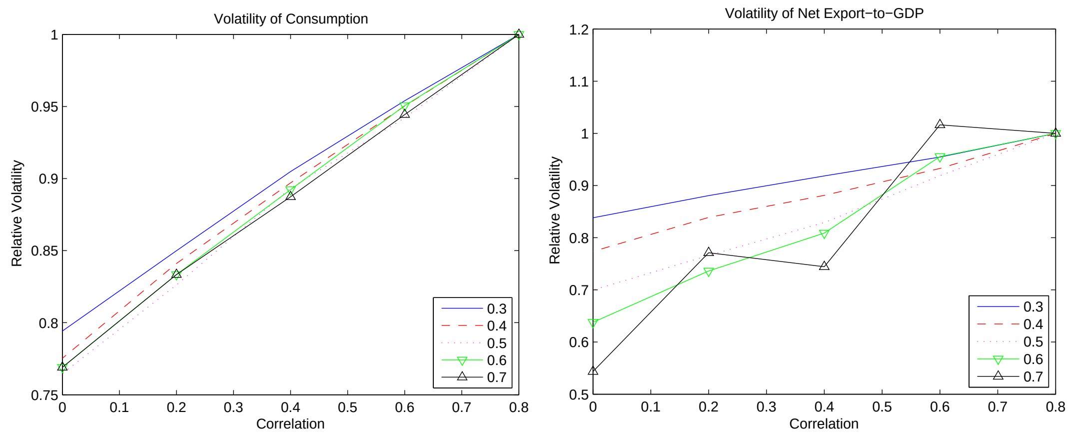

Figure 8: Stabilization Gains Under Different $\bar{\varphi}$ Values.

Each plot corresponds to the volatility of the series for a given long-run leverage ($\bar{\varphi}$) under different degrees of correlation ($\rho_{(A,\varphi)}$), relative to its own volatility when $\rho_{(A,\varphi)} = 0.8$. All series have been filtered using the Hodrick-Prescott filter.

cality in lending standards can have seizable results in terms of volatility of macroeconomic aggregates. Although the model is highly stylized and abstracts from several elements that can be relevant for policy analysis, it can provide much of the insight into how the procyclical behavior of the financial frictions can affect macroeconomic volatility. Some caveats are of course in order. First, the simulations presented in this section are based on first order approximations of the dynamic system under the conjecture that the collateral constraint is always binding. I do check that the Lagrange multiplier μ_t is always positive along the simulated paths. However, although a negative value of μ_t for some period would question the solution approach, a positive multiplier is not a proof that the collateral constraint has always been binding. A nonlinear approximation method would constitute a more robust alternative.[22] My guess though is that the presence of nonlinearities associated with occasionally binding constraints would, if any, amplify the effects of procyclical lending standards on

[22]Although the model details differ, it is worth noting that some studies have found linear approximations relatively accurate in contexts similar to the one in this paper. In a model using an asset in fixed supply as collateral, Iacoviello (2005) presents evidence suggesting that only for extreme parameterizations the accuracy of the linear approximation becomes questioned. Also Jermann and Quadrini (2009) solve a model with collateral constraints under both linear and nonlinear approximations and find that the solution based on a linear approximation is quite accurate. Nonetheless, the extent to which model details and parameter values might imply accuracy problems is an open question for future research.

macroeconomic volatility. Second, the model in this paper abstracts completely from nominal issues, among which the presence of nominal frictions and of monetary policy, that might affect the transmission of financial shocks. Finally, the small open economy nature of the model implies that the real interest rate does not react to financial shocks that affect credit supply. Also, the model assumes that the financial friction affects the whole population in the economy. Exploring the quantitative implications of procyclical lending standards in a closed economy model with two groups of agents or in a two country model–where relative prices may also play a relevant role–are interesting avenues for future research.[23]

4.4 Persistence of Shocks and Business Cycles

In this section I repeat the numerical experiments under the alternative assumption of iid shocks, both for productivity and the LTV ratio. Figure 9 depicts the responses of the main macro-aggregates under both a fixed LTV ratio and procyclical lending standards when shocks to TFP and to the LTV ratio are iid instead of persistent as in the previous sections. Besides confirming the amplified overreaction of asset prices when φ_t behaves procyclically, the remarkable result in Figure 9 is the strong persistence of deviations from trend of asset prices despite the iid nature of the shocks. This persistent deviation of q_t gets reflected in the persistent responses of debt and consumption.

