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An Assessment Using a DSGE Model

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The Volatility Costs of Procyclical Lending Standards: An Assessment Using a DSGE Model.[*]

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Abstract

The ongoing financial turmoil has triggered a lively debate on ways of containing systemic risk and lessening the likelihood of future boom-and-bust episodes in credit markets. Particularly, it has been argued that banking regulation might attenuate procyclicality in lending standards by affecting the behavior of banks capital buffers. This paper uses a two-country DSGE model with financial frictions to illustrate how procyclicality in borrowing limits reinforces the "overreaction" of asset prices to shocks described by Aiyagari and Gertler (1999), and to quantify the stabilization gains from policies aimed at smoothing cyclical swings in credit conditions. Results suggest that, in financially constrained economies, the ensuing volatility reduction in equity prices, investment, and external imbalances would be sizable. In the presence of cross-border spillovers, gains would be even higher.

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I. Introduction

The ongoing financial turmoil—stemming from creditworthiness problems in U.S. subprime mortgage market—has made evident that asset price dynamics are likely to amplify business cycle fluctuations by making bank lending procyclical. Indeed, the rapid growth of asset prices during booms raises the value of collateral, thus stimulating credit growth. Speculation on price swings represents an additional source of demand for credit, while resulting wealth effects accentuate the spending boom. This process is further reinforced by the greater liquidity that characterizes fixed assets during periods of financial euphoria. However, this behavior will tend to increase the vulnerability of the financial system during the subsequent downswing, when it becomes clear that the loans did not have adequate backing. Asset price deflation will then be reinforced as debtors strive to cover their financial obligations and creditors will seek to liquidate their collateral in conditions of reduced asset liquidity.

The traditional focus of risk-sensitive capital adequacy requirements on microeconomic (rather than macroeconomic) risk assessment—with individual financial intermediaries failing to internalize the collective risks assumed during the upswing—can further increase such a procyclical bias in bank lending. In fact, it is during crises that the excess of risk assumed during economic booms becomes evident and ultimately makes it necessary to write off loan portfolios. In a system where loan-loss provisions are tied to loan delinquency, the sharp increase in such delinquency during crises reduces financial institutions' capital and, hence, their lending capacity. This, in conjunction with the greater perceived level of risk, triggers the credit squeeze that characterizes such periods, further reinforcing the downswing in economic activity and asset prices, and thus the quality of the portfolios of financial intermediaries.[1]

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. Some supervisors (for example, in Spain) have advocated (and implemented) the use of countercyclical provisioning methodologies (sometimes referred to as "dynamic" or "statistical"), which require banks to provision more (than evidenced by losses) in good times, when the identified need for provisioning is smaller, and draw against these reserves in bad times, when the need for provisions is larger. Given the interaction between provisions and capital, it is argued that such forward-looking provisioning methods could reduce the procyclicality of regulatory requirements.[2] Others, however, have argued that it is rather the lack of complete implementation of risk-sensitive bank capital regulation that produces such undesired effects.[3] The adoption of mark-to-market accounting guidelines—such as the IAS 39—has also been blamed as a predomi-

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[1]Borio and others (2001) review the factors contributing to swings in credit conditions which may amplify macroeconomic cycles. They stress the role played by the inappropriate response of financial market participants to shifts in the level of risk—especially in its systematic component—as an important source of this amplification. Incorrect responses appear to be due not only to a misassessment of risk over time, but also to distortive incentives, likely to make financial market participants react in a socially suboptimal way.

[2]There is a growing literature on the potential procyclicality of the new risk-sensitive bank capital regulation—known as Basel II—mirroring the concern that the increase in capital requirements during downturns might severely contract the supply of credit. On this point see, among others, Saurina and Trucharte (2007) and Repullo and Suarez (2008). For a recent policy discussion, see Goodhart and Persaud (2008).

[3]On this point, see Caruana and Narain (2008).

nant source of procyclicality in lending standards, through its effects on loan-loss provisions.[4]

As the ongoing credit squeeze keeps fueling fears about its impact on real activity, the debate on how best to amend current bank regulation is expected to continue for quite a while. In the meantime, a question arises: how large would be the gains, in terms of macroeconomic volatility, from introducing policy measures aimed at mitigating procyclical swings in credit conditions? This paper attempts to provide a quantitative answer to this question in the context of a two-country, two-good, incomplete markets model where Home agents are assumed to be more impatient than Foreign agents and international debt contracts are imperfectly enforceable. Reflecting inefficiency in the debt enforcement procedure, the model allows for a financial friction à la Kiyotaki and Moore (1997), according to which borrowing is limited to a given fraction of the value of a collateral, the "loan-to-value ratio" (LTV hereafter). The model explores the channels through which the behavior of lending standards interacts with the business cycle, highlighting the role of asset prices. It shows that, in a credit-constrained economy, a procyclical behavior of credit standards would reinforce the "overreaction" of asset prices to shocks presented in Aiyagari and Gertler (1999).

In our model, financial friction and asset-pricing behavior is similar to Mendoza (2006) and Mendoza and Smith (2006), although with important differences. First, our setting corresponds to a two-country, two-good model. Second, in our framework, foreign debt is traded only by Households, whereas Mendoza (2006) assume that both Households and firms face a borrowing constraint, the latter affecting working capital loans. Third and most importantly, both Mendoza (2006) and Mendoza and Smith (2006) consider "occasionally binding" collateral constraints, as they focus on the ability of these constraints to trigger "sudden stop phenomena" at times when they are binding. On the contrary, in this paper we are interested in normal credit cycles in financially constrained economies; we hence focus on the dynamics around a steady state where the collateral constraints are always binding.[5] Finally, all the abovementioned studies using collateral constraints regard the LTV ratio as a time-invariant structural parameter.[6] However, empirical evidence suggests that lending standards vary over time and tend to co-move with the business cycle. To mirror such procyclicality in credit standards, we assume that leverage is stochastic and we calibrate this process in such a way that its cyclical pattern matches the one found in actual data.

To calibrate the model, we use standard values in the literature and, where pertinent, post-1999 data from Estonia and Sweden. As explained below, some features of these two economies resemble closely those of a representative-agent two-country model—that is, the theoretical framework adopted in this paper.[7] The model is subsequently used to assess quantitatively the impact on macroeconomic volatility from adopting policies aimed at smoothing the procyclicality of lending

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[4]See, for example, Jiménez and Saurina (2006) and Taylor and Goodhart (2006).

[5]Several models deal with always-binding constraints; some examples include Iacoviello (2005), Iacoviello and Minetti (2006), Callegari (2007), and Calza and others (2007).

[6]Guajardo (2008) develops a small open economy model with a credit-market imperfection in the form of a liquidity- (rather than collateral-) constraint where the fraction of expenditures that households are required to self-finance *does* vary over time. In the model—calibrated using Chilean data—the evolution of the liquidity requirement is found to be highly persistent and more volatile than output.

[7]It is worth stressing, nonetheless, that the role of procyclical lending standards in amplifying business cycles fluctuations could have equally been studied using alternative setups like, for instance, a financially-constrained (closed or small open) economy with heterogeneous agents, as in Iacoviello (2005) or Iacoviello and Minetti (2002).

standards. Specifically, we analyze the impact of an exogenous drop in the correlation of the LTV ratio with the cycle. We interpret such an exogenous change in the cyclical pattern of the leverage ratio as a policy measure, i.e. the introduction of a countercyclical element in banking prudential regulation. We do not intend here to explore how such a policy could be implemented nor which would be the optimal way to do it. Rather, we try to provide a first gauge of the eventual gains in terms of macroeconomic volatility thanks to the implementation of such a policy. We believe that quantifying these gains constitutes a valuable input for deciding whether or not to engage in the greater effort of exploring feasible regulatory alternatives.

The structure of the paper is as follows. Section II presents the empirical evidence on the procyclicality of firms' leverage and its relationship with economic growth and macroeconomic volatility. Section III develops the theoretical model whose calibration is provided in section IV. This model is used for policy experiments, the results of which are discussed in section V. Section VI performs sensitivity analysis of the outcomes to different model specifications, while section VII draws conclusions.

II. EMPIRICAL EVIDENCE

Several studies have been looking into the behavior of banks' capital buffers and lending standards, in order to explain their relationship with the aggregate fluctuations. There seems to be conclusive evidence that credit conditions not only vary over the cycle but also behave procyclically. This may happen for a number of different reasons, as stressed, for instance, by Borio and others (2001) and Dell'Ariccia and Marquez (2006).[8]

Ayuso and others (2004), for example, estimate the relationship between the Spanish business cycle and capital buffers held by Spanish banks, using data from 1986 to 2000. They argue that the procyclicality of capital buffers is due to factors which are beyond the inherent features of risk-sensitive bank capital regulation, such as Basel II.[9] How about banks' lending standards? By looking at the contract terms of loans granted by 483 US banks from 1977 to 1993, Asea and Blomberg (1998), for instance, suggest 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. Changes in lending standards are also found to have the greatest impact during expansions, when banks tend to lend to riskier borrowers.[10] More recently, Mendoza and Terrones (2008) have examined the dynamics of both macro aggregates

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[8]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. In equilibrium, this reduction in standards leads to a deterioration of banks' portfolios, a reduction in their profits, and an aggregate credit expansion, while increasing the risk of financial instability.

[9]Ayuso and others (2004) focus their attention on voluntary capital buffers, as most of the banks in their sample appear to hold capital well beyond the level required by regulators. After controlling for other determinants of the surplus capital—which could themselves behave procyclically—they find a significant negative relationship between business cycle and capital buffers.

[10]Asea and Blomberg (1998) explore the relationship between changes in bank lending standards and the economic cycle using a Markov-switching panel data model. As opposed to other empirical works, the focus is not exclusively on extreme periods of financial distress but on lending standard cycles due to normal bank activity.

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.

In this section, we contribute to this literature by focussing on the behavior of firms' leverage in 16 advanced and 12 emerging European economies over the period from January 1999 until April 2008, using the ratio between private credit to the corporate sector and the value of equities.[11] A first glance at the data seems to confirm that firms' leverage is not constant over time: indeed, in selected European countries, it varies substantially over the sample period (Figure 1 and Table 1). To examine more closely the dynamic relationship between corporate financial conditions and real activity and to unveil divergences in the strength and in the timing of macrofinancial linkages across Europe, financial conditions indices (henceforth, FCIs) have been constructed by means of country-specific vector autoregression models and corresponding impulse response functions. Specifically, impulse responses from relevant financial variables are combined with estimates of the shocks to each of these variables to calculate the total impulse to growth in a given month. For each economy, the estimated FCI contains statistically significant effects on GDP growth from shocks to domestic (real) credit growth, (real) equity price changes, and real interest rates.[12] National FCIs are meant to account for the timing of transmission from financial markets to real activity and to incorporate the endogenous response of financial variables to the business cycle, as well as to each other. Allowing for these dynamic interrelations is important when attempting to disentangle the impact of multiple variables that are highly correlated.[13]

Do increases in firms' leverage contribute to a nation's economic growth? In which economies is this contribution more relevant? Overall changes in financial conditions are estimated to account for a large portion of the variation in real GDP growth over the business cycle of almost all European countries in the sample, although with substantial cross-country heterogeneity (Figure 2). Among the advanced economies, innovations to firms' borrowing are found to have contributed substantially to fluctuations in annual growth in Austria (40 percent), Sweden (25 percent), and, to a lesser extent, the United Kingdom and Greece (10 percent). Among emerging economies, financial conditions play—overall—a much greater role. They account for over 70 percent of growth

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[11]Ideally, an aggregate measure of firms' leverage should relate the amount of firms' reliance on bank lending to the value of equities for the same sample of firms. This is not the case in our empirical measure of country-level firms' leverage, which is constructed using data from national central banks for credit to the corporate sector and data from the Bloomberg dataset for the value of market capitalization. However, a comparison of our leverage indicator and one derived from Moody's firm-specific dataset—spanning a shorter time period and covering a smaller number of European economies—features similar levels and time profiles.

[12]Monthly data for credit growth in the corporate sector have been provided by national central banks; equity prices are taken from Bloomberg, while 3-month interbank interest rates and consumer price indices have been collected from the IMF International Financial Statistics. Quarterly data on GDP growth have been exponentially interpolated to derive corresponding series with monthly frequency.

[13]The construction of FCIs follows closely the methodology developed in Swiston (2008) and is detailed for convenience in the appendix.

variation in Hungary, Russia, Latvia, and Estonia, underscoring, once again, the vulnerability of these economies corporate sector to downswings in financing conditions. Given the relatively lower level of development of these financial markets, it is not surprising that these contributions are mostly due to changes in bank lending conditions.

Possibly more importantly, our empirical analysis shows that—on average—an increase in firms' leverage provides a greater contribution to growth in periods of economic expansion. In other words, according to our estimates, the impact on growth of innovations to firms' leverage tends to be procyclical, although with important differences on a country-by-country basis (Figure 3). Building on this evidence, other interesting empirical regularities can be identified. First, 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 (Figure 4). Second, a higher degree of procyclicality in firms' leverage seems to be associated with higher volatility in private investment (Figure 5). Remarkably, oversensitivity of credit availability to asset price changes, greater procyclicality in firms' leverage, and higher investment volatility appear to be characterizing mostly those economies—like the Baltic countries—where bank lending conditions are also found to play the greatest role in explaining growth fluctuations.

III. THE MODEL

In order (i) to better understand these empirical regularities and (ii) to assess quantitatively the impact of reducing the degree of procyclicality in lending conditions, we develop a stylized two-country (Home and Foreign), two-good model with incomplete financial markets. The only financial asset in the model is a non-contingent bond. A financial friction à la Kiyotaki and Moore (1997) is also assumed, so that borrowing is limited to a given fraction of the value of the collateral. The asset used as collateral in this economy is equity. The model is calibrated such that the Home economy is a net borrower and the Foreign economy a net lender. Home agents are assumed to be more impatient than Foreign agents.[14]

A. HOME ECONOMY

Households and preferences

The economy is populated by identical, infinitely-lived Households with preferences described by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[U\left(c_t, (1-h_t)\right) \right] , \qquad (1)$$

$$U\left(c_t, h_t\right) = \frac{c_t^{1-\sigma}}{1-\sigma} - \nu \frac{h_t^{1+\psi}}{1+\psi} , \quad \text{when} \quad \sigma > 0, \sigma \neq 1 ,$$

$$U\left(c_t, h_t\right) = \ln(c_t) - \nu \frac{h_t^{1+\psi}}{1+\psi} , \quad \text{when} \quad \sigma = 1 ,$$

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[14]On this issue, see also Ghironi, Iscan and Rebucci (2005).

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where h_t denotes the fraction of the time endowment devoted to work. c_t is Households' consumption of a composite good indexed by:

$$c_t \equiv \left[\gamma^{\frac{1}{\eta}} (c_t^H)^{\frac{\eta-1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}} (c_t^F)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{2}$$

where c_H and c_F denote the domestic and foreign goods respectively. Optimality conditions imply the following Home demand of domestically- and foreign-produced goods:

$$c_t^H = \gamma \left(\frac{P_t^H}{P_t} \right)^{-\eta} c_t \quad ; \quad c_t^F = (1-\gamma) \left(\frac{P_t^F}{P_t} \right)^{-\eta} c_t, \tag{3}$$

implying that

$$\frac{c_t^H}{c_t^F} = \frac{\gamma}{1-\gamma} \left(\frac{P_t^H}{P_t^F} \right)^{-\eta} \tag{4}$$

$$P_t = \left[\gamma (P_t^H)^{1-\eta} + (1-\gamma)(P_t^F)^{1-\eta} \right]^{\frac{1}{1-\eta}}, \tag{5}$$

where (5) is the utility-based aggregate price index in the Home economy. We set the composite good in (2) as the numéraire good and we normalize its price to one: $P_t = 1$.

Households supply labor and invest in domestic equity (capital). They receive labor payments and dividends from their equity holdings, make consumption decisions, and lend or borrow in a one-period non-contingent zero-coupon internationally-traded bond. The Households' budget constraint at period t is given by:

$$c_t + p_t^H q_t (k_{t+1} - k_t) + d_t + \frac{\omega}{2}(d_{t+1} - \bar{d})^2 = \frac{d_{t+1}}{R_t} + p_t^H w_t h_t + p_t^H r_t k_t, \tag{6}$$

where d_{t+1} is the amount of debt issued at t paying back d_{t+1} units of the Home consumption composite at period $t + 1$, R_t is the -gross- real interest rate, and p_t^H is the relative price of the domestically-produced good in terms of the consumption index ($p_t^H = \frac{P_t^H}{P_t} = P_t^H$ since $P_t = 1$). As the real wage (w_t), the dividend rate on equity holdings (r_t), and the market price of equity (q_t) are valued in terms of the domestically-produced good (y_t), they all appear multiplied by p_t^H in the budget constraint, in order to express them in terms of the consumption index. The last term on the left-hand side is the adjustment cost on debt holding, with $\bar{d}$ denoting the steady-state level of debt.[15].

Financial frictions. The world credit market is assumed to be imperfect: Households need to guarantee their debt by offering domestic assets as collateral. Since the seminal contribution of Kiyotaki and Moore (1997), endogenous credit constraints have been widely used to analyze a number of different issues in business cycle models. For example, in a close economy setting, Aiyagari and Gertler (1999) build a variant of Lucas' (1978) asset pricing model and use a collateral constraint to explain the overreaction of asset prices to shocks to fundamentals. Iacoviello

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[15]Given that markets are incomplete, the law of motion for bonds is nonstationary. We hence introduced a quadratic cost on debt adjustment to make it stationary, without affecting the final solution (Schmitt-Grohé and Uribe (2003))

(2005) and Iacoviello and Neri (2008) analyze the transmission and amplification of monetary policy, asset prices and technology shocks. Calza and others (2007) study the role of institutional aspects of credit markets in affecting the transmission of monetary policy shocks. Mendoza and Smith (2006) and Mendoza (2006) extend the role of the collateral constraint in Aiyagari and Gertler (1999) to a small open economy setup to analyze its ability to trigger sudden stops in emerging economies. Also in a small open economy setup, Iacoviello and Minetti (2002) study how the transmission of monetary policy shocks to house prices is affected by the degree of financial liberalization. In a two-country model with collateralized borrowing in domestic and international capital markets, Iacoviello and Minetti (2006) examine the impact of financial constraints in the international transmission of business cycles. Callegari (2007) also uses a two-country model, even though in this case the collateral constraint applies to domestic debt in each country and the focus is on the international transmission of fiscal shocks.

In our model the collateral constraint takes the form of the margin requirement proposed by Aiyagari and Gertler (1999) and used in Mendoza (2006)[16]. Similar to the latter, Households use domestic equity as collateral for their debt.[17] Specifically, the borrowing constraint is given by:

$$d_{t+1} \leq \varphi_t p_t^H q_t k_{t+1}. \tag{7}$$

The borrowing limit is here expressed as an ex-ante collateral constraint: the maximum amount that can be borrowed is a fraction φ_t of the market value of the capital stock owned by Households.[18] While a specification like (7) makes the constraint resemble a debt contract with a margin clause, there are several other financial arrangements that operate in a similar fashion, without explicitly allowing for margin clauses. These include the use of value-at-risk models by investment banks to set collateral or capital requirements, or simply the capital requirements imposed to financial institutions by regulatory agencies (Mendoza (2006)).

The leverage ratio is typically introduced in the literature as an invariant structural parameter of the model. In our model, instead, the LTV ratio is allowed to vary over time. In particular, we assume that φ_t is a stochastic variable and that its evolution reflects changes in lending standards.