Figure 10 shows the volatility results from simulations assuming iid shocks. The main results on volatility of reducing procyclicality of lending standards does not depend on the persistence of the shocks. In particular, the volatility of consumption, the only argument in the utility function of the representative agent, drops by almost 1/4 when the correlation $\rho_{(A,\varphi)}$ is reduced from 0.8 to 0, similarly to the result with persistent shocks. The main difference

[23]See Gruss and Sgherri (2009) for a model that introduces cycles in lending standards in a two-country two-good model, with endogenous fluctuations in the terms of trade.

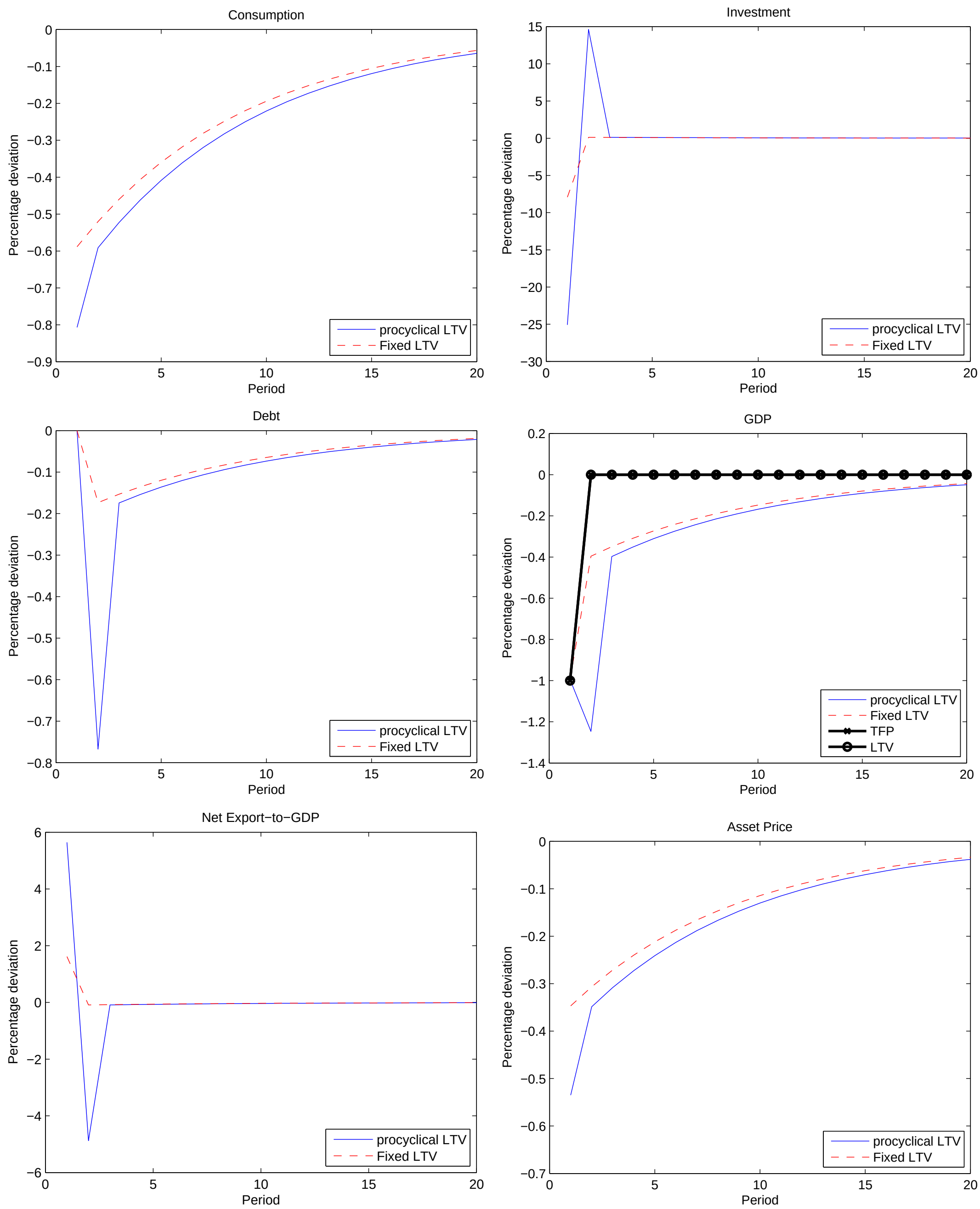

Figure 9: Impulse Responses, Procyclical Lending Standards, iid Shocks.