Optimality conditions.   Given initial values of debt and capital d_0 and k_0, the Households' problem is to choose sequences $\{c_t^H, c_t^F, h_t, k_{t+1}, d_{t+1}\}$, taking $w_t, r_t, q_t, p_t^H, p_t^F, \varphi_t$ and R_t as given, in order to maximize (1), subject to equations (6) and (7). Letting λ_t and $\lambda_t \chi_t$ be the multipliers on those constraints and $U_{i,t}$ the marginal utility of variable i at time t, the efficiency conditions for the Households' problem in the Home economy are:

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[16]We do not derive here the constraint from an optimal contract but we impose it directly, as in the models with endogenous borrowing constraints by Kiyotaki and Moore (1997), Aiyagari and Gertler (1999), Iacoviello (2005) and Mendoza (2006). This constraint could result, for example, from an environment of limited enforcement.

[17]Most of the studies using endogenous credit constraints employ housing or real estate as collateral, while in this model we use equity. This is in line with the works by Aiyagari and Gertler (1999), Mendoza and Smith (2006), and Mendoza (2006). Iacoviello and Minetti (2006) also use capital as collateral in one version of their model but, as its price is fixed, the transmission mechanism is still driven by real estate as collateral.

[18]An ex-post collateral constraint, as in Kiyotaki and Moore (1997), would instead imply that debt cannot exceed the expected discounted one-period-ahead liquidation value of the collateral.

$$U_{c,t} = \lambda_t \tag{8}$$

$$-\frac{U_{h,t}}{U_{c,t}} = p_t^H w_t \tag{9}$$

$$\frac{1}{R_t} = \chi_t + E_t \beta \left[\frac{U_{c,t+1}}{U_{c,t}} \right] + \omega(d_{t+1} - \bar{d}) \tag{10}$$

$$q_t = E_t \left[\beta \frac{U_{c,t+1}}{U_{c,t}(1 - \varphi_t \chi_t)} \frac{p_{t+1}^H}{p_t^H} \right] [q_{t+1} + r_{t+1}]. \tag{11}$$

If the borrowing constraint were not binding, χ_t would be zero and equation (10) would be a standard Euler equation for debt. However, we assume that agents in the Home economy are more impatient than agents in the Foreign economy and therefore (7) is always binding. Indeed, given the assumptions on the discount factors β and β^*, in a deterministic steady state χ is strictly greater than zero and, hence, (7) 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 the Home and Foreign discount factors and the variance of the shocks hitting the economy. In this paper, as in Iacoviello (2005) and Iacoviello and Neri (2008) among others, we keep the variability of shocks "small enough" relative to the degree of impatience and solve the model by linearizing around the steady state with a binding collateral constraint. Note that this implies, from equation (10), that Households in the Home economy always face an endogenous external financing premium on the effective (i.e. shadow) real interest rate at which they borrow: $\frac{R_t}{1-\chi_t R_t} > R_t$. The higher effective interest rate reflects the fact that, at the prevailing market interest rate R_t, agents in the Home economy would like to borrow more than they are actually allowed to.

By denoting the Households' stochastic discount factor in equation (11) as $\widetilde{\beta}_t$ and solving that equation forward, we obtain a standard asset pricing condition for equity:

$$q_t = E_t \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \widetilde{\beta}_{t+i} \right) r_{t+1+j}, \tag{12}$$

where the actual valuation of equity by Households corresponds to the expected discounted flow of future dividend payments.[19]

Firms and technology

Every period firms produce y_t of an international tradable good through a constant returns to scale technology combining capital and labor:

$$y_t = A_t k_t^\alpha h_t^{1-\alpha}, \tag{13}$$

where A_t is the stochastic country specific level of total factor productivity (TFP hereafter). Firms make plans for labor demand and investment and, since they are owned by Households, they discount future profits taking as given $\widetilde{\beta}_t$. The representative firm's problem is to choose labor demand

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[19]Note, however, that here $\widetilde{\beta}_t$ includes both the multiplier χ_t and the LTV ratio φ_t, none of which would appear in a frictionless model.

and investment in order to maximize its value:

$$E_0 \sum_{t=0}^{\infty} \left(\prod_{i=0}^{t} \widetilde{\beta}_{i-1} \right) \left(y_t - w_t h_t - \delta k_t - x_t \left[1 + \Phi \left(\frac{x_t}{k_t} \right) \right] \right),$$ (14)

with $\widetilde{\beta}_{-1} = 1$ and subject to the law of motion for capital (net investment):

$$x_t = k_{t+1} - k_t.$$ (15)

The presence of function $\Phi(.)$ implies that investment expenditure needs to cover for a capital adjustment cost. This cost is usually included to avoid counterfactual volatility of investment. The functional form for this cost is assumed to be $\Phi \left(\frac{x_t}{k_t} \right) = \frac{\phi}{2} \left(\frac{x_t}{k_t} \right)$, as in Mendoza (2006).

Letting Q_t be the multiplier on constraint (15), the first-order conditions for this problem are:

$$(1 - \alpha) \frac{y_t}{h_t} = w_t,$$ (16)

$$Q_t = 1 + \Phi \left(\frac{x_t}{k_t} \right) + \Phi' \left(\frac{x_t}{k_t} \right) \frac{x_t}{k_t},$$ (17)

$$Q_t = E_t \widetilde{\beta}_t \left[Q_{t+1} + R_{t+1}^k \right],$$ (18)

$$\text{where} \quad R_{t+1}^k = \alpha \frac{y_{t+1}}{k_{t+1}} - \delta + \Phi' \left(\frac{x_{t+1}}{k_{t+1}} \right) \left(\frac{x_{t+1}}{k_{t+1}} \right)^2.$$

Equation (17), the first order condition with respect to x_t, determines the firm's demand for investment or, equivalently, its equity supply function. Equation (18) is the firm's optimality condition with respect to k_{t+1}. Solving it forward yields:

$$Q_t = E_t \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \widetilde{\beta}_{t+i} \right) R_{t+1+j}^k.$$ (19)

In equilibrium, the equity market clears: equity price adjusts such that Households' and Firms' investment plans are consistent with each other. Indeed, from equations (12) and (19), this implies that $q_t = Q_t$ and $r_t = R_t^k$ for asset prices to be consistent with Households' demand and Firms' supply of equity.

The role of equity

To understand the role of equity and its price in shaping equilibrium dynamics, it is useful to derive an expression for the equity premium in the Home economy and explore how it is affected by the fact that such an economy is financially constrained. The return on equity in units of the domestic consumption index is defined as $R_{t+1}^q \equiv \frac{p_{t+1}^H}{p_t^H} \left(\frac{r_{t+1} + q_{t+1}}{q_t} \right)$. Using the Euler equations for bonds and equity (10) and (11) we can retrieve the equity premium, e.g. the excess return on equity

relative to the real interest rate on international debt.[20]

$$E_t(R^q_{t+1}) - R_t = \frac{-cov(\beta \frac{U_{c,t+1}}{U_{c,t}}, R^q_{t+1})}{E_t \beta \frac{U_{c,t+1}}{U_{c,t}}} + \frac{1 - \varphi_t \chi_t}{E_t \beta \frac{U_{c,t+1}}{U_{c,t}}} - \frac{1}{E_t \beta \frac{U_{c,t+1}}{U_{c,t}} + \chi_t}. \tag{20}$$

Equation (20) can be rewritten as:

$$E_t(R^q_{t+1}) - R_t = \frac{-cov(\beta \frac{U_{c,t+1}}{U_{c,t}}, R^q_{t+1})}{E_t \beta \frac{U_{c,t+1}}{U_{c,t}}} + \frac{\chi_t(R_t - \varphi_t)}{E_t \beta \frac{U_{c,t+1}}{U_{c,t}}}, \tag{21}$$

making it clear that if the collateral constraint is binding ($\chi_t > 0$), then there is a positive *wedge* between the economy equity premium and the "fundamental" one—that is, the one that would prevail in a frictionless environment.[21] Indeed, if the collateral constraint is not binding ($\chi_t = 0$), then the equity premium reduces to $\frac{-cov(\beta \frac{U_{c,t+1}}{U_{c,t}}, R^q_{t+1})}{E_t \beta \frac{U_{c,t+1}}{U_{c,t}}}$, which is the standard excess return corresponding to a frictionless asset-pricing model (the "fundamental" risk premium). Given the definition on return on equity, equation (20) also shows how the equity premium (and the mentioned wedge) affects the equity price. Taking expectations on the return on equity, it yields:

$$E_t(R^q_{t+1}) = E_t \left[\left(\frac{r_{t+1} + q_{t+1}}{q_t} \right) \left(\frac{p^H_{t+1}}{p^H_t} \right) \right].$$

Solving for q_t and iterating forward, this implies:

$$q_t = E_t \sum_{j=0}^{\infty} \left(\prod_{i=0}^{j} \frac{1}{E_t(R^q_{t+1+i})} \right) \frac{p^H_{t+1+j}}{p^H_t} r_{t+1+j},$$

where the sequence $\{E_t(R^q_{t+1+j})\}_{j=0}^{\infty}$ is given by (20). It should thus be clear that an increase of the equity premium 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 equity at period t.

The behavior of the equity premium (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. In turn, as Aiyagari and Gertler (1999) and Mendoza (2006) point out, the behavior of the equity premium is affected both directly and indirectly by the presence of financial market frictions. Indeed, 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 (21). For a given value of the LTV ratio, a tighter borrowing constraint (χ) in period t—originated for example by a drop in productivity that lowers equity prices—would reinforce such a drop, by pushing up the equity premium (e.g. by pushing down the current price of equity).

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[20]To simplify the algebra, in what follows we neglect the terms related to the portfolio adjustment cost (i.e. $\omega = 0$). In any case, those terms are negligible.

[21]Note that the gross real interest rate is always larger than the LTV ratio.

Indirectly, the probability that the constraint will be binding in the future is captured by the covariance expression in the first term of equation (21). Intuitively, the possibility of a tighter borrowing constraint in period $t+1$ is likely to reduce (i.e., make more negative) the covariance with the stochastic discount factor. 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 these effects—which are due to financial frictions—may hence amplify the volatility of the equity premium and, thereby, the volatility of equity prices.