The line labeled "Fixed LTV" corresponds to the responses to a 1% negative productivity shock, with φ_t constant and equal to $\bar{\varphi}$. The "procyclical LTV" corresponds to the responses to 1% negative shock to both TFP and the LTV ratio.

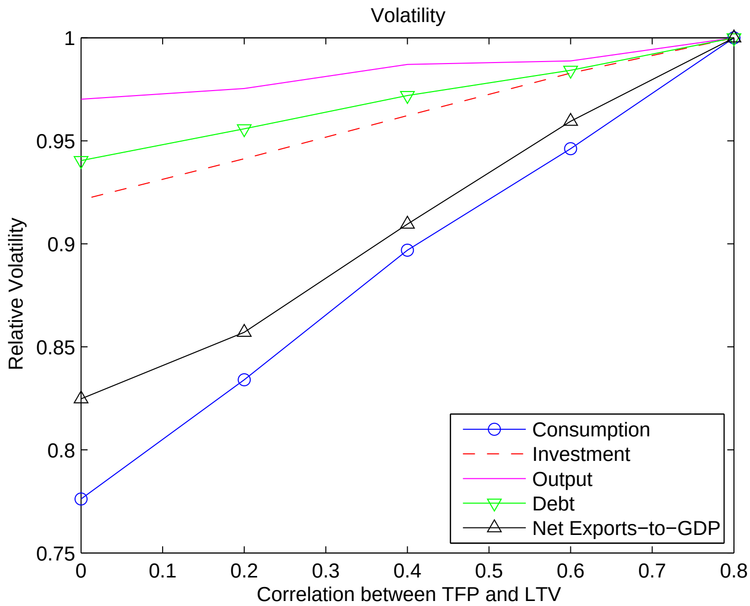

Figure 10: Stabilization Gains Assuming iid Shocks.

Each plot corresponds to the volatility of the series under different degrees of correlation ($\rho_{(A,\varphi)}$), relative to its own volatility when $\rho_{(A,\varphi)} = 0.8$. The long-run mean of the LTV ratio ($\bar{\varphi}$) is 0.5 in all cases. Shocks to TFP and to LTV ratio are iid. All series have been filtered using the Hodrick-Prescott filter.

between the exercise with persistent shocks refers to the volatility of output: with iid shocks the volatility of GDP gets reduced much less than when shocks are persistent.

Table 4: Persistence of Business Cycles

Procyclicality of Lending Standards ($\rho_{(A,\varphi)}$)	0	0.2	0.4	0.6	0.8
Autocorrelation of Output	0.16	0.25	0.32	0.39	0.44

Credit constraints have been signaled as a key mechanism transforming shocks into persistent movements in output (e.g. Kocherlakota 2000). This model confirms this result. The first column in Table 4 reports the autocorrelation of output when shocks to TFP and to φ_t are iid and $\rho_{(A,\varphi)} = 0$, fixing $\bar{\varphi} = 0.5$. Even if shocks are iid, output displays positive autocorrelation (0.16). Interestingly, however, procyclicality in lending standards implies higher persistence of business cycles relative to the shocks hitting the economy: When the simulations are repeated for positive $\rho_{(A,\varphi)}$ under iid shocks, the autocorrelation of output increases substantially. Indeed, when $\rho_{(A,\varphi)} = 0.8$ the autocorrelation of output is 0.44, three times higher than when $\rho_{(A,\varphi)} = 0$.[24] In sum, the procyclicality of lending standards also introduces a significant source of persistence of output.