Time-varying lending standards. Let us first consider the variability of credit conditions around the average LTV ratio ($\overline{\varphi}$). If, for example, an adverse productivity shock pushes the economic into a downturn, domestic production declines and the shadow value of relaxing the borrowing constraint on international debt (χ) increases above its long term average. This implies a rise in the equity premium (and hence a decline in the equity price), as shown by the second term of equation (21). What if lending conditions behave procyclically? In this case, during the downturn, lending standards would be tightened, meaning that less debt will be issued for the same value of collateralized assets. The drop in φ_t would increase even more the equity premium wedge, implying an even higher risk premium and an even lower equity price. Therefore, a procyclical behavior of lending standards in this model would accentuate the overreaction and volatility of asset prices, as signaled by Aiyagari and Gertler (1999). More importantly—and as shown below by numerical simulations—the increased overreaction of asset prices implied by the procyclical behavior of lending carries important costs in terms of the volatility of key macroeconomic variables.

Let us then consider the behavior of the equity premium under different average LTV ratios. A higher average value of φ in equation (21) would narrow the gap between the actual and the "fundamental" risk premium for given values of the collateral multiplier (χ). This implies that the overreaction—and thus the volatility—of equity prices caused by the financial friction would be lower in an economy that enjoys a higher leverage on average.

B. Foreign economy

To close the model, one needs to specify the behavior of the Foreign economy. Here too, Households face a borrowing constraint as in equation (7). It is assumed, nevertheless, that agents in the Home economy are more impatient than in the Foreign economy: $\beta < \beta^*$. This implies that the Foreign economy is a net creditor, so that the borrowing constraint becomes irrelevant for this economy. Accordingly, one can abstract from capital accumulation in the Foreign economy, without any loss of generality: output is here modeled as an endowment process, with Households deriving utility only from consumption.

In the Foreign economy, consumption is given by:

$$c_t^* \equiv \left[(\gamma^*)^{\frac{1}{\eta}} (c_t^{F*})^{\frac{\eta-1}{\eta}} + (1-\gamma^*)^{\frac{1}{\eta}} (c_t^{H*})^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{22}$$

and optimizing behavior implies:

$$c_t^{F*} = \frac{\gamma^*}{1-\gamma^*}\left(\frac{P_t^{F*}}{P_t^{H*}}\right)^{-\eta} \tag{23}$$

$$P_t^* = \left[\gamma^*(P_t^{F*})^{1-\eta} + (1-\gamma^*)(P_t^{H*})^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{24}$$

The budget constraint for the Households in the Foreign economy can hence be expressed in terms of the Foreign Households' consumption index (22), as follows:

$$c_t^* + \frac{d_t^*}{\zeta_t} + \frac{\omega}{2}\left(\frac{d_{t+1}^* - \bar{d}^*}{\zeta_t}\right)^2 = \frac{d_{t+1}^*}{R_t \zeta_t} + \frac{P_t^F}{P_t^*}y_t^*, \tag{25}$$

where ζ_t is the real exchange rate and y_t^* is a random endowment process. Given the budget constraint (25), the optimality conditions for the Households' problem in the Foreign economy are:

$$U_{c^*,t} = \lambda_t^* \tag{26}$$

$$\frac{1}{R_t} = E_t \beta^* \left[\frac{U_{c^*,t+1}}{U_{c^*,t}}\frac{\zeta_t}{\zeta_{t+1}}\right] + \omega\left(\frac{d_{t+1}^* - \bar{d}^*}{\zeta_t}\right). \tag{27}$$

As a result, the trade balance in the Home economy (expressed as a ratio to GDP) is given by:

$$\left(\frac{nx}{y}\right)_t = \frac{y_t - c_t/p_t^H - \left(k_{t+1} - (1-\delta)k_t + \Phi\left(\frac{x_t}{k_t}\right)x_t\right)}{y_t}, \tag{28}$$

whereas the corresponding current account balance (expressed as a ratio to GDP) is denoted as:

$$\left(\frac{ca}{y}\right)_t = \left(\frac{nx}{y}\right)_t - \frac{d_{t+1}\left(\frac{R_t-1}{R_t}\right)}{y_t}. \tag{29}$$

Under the abovementioned simplifying assumptions, the net foreign asset position of the Home economy at period t is simply equal to $-d_t$, while the real exchange rate is given by $\zeta_t = P_t^*$.[22] Accordingly, the terms of trade are defined as $TOT_t = \frac{P_t^F}{P_t^H}$.

C. Shocks

Two sources of shocks are considered in this paper: technological and financial shocks.

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[22]Since the law of one price holds and we abstract from nominal issues—assuming that the nominal exchange rate is identically equal to one—then $P_t^{H*} = P_t^H$. In the absence of a home bias ($\gamma = \gamma^* = 0.5$), this would imply that purchasing power parity holds and that the price of the consumption index is the same in both economies. Under this peculiar condition, the real exchange rate would also be constant and equal to one. In the presence of a home bias, the real exchange rate is given by the price of the Foreign consumption index ($\zeta_t = P_t^*$), as the Home consumption index is set as the numéraire (and its price is equal to 1).

Productivity shocks. The two stochastic processes that govern productivity are A_t in the Home economy and y_t^* in the Foreign economy. We assume that productivity follows a first-order bivariate autoregressive process:

$$\begin{pmatrix} ln(A_t) - ln(\overline{A}) \\ ln(y_t^*) - ln(\overline{y^*}) \end{pmatrix} = \begin{pmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{pmatrix} \begin{pmatrix} ln(A_{t-1}) - ln(\overline{A}) \\ ln(y_{t-1}^*) - ln(\overline{y^*}) \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ , \end{pmatrix} \tag{30}$$

where the vector of shocks $\varepsilon_t = (\varepsilon_{1,t}, \varepsilon_{2,t})'$ follows a bivariate normal distribution with zero mean and contemporaneous variance-covariance matrix V. The technology shocks in both economies are thus stochastically related by the spillover parameters B_{12} and B_{21} and by the off-diagonal elements of the covariance matrix V.

Credit shocks. As the main purpose of the model is to assess quantitatively the impact of changing the cyclical pattern of lending standards on the volatility of key macroeconomic aggregates, we allow the LTV ratio—a proxy for the lending conditions in the economy—to vary over time. In this way, a reduction in the LTV (φ_t) is interpreted as a downswing in the credit cycle—that is, a tightening in lending standards.

The LTV ratio is assumed to follow a stochastic autoregressive process of order one, namely:

$$ln(\varphi_t) = (1 - \rho_\varphi)ln(\bar{\varphi}) + \rho_\varphi ln(\varphi_{t-1}) + \varepsilon_t^\varphi, \quad \varepsilon_t^\varphi \sim \text{iid } N(0, \sigma_\varphi^2), \tag{31}$$

where $\bar{\varphi}$ is the steady-state LTV. A higher $\bar{\varphi}$ corresponds to an economy that is less financially constrained, on average.

Regarding the link of lending standards with the business cycle, we consider different cyclical patterns, by assuming a non-zero correlation between shocks to the LTV ratio and shocks to domestic productivity.

D. EQUILIBRIUM AND SOLUTION METHOD

We assume that the Home economy is populated by a continuum of agents of unit mass while the Foreign economy is populated by a continuum of mass N. If $N = 1$, the model is a symmetric two-country model, while for $N \to \infty$ and $\gamma^* \to 1$ the Home economy becomes a small open economy.

Market clearing conditions. The Home-produced and Foreign- produced goods market clearing conditions are:

$$y_t = c_t^H + Nc_t^{H*} + k_{t+1} - (1-\delta)k_t + \Phi\left(\frac{x_t}{k_t}\right)x_t \tag{32}$$

$$Ny_t^* = Nc_t^{F*} + c_t^F \tag{33}$$

The market clearing condition for the world credit market is:

$$d_t + Nd_t^* = 0 \tag{34}$$

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Given the assumptions on the discount factors and the financial friction, in the absence of shocks the model has a unique stationary equilibrium in which the borrowing constraint is always binding in the Home economy. The equilibrium is a sequence of allocations $\{c_t^H, c_t^F, c_t^{H*}, c_t^{F*}, d_{t+1}, d_{t+1}^*, k_{t+1}, h_t\}$ and values
$\{q_t, r_t, w_t, p_t^H, p_t^F, P_t^*, \chi_t, R_t\}$ satisfying equations (2), (4) to (11)—with equation (7) holding with equality—(13), (15) to (18), (22) to (25) and (32) to (34), given equations (31) to (30), k_0, d_0 and together with the relevant transversality conditions.

Numerical solution technique. As explained above, the collateral constraint is assumed to be always binding in this model. 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 (2008), and Calza and others (2007). Accordingly—and as it is indeed the case in all the abovementioned studies—the model is solved by log-linearizing the equations characterizing the equilibrium around the deterministic steady-state and by solving the resulting system of linear difference equations to obtain the policy functions.[23]

IV. CALIBRATION

To calibrate the model, we use standard values in the literature and— where pertinent—post-1999 data from Estonia and Sweden proxying for the Home and Foreign economy, respectively. This choice is due to the fact that some features of these two economies seem to constitute good empirical counterparts for a representative-agent two-country model—that is, the theoretical framework adopted in this paper. First, Estonia is—on aggregate—a net borrower and relies heavily on foreign bank credit (see Figure 6); on the contrary, Sweden is—on aggregate—a net creditor. Second, Estonia faces a highly concentrated pool of foreign lenders, with Sweden accounting for more than 90 percent of outstanding claims (see Figure 7). Modeling each economy by means of a two-country, representative-agent model seems, therefore, to be a reasonable stylization of reality. It is, nonetheless, important to stress that we simply use data from these two economies for calibration purposes: we have no intention to use the model to replicate Estonian corporate borrowing and asset price dynamics over recent years.

Preferences, technology and productivity shocks. A summary of the parameter values used for calibration is shown in Table 2. Specifically, the discount factor in the "patient" economy, β^*, is set to 0.99, while $\beta = 0.96$, in line with the values used in the literature. These values imply an equity premium in the deterministic steady state of 7.6 percent when the $LTV = 40$ percent and 3.9 percent when the $LTV = 70$ percent, which are reasonable values. The coefficient of risk aversion σ is set to 1 in the benchmark calibration (i.e. logarithmic utility in consumption). Nevertheless, alternative values are used for sensitivity analysis. The inverse of the (Frisch) wage elasticity of labor supply (ψ) is set to 3, which gives an elasticity of $1/3$, well in the range suggested by

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[23]Note that if the focus were on the effect of occasionally-binding constraints, as it is the case in Mendoza (2006), 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.

evidence from micro-data (0.05 to 0.5). However, as the business cycle literature typically uses values of elasticity of unity and even higher, alternative parameterizations are assumed for sensitivity analysis (see section VI). [24] We set ν in order to match an average time spent working of 33 percent of total time in steady state. The elasticity of substitution between domestic and foreign goods η is set equal to 1.5 in the benchmark calibration (as in Backus, Kehoe and Kydland (1992); common values in the literature range from 0.5 to 2.5). The shares of domestic goods in the consumption index for each economy—denoted as γ and γ^*, respectively—are set to 57.5 percent.[25] The portfolio-adjusting cost parameter (ω) is set equal to 0.00074, as in Schmitt-Grohé and Uribe (2003).[26] In the benchmark model $N = 1$, meaning the two economies are of equal size.

The capital share in y_t, α, has been set to 0.30. Capital depreciation rate δ is set to 2.5 percent per quarter, a standard value in the literature. The capital adjustment cost parameter ϕ is set to 10 in order to obtain a plausible level of investment volatility under the benchmark calibration.

The Home TFP autoregressive parameter B_{11} is set to 0.94 and the Foreign endowment autoregressive coefficient B_{22} to 0.97. The spillover parameters B_{12} and B_{21} are set to zero in the benchmark calibration, while in section VI positive spillovers are considered, in line with Backus, Kehoe and Kydland (1992) and Heathcote and Perri (2002). The standard deviation of TFP shocks (σ_{ε_1}) is set to 2.2 percent, which gives a volatility of Home GDP close to 2.8 percent, roughly in line with evidence from Estonia. σ_{ε_2} is set to 1.14 percent, broadly in line with Swedish data. Finally, the correlation between Home and Foreign technology shocks ($\rho_{(\varepsilon_1,\varepsilon_2)}$) is set to 0.04, implying a quite low degree of technology interdependence between the two economies.

The loan-to-value ratio. In all cited studies using endogenous collateral constraints the LTV ratio is introduced as a time-invariant structural parameter. In particular, among the papers using housing as collateral, LTV ratios are in the order of 80-90 percent, although in some cases values of 50 percent are also considered.[27] In a model using equity as collateral—although within an "occasionally-binding constraint" setting—Mendoza (2006) assumes LTV ratios of 13.9 percent for firms' debt and 24.8 percent for households' debt. In our benchmark calibration, the LTV ratio is assumed to be a stochastic variable, whose unconditional mean ($\bar{\varphi}$) is set to 40 percent, which is somehow within the two extremes.

The benchmark parameterization for the stochastic process driving the LTV ratio implies $\rho_\varphi = 0.9$ and $\sigma_\varphi = 1.85$ percent. In Table 1, we show the results of fitting an AR(1) model to demeaned LTV ratios from a sub-sample of emerging European economies. Remarkably, the calibrated autoregressive parameter (ρ_φ) is within the range of estimates, whereas the shocks' standard error (σ_φ) is clearly on the conservative side.

We also consider alternative non-zero degrees of correlation between the shock to the LTV and

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[24]See discussion in Galí, Gertler and López-Salido (2007).

[25]We consider alternative values in section VI.

[26]This parameter is set to 0.01 in Callegari (2007) and estimated to be 0.00042 in Uribe and Yue (2006).

[27]Calza and others (2007) consider LTV ratios ranging from 50 to 90 percent to analyze the effect of different institutional characteristics of mortgage markets, 50 percent being the LTV ratio estimated for the Italian mortgage market.

the shock to the Home TFP ($\rho_{LTV,A}$), in order to proxy for different cyclical patterns in lending standards, some of them associated with active prudential regulation policies. In the benchmark calibration, we set this correlation equal to 0.5, in line with the empirical evidence for the Baltics, as shown in Figure 3.

V. POLICY EXPERIMENT: ALTERING THE CYCLICAL PATTERN OF LENDING STANDARDS

The model presented in the previous sections is used to assess the impact of introducing a (generic and unspecified) policy measure aimed at reducing procyclicality in lending standards. In particular, we try to assess its impact on the cyclical properties of the key macroeconomic variables of the model economy.

In our benchmark specification, lending standards behave procyclically: during an economic upturn, borrowing constraints are relaxed more that proportionally. This means that credit grows by more than the (cyclical) increase in the market value of collateralized assets, leading to a credit "boom".[28] Viceversa, during an economic downturn, credit contracts are tightened by more than the reduction in the value of the collateralized assets, causing a credit "squeeze". This regularity is consistent with findings on bank capital buffers' behavior in Europe.[29]

We thus simulate 500 replications of our model economy under the benchmark parameterization, each of them 150 periods long, while dropping the first 50 periods to avoid starting value bias. The time unit in the model is set to be one quarter. We filter the resulting time series using the Hodrick-Prescott filter and compute the corresponding average moments across simulations. The impulse responses to a negative (one standard deviation) shock to productivity and lending standards—plotted, respectively, in Figures 8 and 9—provide important intuitions behind the behavior of the model economy under the benchmark calibration, allowing for alternative leverage levels. We then repeat the simulation process for two different levels of leverage (i.e., two different average LTV ratios), assuming zero ex-ante correlation of lending conditions with the cycle. Figure 10 summarizes the policy simulation's results for different combinations of LTV ratios (ranging from 0.3 to 0.7) and different degrees of correlation between lending standards and productivity (considering correlations within the range of 0.6 to -.03). In this figure we highlight the impact of our hypothetical policy on the volatilities of equity prices, gross investment over GDP, consumption over GDP, and the current-account-to-GDP ratio.[30]

A. BENCHMARK LEVERAGE LEVEL

Table 3 presents the main statistics corresponding to the Benchmark calibration, where credit conditions are procyclical (the correlation between innovations to the LTV ratio and productivity, $\rho_{LTV,A}$, is assumed to be 0.5). Note, first, that using this parameterization we obtain a volatility

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[28]Here, we refer to collateral value in a broad sense: it can be the value of an explicit collateral asset, put up by Firms or Households at the moment of contracting debt, or an implicit collateral—that is, the lenders' assessment of the present value of the project to be financed.

[29]See, for instance, Jokipii and Milne (2006) and Ayuso and others (2004).

[30]Consumption is deflated by the GDP deflator to construct this ratio; that is, $\frac{c/p^H}{y}$ is considered.

of consumption σ_{c/p^H} (deflated with the GDP deflator p^H) slightly bigger than the one of GDP (a relative volatility of consumption above one is found to be a characteristic of emerging economies business cycles). Foreign debt is very volatile and highly correlated with the price of equity in the Home economy ($\rho_{d,q} = 0.77$), and hence highly procyclical. Accordingly, the current account is found to be negatively correlated with the price of equity ($\rho_{ca/y,q} = -0.32$) and highly volatile.

We then replicate the simulations assuming the introduction of the abovementioned policy measure. While the LTV ratio is still assumed to fluctuate around the same long-run average, the innovations to the LTV ratio are now regarded as fully independent of those to domestic TFP ($\rho_{LTV,A} = 0$). The results are reported in Table 4.

Moving from a procyclical to an acyclical pattern of credit conditions reduces significantly the volatility of equity prices and, consequently, the volatility of investment: σ_q and σ_x are 3.5 percent and 3.6 percent lower than in the benchmark scenario.[31] Because of the role of equity as a collateral, the volatility of debt and current account are also strongly reduced: the reduction in these volatilities is as high as 14 percent. Gains from this policy are also substantial in terms of consumption volatility (σ_{c/p^H} decreases by 1.7 percent), especially in terms of its share of domestic GDP ($\sigma_{(c/p^H)/y}$ decreases 13.5 percent). The volatility of GDP gets also reduced, though mildly. The correlation of equity prices with foreign debt and with the real interest rate decreases after the introduction of the policy measure, resulting in a lower correlation of equity prices with the current account deficit ($\rho_{ca/y,q}$ decreases by about one third).

The mechanism driving this reduction in volatility is linked to the behavior of the wedge between the actual and the "fundamental" equity premium illustrated in section III. This wedge exists because the economy is financially constrained and its behavior is endogenous to the model. A procyclical behavior of the LTV ratio would further magnify such a mechanism, implying a higher volatility of both the equity premium and the equity price. In this sense, introducing a policy measure that reduces the procyclicality of the credit conditions allows to reduce the volatility of macroeconomic aggregates—mainly by smoothing the "overreaction" of equity prices to shocks to fundamentals.

B. ALTERNATIVE LEVERAGE LEVELS

In this section we analyze how the behavior of the artificial economy changes when we consider a less financially constrained setting, i.e. a higher average LTV ratio. Again, we simulate both a benchmark scenario—with procyclical credit conditions—and an active policy scenario.

Before considering the effects of introducing the policy measure, it is worth analyzing the behavior of a higher leveraged economy under the original assumption of procyclical lending standards. As it can be seen from Table 5, a more leveraged economy would be characterized by a lower volatility of equity prices, investment, real interest rate and foreign debt, but by a higher volatility of consumption, both in levels and as a fraction of GDP. The intuition behind this is the following.

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[31] The results we report for investment (x) correspond to gross investment ($k_{t+1} - (1-\delta)k_t$), as it is usual in the literature. Note also that the reduction of volatility of each variable is expressed as a percentage difference with respect to the volatility under the benchmark cyclicality of lending standards.