4.5 An Endogenous Function for Lending Standards

Fully endogenizing the procyclical behavior of lending standards in a DSGE model is beyond the scope of this paper.[25] However, in this section and as a robustness exercise I replace the stochastic process for φ_t in equation (3) postulating an endogenous functions that links lending standards with the cyclical stance of the economy. Adrian and Shin (2010) suggest that financial intermediaries adjust their balance sheets to changes is asset prices in a way that implies an aggregate increase/reduction in credit supply. There is evidence suggesting that this behavior entails relaxation/tightening in lending standards (see Bayoumi and Melander 2008 for example). Motivated by this evidence I assume an ad-hoc functional form for φ_t that links lending standards to the cyclical stance of asset prices in the economy. More precisely, I postulate:

$$\varphi_t = \frac{\exp\left(a(q_t - \bar{q}) + b\right)}{1 + \exp\left(a(q_t - \bar{q}) + b\right)}, \tag{12}$$

where b is a parameter determining the LTV ratio in the non-stochastic steady state and a determines the sensibility of φ_t to deviations of q_t from its steady state value.[26] Figure 11

[24] These results correspond to unfiltered series. The same result holds for HP filtered series.

[25] Fostel and Geanakoplos (2008) model the tightening of margins explicitly, but in a finite-horizon model with limited rationality.

[26] Under the specification of φ_t in equation (12), its long-run level is $\bar{\varphi} = \frac{\exp(b)}{1+\exp(b)}$.

shows the response of the LTV ratio to a negative 1% productivity shock for $a = 0$ and $a > 0$. The parameter b was set to 0 such that the long-run LTV ratio is 0.5, the intermediate value in the exercises in the previous sections. In the procyclical lending standards case, the parameter a was set to 160 so that the unconditional standard deviation of the LTV ratio is similar than under the specification of lending standards in (3) used in the previous sections. With these parameter values, a 1% negative TFP shock leads to a drop of $\hat{\varphi}_t$ on impact of around 2.5% (see Figure 11).

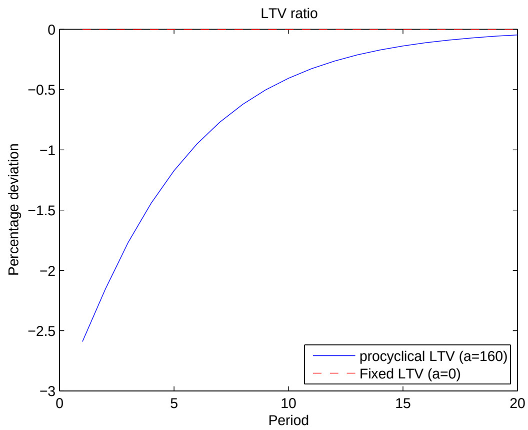

Figure 11: Response of LTV Ratio in (12) to a -1% TFP Shock.

Figure 12 shows the response of consumption, investment, debt, output, excess returns and asset prices to a negative productivity shock assuming alternatively $a = 0$ (i.e. a fixed LTV ratio) and $a > 0$ (procyclical lending standards). When lending standards get eased as asset prices are above trend and tightened when they are below trend, the responses of all the variables are much more accentuated than when the LTV ratio is a constant. The last two graphs show the amplified "overreaction" of asset prices due to procyclical lending standards: Excess returns rise on impact by 15% above their steady state level when $a = 160$. Instead, when $a = 0$ they only rise gradually, reaching a maximum deviation from trend of around 2% five periods after the shock. The asset price drops to only 0.7% below its steady state

Table 5: Simulation Results, LTV Ratio in equation (12).

Standard Deviations	a:	0	160
Lending Standards	$std(\varphi)$	0%	2.44%
Output	$std(y)$	2.23%	7.64%
Consumption	$std(c)$	2.11%	6.38%
Investment	$std(i)$	22.7%	145.1%
Asset Price	$std(q)$	1.37%	5.05%

Notes: a takes 2 alternative values: 0 (fixed LTV) and 160 (procyclical LTV); $b = 0$; the other parameter values are as in Table 6. The series are filtered using the Hodrick-Prescott filter and a smoothing parameter equal to 100.

level when $a = 0$ while it decreases almost 3% when lending standards are procyclical. Due to the higher drop in the value of the collateral under procyclical lending standards, $\hat{d}_t$ drops by five times more than when the LTV is fixed. Consequently, the drops in consumption and in investment in response to a negative productivity shock is much more pronounced when the LTV ratio behaves procyclically: the drop in consumption is more than 3 times bigger and, in the case of investment, the decrease is around 7 times bigger. The latter gets reflected in the much higher drop in output under procyclical lending standards: $\hat{y}_t$ reaches a bottom of -1.2% when the LTV is fixed but of almost -4.5% when the LTV ratio behaves procyclically.