On the one hand, a higher leverage implies that a given shock to the value of the collateral now implies a higher wealth effect in the budget constraint of domestic Households, thereby inducing a higher change in spending—both on consumption and on equity accumulation. On the other hand, a higher leverage implies that the size of the wedge between the actual and the "fundamental" price of equity—and hence the size of the distortion—is lower on average. This implies a lower "over-reaction" of equity prices to shocks to fundamentals in the "higher-leverage" setting and, hence, a lower incentive to adjust equity accumulation. Indeed, following a positive shock to fundamentals, the trade-off between consuming and investing a given extra amount of borrowing is more tilted toward consumption in a "higher-leverage setting" than in a "lower-leverage setting". The magnitude of this second effect is predominant, resulting in a lower volatility of investment and a higher volatility of consumption. This is captured by the impulse responses functions of equity prices, consumption, investment and debt to a shock that moves the "fundamental" price of equity (e.g. a shock to productivity) under different values of the LTV ratio (see Figure 8). Note also that, in a higher-leverage economy, the real interest rate is more correlated to the evolution of GDP and less correlated to the evolution of equity prices. Moreover, the trade balance becomes positively correlated with equity prices, while the current account deficit becomes essentially independent from the evolution of equity prices.

Although the volatilities of the key macroeconomic variables are different in this higher-leverage context, the main qualitative effects from introducing this policy measure are essentially the same as in the lower-leverage scenario (see Table 5). In particular, lower volatility of equity prices, investment, foreign debt and consumption are achieved, the reductions being 4 percent, 4.4 percent, 11.5 percent, and 1.5 percent, respectively. Also, the correlations of equity prices with debt and with the real interest rate get reduced, with the latter becoming even negative. Finally, in a higher-leverage economy, equity prices and the current account deficit start co-moving in the opposite direction: a rise of equity prices is now associated with an improvement in the external deficit.

Comparing the relative volatility gains from the introduction of the policy measure under the two leverage scenarios seems to suggest that, when the economy is more financially constrained, there is slightly more to gain in terms of consumption and external imbalances stabilization (debt, trade balance and current account deficit); the opposite holds true for the stabilization of equity prices and investment.[32]

VI. SENSITIVITY ANALYSIS

We perform sensitivity analysis of the policy simulation results along several dimensions.[33] In particular, we test alternative values for the (Frisch) wage elasticity of labor supply $(1/\psi)$, the degree of productivity spillover across countries (B_{12} and B_{21}), the degree of home bias(γ and γ^*), and the coefficient of risk aversion (σ). Overall, the simulation results seem extremely robust, with the most relevant differences associated with the change in preferences.

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[32]Note however that the volatility gains are estimated around two different steady states when considering the two leverage scenarios.

[33]The results are shown in Table 6.

Wage elasticity of labor supply. As illustrated in section IV, the value of ψ assumed for the benchmark calibration is well in line with evidence from micro-data, but the values used in business cycle models are typically much smaller. Thus, we perform again our simulations using a lower parameter value: $\psi = 0.3$ instead of $\psi = 3$. As can be seen from Table 6, the volatility gains associated with the adoption of a policy aimed at smoothing the procyclicality of lending standards are broadly unchanged, both qualitatively and quantitatively. The reduction in volatility of investment is slightly higher, while the opposite holds for consumption (although, in terms of ratios to GDP, the volatilities are essentially unchanged). Probably the most remarkable change is associated with the bigger fall in GDP volatility implied by the policy under this alternative parameterization.

Spillovers. For the benchmark calibration we assumed zero spillovers between technology shocks to Home and Foreign economies, as well as a low value for the correlation of the innovations. However it seems reasonable that two economies that are strongly financially integrated also face important technology spillovers. In this section, we thus assume $B_{12} = B_{21} = 0.08$, which is very similar to the value used in Backus, Kehoe and Kydland (1992) and within the range 0-0.1 used in Heathcote and Perri (2002).[34] In order to keep unchanged the overall persistence of the stochastic processes, we simultaneously adjust B_{11} and B_{22} (in the same proportion), such that the largest eigenvalue is the same than in the benchmark case. The results in Table 6 show that implementing the policy in the presence of spillovers between the two economies would lead to even higher gains in terms of stabilizing investment (-4.3 percent instead of -3.6 percent), consumption (-3.3 percent vs. -1.7 percent) and GDP (-0.7 percent instead of -0.4 percent), than it would have been the case in the absence of spillovers.

Consumption home bias. A higher degree of home bias in consumption (in both economies) would imply that the policy has roughly the same gains in terms of investment volatility, but consumption volatility gains from the policy experiment would be lower. Naturally, the volatility of the real exchange rate would be higher with higher home bias (approximately four times as higher as in the benchmark calibration). Accordingly, the volatility gains from reducing it—thanks to the introduction of the policy measure—would be higher.

Preferences. The functional form for preferences and the risk aversion parameter (i.e. implying logarithmic utility in consumption) adopted in this paper are standard for models using always-binding collateral constraints (see for example Iacoviello (2005), Iacoviello and Neri (2008), Calza and others (2007) and Callegari (2007)). Nevertheless, we solve and simulate the model under the alternative assumption that $\sigma = 2$. In this case, there is a higher gain in terms of GDP stabilization, while the gains in terms of investment volatility are unchanged. The main difference originates form the behavior of consumption. With $\sigma = 2$, consumption is much less volatile than with log utility, under any degree of ciclicality of leverage. Moreover, there is no reduction in consumption volatility from implementing this policy measure: if anything, consumption deflated by p^H is even more volatile. The gains in terms of consumption-to-GDP volatility are nevertheless unchanged with respect to the benchmark calibration, and hence robust to changes in the risk aversion parameter.

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[34]These studies consider two-blocks given by US and Europe.

VII. Conclusions

While the final impact of the ongoing financial turmoil—and the consequent turnaround in the credit cycle—still remains to be assessed, the discussion on the need to introduce modifications in regulation of the financial industry has already emerged strongly in policy and academic circles. In particular, there seems to be a consensus on the pervasive effects of procyclical credit standards on amplifying business cycles. This paper provides further evidence suggesting that: (i) 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; (ii) a higher degree of procyclicality in firms' leverage tends to be associated with higher volatility in private investment; and (iii) oversensitivity of credit availability to asset price changes, greater procyclicality in firms' leverage, and higher investment volatility is likely to characterize mostly those economies—like the Baltic countries—where growth fluctuations are more vulnerable to changes in bank lending conditions.

To provide a first gauge of the potential effectiveness of policies aiming at smoothing the cyclical pattern of lending standards, a stylized two-country model economy is developed. It illustrates how the double role of equities—as collateral in the (international) lending process and as value of the capital used for production—may affect the volatility of investment, corporate debt, and the current account. The model captures the idea that observed cross-country differences in investment and current account dynamics may be consistent with the fact that lending conditions and discount factors are not symmetric across countries. This is achieved by assuming that in one of the two economies agents are credit constrained and "impatient": that is, they do not smooth consumption based on permanent income, but have preferences tilted toward current consumption. Their access to credit on international financial markets is constrained by the value of their collateral, which is endogenously tied to the evolution of equity prices. A less financially constrained financial market is represented by a higher borrowing limit—a stochastic process that determines the extent to which capital can be used as collateral for corporate borrowing. This structural model is consistent with the empirical findings that investment and current account dynamics are more responsive to changes in financial conditions in economies with tighter borrowing constraints. In economies with lower borrowing limits—as equity prices have fallen following either a technology shock or an exogenous tightening to the lending standard—impatient agents see their borrowing curtailed by more against the declining value of their collateral, and are thus able to borrow less against collateral for any given value of their capital, compared with those in economies with higher borrowing limits. Although the model is highly stylized—abstracting from many factors, such as monetary policy and nominal issues in general—the exercise is nevertheless instructive: it provides some insight into how macroeconomic volatility varies according to the characteristics of financial markets in economies where firms' borrowing limits are tied to collateral values and where agents do not behave in the farsighted way that is more traditionally supposed.

To calibrate the model, we use post-1999 data for one of the Baltic economies, relying heavily on international credit from advanced—and arguably not financially constrained—European economies, such as Sweden. In the context of a financially-constrained economy, simulating the effects of a policy measure aimed at smoothing the cyclical pattern of lending standards leads to sizeable reductions in the volatility of equity prices, investment, consumption, and an even higher reduction in the volatility of external imbalances: current account deficit, trade balance, and net for-

eign position. In the presence of cross-country technology spillovers, the simulations suggest that stabilization gains might be even higher. The results are robust to different assumptions regarding wage elasticity of labor supply, home-bias in consumption and—to a given extent—modifications in preferences.

APPENDIX

This section estimates VAR-based financial condition indices (FCIs) for 16 advanced European economies and 12 emerging European economies. We estimate country-specific VAR models using monthly data over the sample period 1999:1-2008:4. Each VAR model includes four endogenous variables: (i) (real) GDP growth, (ii) the (real) 3-month interbank rate (CPI); (iii) changes in equity prices (deflated using the CPI); and (iv) changes in (real) private credit to the corporate sector. With the exception of the interest rate, all variables are in logs. A constant is also added as exogenous variables. Based on the Schwartz information criterion, a lag order of three is found optimal for this model across all countries.

Country-specific FCIs are calculated with a dynamic weight structure computed using impulse response functions (IRFs) from each VAR, allowing the FCI to accurately incorporate the timing of transmission from financial markets to real activity. The main advantage of this methodology is its ability to account for endogenous interrelations between the variables in the system. This framework is particularly appropriate for dealing with financial variables, as—a priori—theoretical links between them maybe existing due—for instance—to the implicit effects of the interest rate term structure or the discounted cash flow approach to asset valuation. The main challenge in using a VAR framework relates to the identification of contemporaneous shocks—e.g., the decomposition of the residuals into the portion due to exogenous disturbances to each variable, and the portion due to the effects on each variable of contemporaneous shocks to the other variables in the system. In this paper, the identification of financial shocks is achieved through a standard recursive procedure based on a Cholesky factorization of the estimated variance-covariance matrix. The variables in the model are hence ordered according to their relative sluggishness, e.g., the degree to which they respond to developments occurring in other variables within the quarter.[35] GDP growth is assumed to be relatively more sluggish than the other variables in the system, so that shocks to financial variables in the current period do not affect GDP growth because of the primacy of GDP growth in the Cholesky ordering. The policy-related variable—the 3-month interbank interest rate—is ordered after all other variables, preceded—first—by changes in equity prices and—then—by credit growth.