Table 5 reports the second moments of simulated macroeconomic aggregates assuming alternatively $a = 0$ and $a = 160$. When $a = 0$ the LTV ratio is a constant; when $a = 160$ the LTV ratio reacts to deviations of asset prices from trend and its standard deviation is 2.44%. The volatility of q_t is more than 3.5 times higher when lending standards are assumed to be procyclical. In the case of consumption this ratio is 3 times and for investment it is more than 6 times. The standard deviation of output is 7.64% when $a = 160$ but it is only 2.23% when the LTV ratio is fixed.

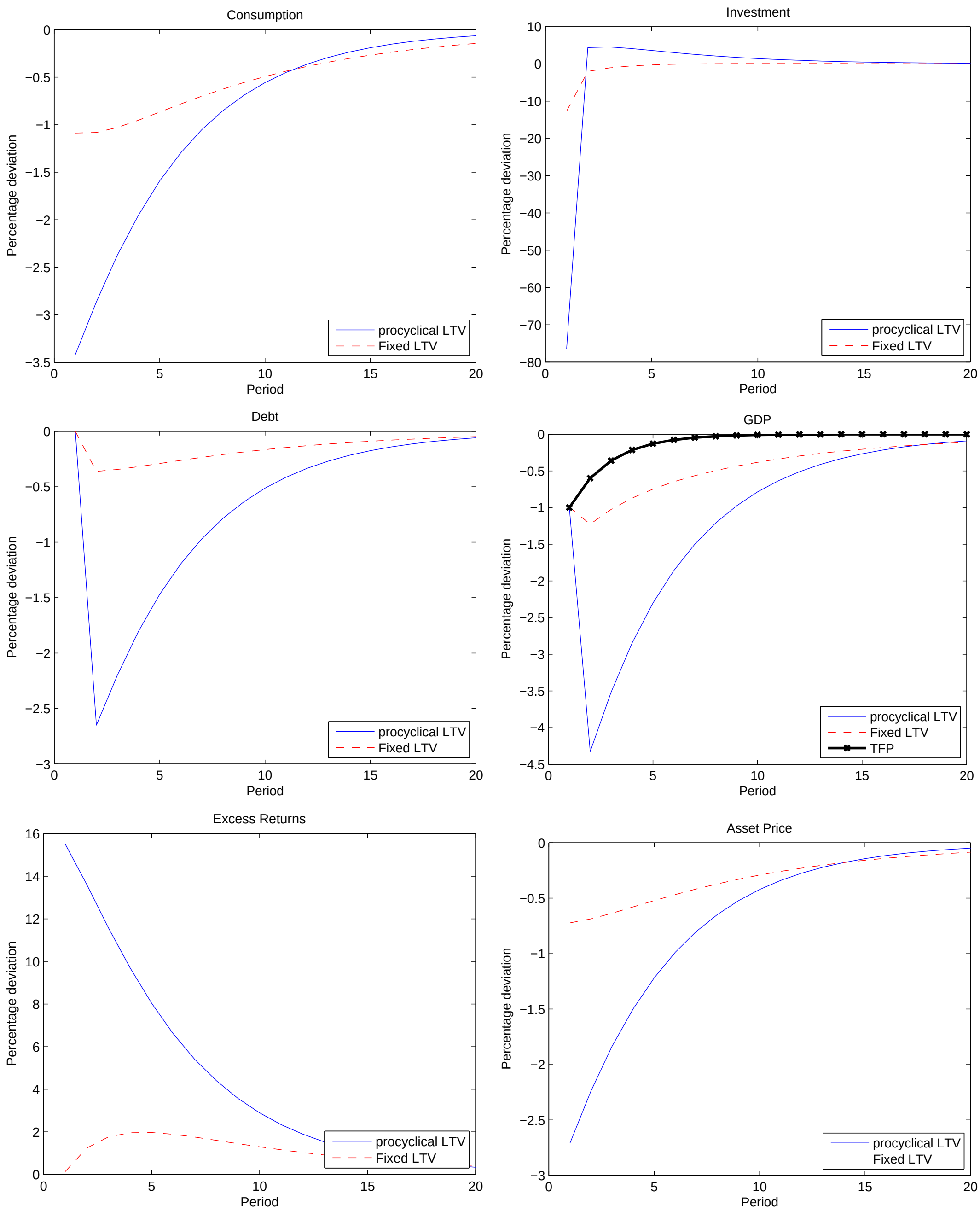

Figure 12: Alternative Specification for Lending Standards in (12).