Within this framework, the estimated response of GDP growth to each of the financial variables can be combined with the measure of shocks to each variable to calculate the total impulse to growth

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[35]To exemplify, the Cholesky decomposition (Sims, 1980) of the shocks of a 3-variable VAR assigns all of the correlation between the errors in the first, second, and third equation to the first variable, while any remaining correlation between the errors in the second and third equation is assigned to the second, and so on for VARs with more variables. This implies that both the magnitude of the shocks and the estimated responses of the variables to each other depend, to some extent, on the assigned ordering.

in a given quarter. The FCI is hence given by the following equation:

$$FCI_t = \sum_{j=1}^{n} \left(r_{t,j_{t-1}} + \sum_{i=2}^{m} r_{t,j_{t-i}} \right) \tag{35}$$

where the r's denote IRFs of GDP growth with respect to each other variable in the VAR, j's index the variables, and the i's index the time period. The first term inside the brackets represents the response of GDP growth in quarter t to a financial shock occurring in the previous quarter. Because the variables in the system are expressed in first differences, the marginal current impact of a shock that occurred before the previous quarter–the term inside the second summation–is measured directly by the shocks effect on GDP growth in the previous period.

The FCI thus measures the total contribution to GDP growth in a given quarter from shocks to financial variables over the previous m quarters. In this way, the issue of dynamic weights in a VAR-based FCI becomes straightforward thanks to the use of IRFs, for which the weight on a particular variable i periods into the future is merely the response of economic activity at time $t+i$ to a shock hitting that variable at time t.

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$$ln(\varphi_t) = \rho_\varphi ln(\varphi_{t-1}) + \varepsilon_t^\varphi, \quad \varepsilon_t^\varphi \sim \text{iid } N(0, \sigma_\varphi^2)$$

Country	Observations	$\widehat{\rho}$	Std.err.	$\widehat{\sigma_\varphi}$
Croatia	46	0.92	0.052	0.055
Estonia	49	0.89	0.0458	0.076
Lithuania	34	0.91	0.083	0.046
Russia	37	0.65	0.157	0.062
Slovenia	52	0.84	0.0922	0.046
Turkey	53	0.8	0.11	0.084

Table 1: Results from Estimating an AR(1) Processes to Demeaned LTVs.

Parameter	Description	Value
Preferences		
β	Home discount factor	0.96
β^*	Foreign discount factor	0.99
σ	Coefficient of risk aversion	1
ψ	Inverse of (Frisch) wage elasticity of labor supply	3
ν	Disutility of labor parameter	Set to match h=33% in SS
γ, γ^*	Bias in consumption towards domestically produced goods	0.575
η	Elasticity of substitution between domestic and foreign goods	1.5
Technology and Productivity		
α	Capital share in Production	0.3
δ	Capital depreciation rate (quarterly)	0.025
ϕ	Capital adjustment cost parameter	10
B_{11}	Home TFP autoregressive parameter	0.94
σ_{ε_1}	Standard deviation of Home TFP shocks	0.022
B_{22}	Foreign endowment autoregressive parameter	0.97
σ_{ε_2}	Standard deviation of Foreign endowment shocks	0.0114
B_{12}	Spillover parameter, Foreign to Home	0
B_{21}	Spillover parameter, Home to Foreign	B12
$\rho_{\varepsilon_1,\varepsilon_2}$	Cross-correlation A-y* shocks	0.07
Credit standards		
$\bar{\varphi}$	Average LTV ratio	0.4
ρ_φ	LTV autoregressive parameter	0.9
σ_φ	Standard deviation of lending standards shocks	0.0185
$\rho_{LTV,A}$	Cross-correlation LTV-A shocks	0.5
Other		
ω	Portfolio adjustment cost parameter	0.00074
N	Relative size of Foreign relative to Home economy	1

Table 2: Benchmark Calibration.

LOAN-TO-VALUE RATIO
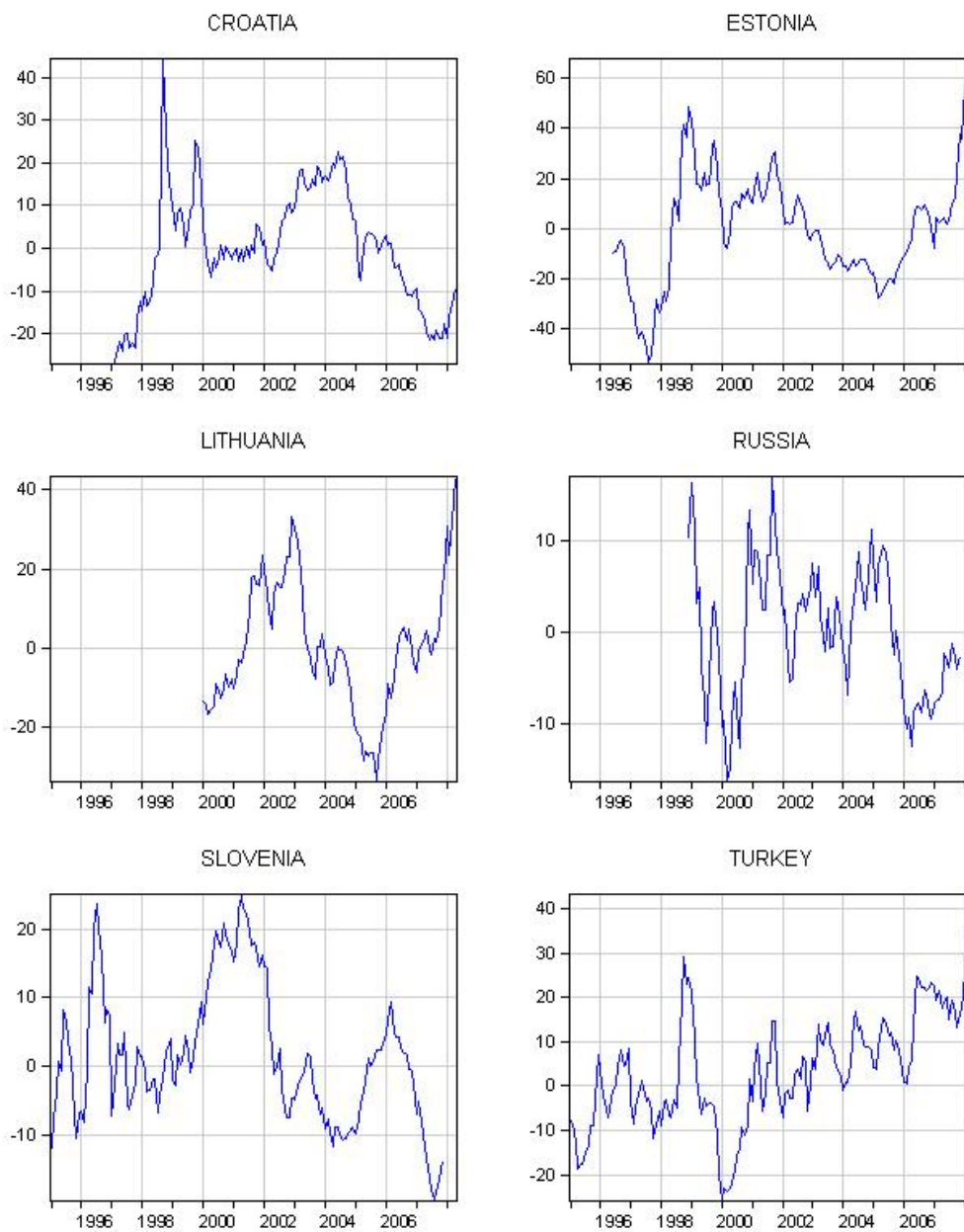
Figure 1: Time Variation in Loan-To-Value Ratios
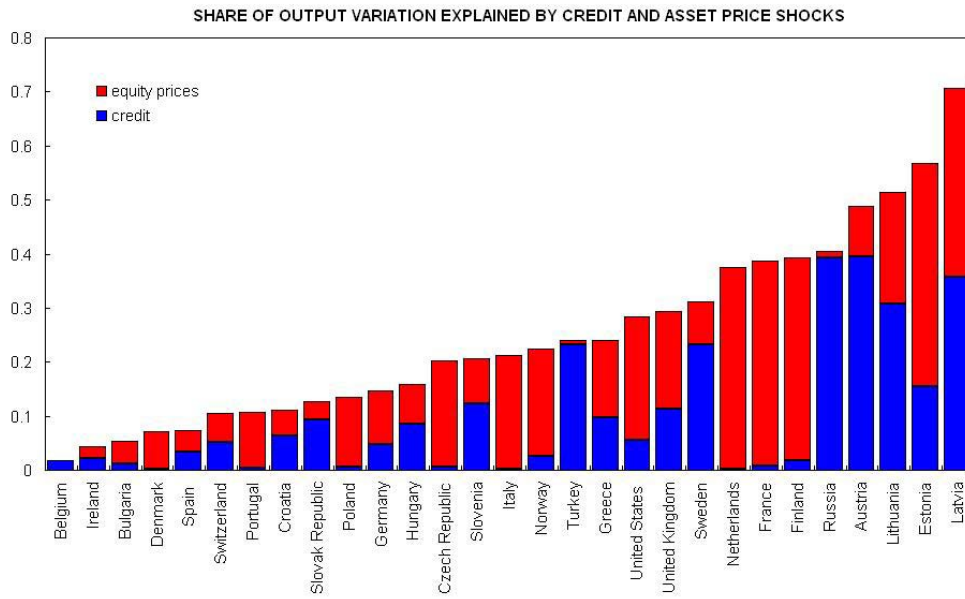
Figure 2: Share of Output Variation Explained by Credit and Asset Price Shocks
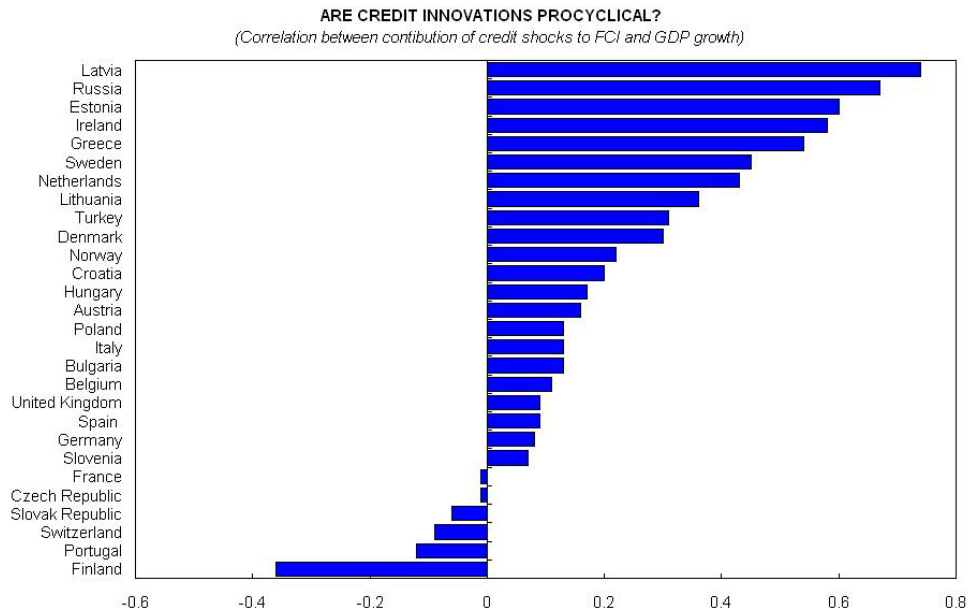
Figure 3: Degree of Cyclicality in Credit Innovations
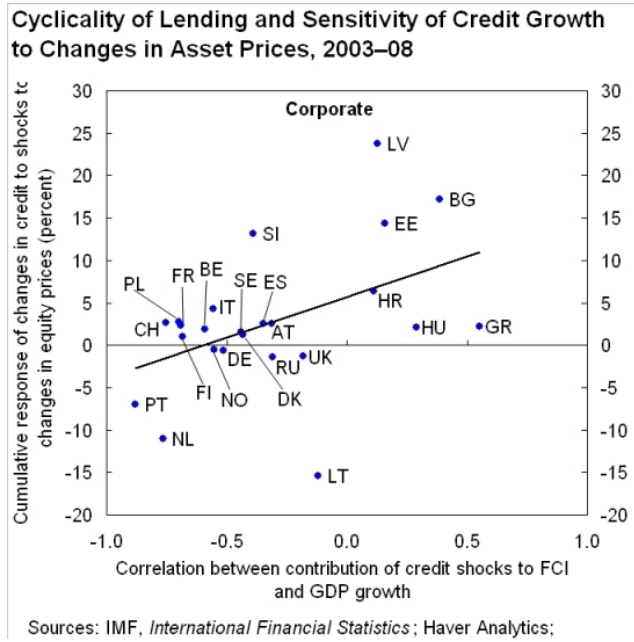
Figure 4: Procyclicality in Credit Innovations and Sensitivity of Credit to Asset Price Shocks
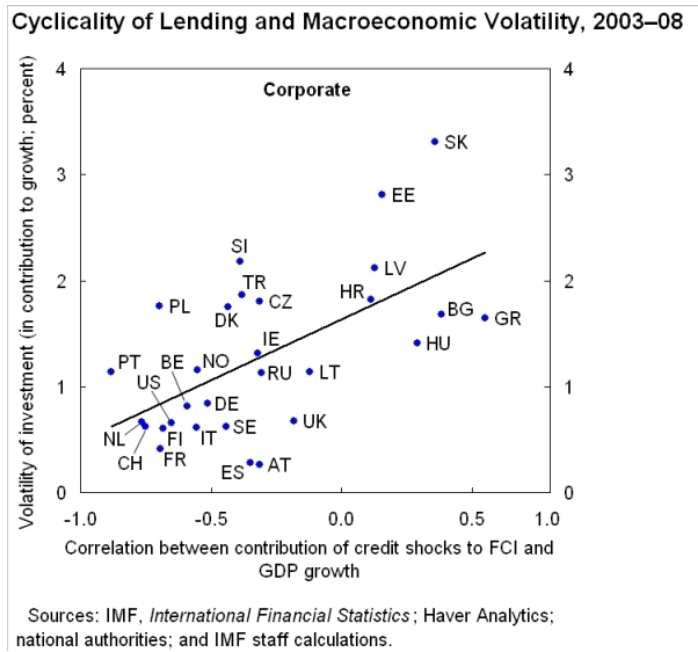
Figure 5: Procyclicality in Credit Innovations and Macroeconomic Volatility