The line labeled "Fixed LTV" corresponds to the responses to a 1% negative productivity shock, with φ_t as in (12) with $a = 0$ while the "procyclical LTV" responses correspond to the case with $a > 0$.

5 Concluding Remarks

Recent contributions in the empirical literature suggest the existence of financing frictions in the relationship between financial intermediaries and their creditors, introducing a credit supply channel that amplifies business cycle fluctuations. Indeed, several studies show that, consistently with the extended use of risk-measures like Value-at-Risk, leveraged financial institutions manage actively their balance sheets in response to changes in the price of assets they hold and in measured risk in the economy, and that this behavior affects in turn the tightness of credit standards, the volume of aggregate credit, asset prices and real activity. Although the role of non-financial borrowers' "creditworthiness" in amplifying or generating cycles in macro models has been amply studied in the literature, the presence of frictions in the funding side of financial intermediaries has been much less explored. This paper develops a small open economy model that, while keeping financial intermediaries as a veil, incorporates the dynamics of their balance sheets documented in the empirical literature in a reduced form. Agents in the domestic economy trade a non-contingent bond with the rest of the world and face an endogenous collateral constraint where the maximum leverage ratio varies with the business cycle, mimicking the procyclical behavior of lending standards. What I am trying to explore, in a simple way, is the macroeconomic effect of financial intermediaries easing/tightening credit standards along the cycle, for some reason not modeled explicitly but consistently with the empirical evidence.

Despite the highly stylized nature of the model, it predicts reactions of the risk premium, asset prices and macroeconomic activity to innovations in productivity or to financial shocks consistent with the empirical evidence documented for instance in Adrian *et al.* (2010b). The tightening of lending standards leads to a sharp increase in the risk premium and a drop in asset prices. The drop in the market value of the collateral decreases the possibility of rolling over debt and forces agents to cut spending in consumption and investment, the latter leading to a drop in output after one period. When I consider shifts in the loan-to-value ratio that are correlated with the business cycle, I find that the "overreaction" of asset prices documented in Aiyagari and Gertler (1999) gets further amplified and this leads to a bigger reaction of real variables. In my quantitative experiments the response of asset prices is twice as big when lending standards get tightened as productivity drops than when the loan-to-value ratio is constant. Also the drop in output is around twice as big, while for the case of consumption the drop is 50% bigger under a procyclical reaction of lending standards.

Regarding the destabilizing effect of procyclicality in lending standards mentioned in the literature, my simulations suggest that introducing some "macro-prudential" regulation to reduce the degree of correlation of credit standards with the cycle can lead to sizable gains in terms of macroeconomic volatility. In this sense, in my model reducing the correlation of the loan-to-value ratio with output from 0.45 to 0.25 is associated with a reduction in the volatility of real consumption of approximately one fourth. The procyclical behavior of lending standards is also found to contribute significantly to the persistence of business cycles relative to the shocks. Although the model is highly stylized, it contributes to the policy debate on macro-prudential regulation by exploring what can be the stabilizing effects of implementing policies aimed at lowering the degree of procyclicality in lending standards.

Assessing the quantitative implications of extending the model to include more realistic features represents a potential avenue for future research. The parsimonious nature of the model in this paper helped to focus on the main aspects of the propagation mechanism. However, a richer model might be needed to explore policy instruments and to evaluate the potential benefit of concrete policies targeting the procyclicality of credit standards. Modeling explicitly financial intermediaries to endogenize the procyclical behavior of lending standards is of course another interesting direction for future research.

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6 Appendix

6.1 Other Tables and Figures

Table 6: Model Parametrization

a) Preferences and Technology	Symbol	Value
Discount factor	β	0.92
Capital income share	α	0.5
Capital depreciation parameter	δ	0.1
Unconditional mean of TFP	$\bar{A}$	0.61
Persistence of TFP shock	ρ_A	0.6
Standard deviation of TFP shock	σ_A	0.02
b) Credit Standards		
b.1) Stochastic Specification (Equation 4)		
Average LTV ratio	$\bar{\varphi}$	$\{.3, .4, .5, .6, .7\}$
Persistence of LTV shock	ρ_φ	0.6
Standard deviation of LTV shock	σ_φ	0.05
Correlation of A_t and φ_t shock innovations	$\rho_{(A,\varphi)}$	$\{0, .2, .4, .6, .8\}$
b.2) Endogenous Function (Equation 12)		
Average LTV ratio	$\exp(b)/(1+\exp(b))$	.5
LTV function parameter	a	160

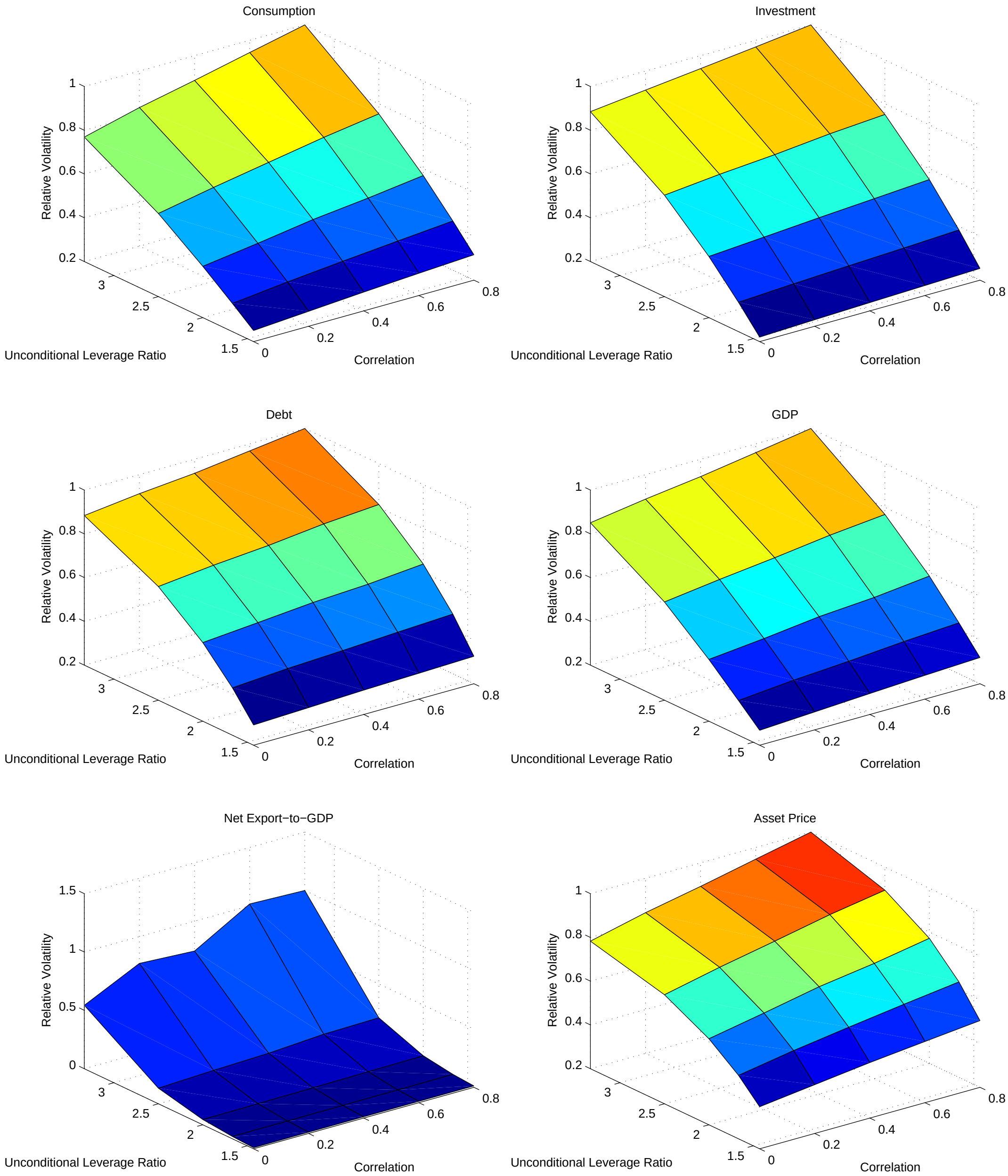

Figure 13: Stabilization Gains from Reducing Procyclicality of φ_t.

Each plot reports the volatility of the series under different degrees of correlation ($\rho_{(A,\varphi)}$) and long-run LTV ratio ($\bar{\varphi}$), relative to its own volatility when $\rho_{(A,\varphi)} = 0.8$ and $\bar{\varphi} = 0.7$. All series have been filtered using the Hodrick-Prescott filter.

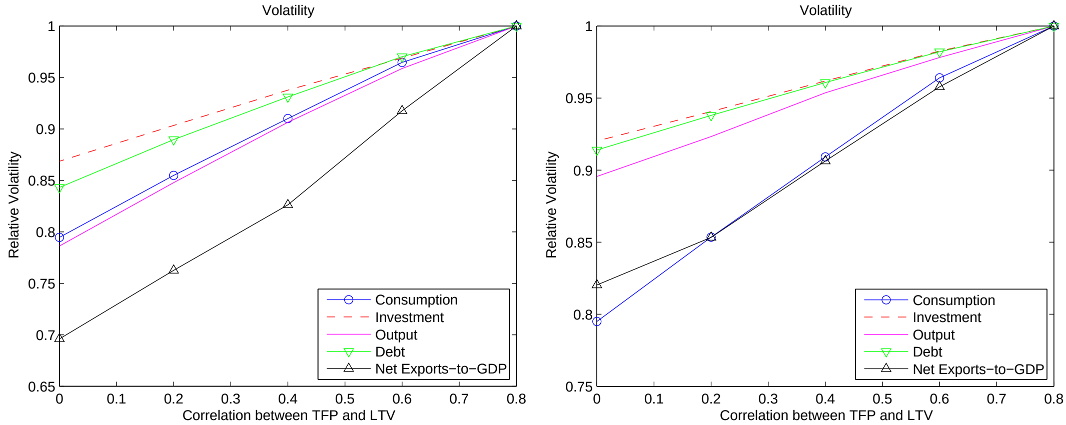

Figure 14: Stabilization Gains from Reducing Procyclicality of φ_t, Unfiltered Series, Persistent and iid Shocks.

Each plot corresponds to the volatility of the series under different degrees of correlation ($\rho_{(A,\varphi)}$), relative to its own volatility when $\rho_{(A,\varphi)} = 0.8$. The long-run mean of the LTV ratio ($\bar{\varphi}$) is 0.5 in all cases. The series are unfiltered. The *left panel* corresponds to persistent shocks ($\rho_A = \rho_\varphi = 0.6$) while the *right panel* corresponds to iid shocks.

Table 7: Simulation Results, Unfiltered Series.

Correlation TFP and LTV:	$\rho_{(A,\varphi)}$	0	0.4	0.8
a) Standard Deviations				
Lending Standards	$std(\varphi)$	3.05%	3.05%	3.05%
Output	$std(y)$	7.84%	9.04%	9.98%
Consumption	$std(c)$	6.00%	6.87%	7.55%
Investment	$std(i)$	110%	119%	127%
Asset Price	$std(q)$	4.13%	4.78%	5.29%
b) Cross-Correlations with Output				
Lending Standards	$corr(\varphi,y)$	0.45	0.56	0.65
Asset Price	$corr(q,y)$	0.76	0.81	0.84
Consumption	$corr(c,y)$	0.76	0.82	0.85
Trade balance to GDP	$corr(nx/y,y)$	0.22	0.17	0.14
c) Cross-Correlations with Asset Prices				
Lending Standards	$corr(\varphi,q)$	0.64	0.76	0.86
Consumption	$corr(c,q)$	0.99	0.99	0.99
Trade balance to GDP	$corr(nx/y,q)$	−0.28	−0.26	−0.25

Notes: All parameters as shown in Table 6. The series are unfiltered.