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Change in Deposit and Credit to GDP, 2003–07
(Percentage points)
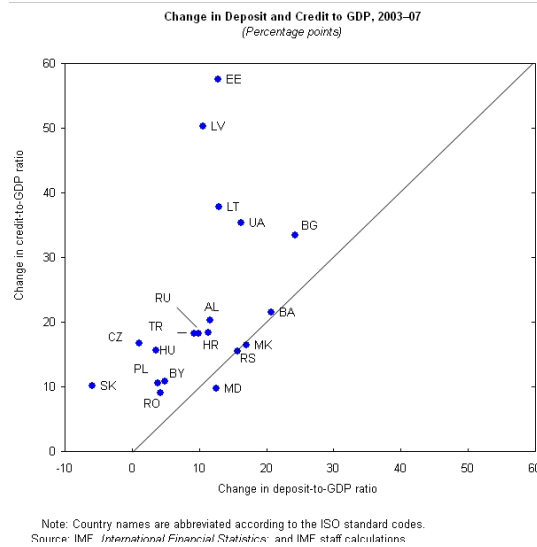
Figure 6: Increasing Reliance of Emerging Europe on Foreign Funding

Concentration of Emerging Europe Exposure to Western Europe, June 2007 1/
(Percent)

Source: Bank for International Settlements, *Quarterly Review*, December 2007.
Note: Country names are abbreviated according to the ISO standard codes.
1/ Emerging Europe exposure to western European banks is defined as the share of the reporting banks in each western European country in the total outstanding claims on a given emerging European country (both bank and nonbank sectors). For example, about 42 percent of Croatia's exposures to Western European reporting banks is owed to Austrian banks, 38 percent to Italian banks, 13 percent to French banks, etc. For the Baltic countries, 85 percent or more of exposures to the reporting banks is owed to Swedish banks.

Figure 7: Concentration of Emerging Europe Exposure to Western Europe

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Volatilities			
σ_y	0.0285	σ_q	0.017
σ_x	0.0674	σ_R	0.022
$\sigma_{x/y}$	0.0396	σ_ζ	0.0026
σ_c	0.0256	$\sigma_{nx/y}$	0.0144
σ_{c/p^H}	0.0286	$\sigma_{ca/y}$	0.0642
$\sigma_{(c/p^H)/y}$	0.0163	σ_d	0.033

Cross-correlations with Home GDP			
$\rho_{x,y}$	0.9843	$\rho_{q,y}$	0.9694
$\rho_{x/y,y}$	0.9538	$\rho_{R,y}$	0.1772
$\rho_{c,y}$	0.6995	$\rho_{d,y}$	0.7244
$\rho_{c/p^H,y}$	0.8369	$\rho_{nx/y,y}$	-0.0939
$\rho_{(c/p^H)/y,y}$	-0.2834	$\rho_{ca/y,y}$	-0.1575
$\rho_{h,y}$	0.2834	$\rho_{y,y_{-1}}$	0.7212

Cross-correlations with equity prices			
$\rho_{x,q}$	0.9963	$\rho_{R,q}$	0.3361
$\rho_{c,q}$	0.7823	$\rho_{nx/y,q}$	-0.2455
$\rho_{d,q}$	0.7721	$\rho_{ca/y,q}$	-0.3161

Table 3: Business Cycle Moments from Simulated Series under Benchmark Calibration

Policy exercise - LTV=0.4			
Volatilities	$\rho_{LTV,A} = 0.5$	$\rho_{LTV,A} = 0$	**% difference**
σ_y	0.0285	0.0284	-0.4%
σ_x	0.0674	0.065	-3.6%
$\sigma_{x/y}$	0.0396	0.0372	-6.1%
σ_c	0.0256	0.0245	-4.3%
σ_{c/p^H}	0.0286	0.0281	-1.7%
$\sigma_{(c/p^H)/y}$	0.0163	0.0141	-13.5%
σ_q	0.017	0.0164	-3.5%
σ_R	0.022	0.0189	-14.1%
$\sigma_{nx/y}$	0.0144	0.0125	-13.2%
$\sigma_{ca/y}$	0.0642	0.0552	-14.0%
σ_d	0.033	0.0284	-13.9%
Cross-correlations with Home GDP	$\rho_{LTV,A} = 0.5$	$\rho_{LTV,A} = 0$	**% difference**
$\rho_{x,y}$	0.9843	0.9865	0.2%
$\rho_{c,y}$	0.6995	0.7574	8.3%
$\rho_{q,y}$	0.9694	0.973	0.4%
$\rho_{R,y}$	0.1772	0.0664	-62.5%
$\rho_{nx/y,y}$	-0.0939	-0.1395	48.6%
$\rho_{ca/y,y}$	-0.1575	-0.0765	-51.4%
$\rho_{d,y}$	0.7244	0.4205	-42.0%
Cross-correlations with equity prices	$\rho_{LTV,A} = 0.5$	$\rho_{LTV,A} = 0$	**% difference**
$\rho_{d,q}$	0.7721	0.4822	-37.5%
$\rho_{R,q}$	0.3361	0.2039	-39.3%
$\rho_{nx/y,q}$	-0.2455	-0.2605	6.1%
$\rho_{ca/y,q}$	-0.3161	-0.2124	-32.8%

Table 4: Policy Exercise Results (Average LTV = 0.4)

Policy exercise - LTV=0.7			
Volatilities	$\rho_{LTV,A}=0.5$	$\rho_{LTV,A}=0$	**% difference**
σ_y	0.0281	0.028	-0.4%
σ_x	0.0596	0.057	-4.4%
$\sigma_{x/y}$	0.034	0.0315	-7.4%
σ_c	0.0307	0.0297	-3.3%
σ_{c/p^H}	0.0335	0.033	-1.5%
$\sigma_{(c/p^H)/y}$	0.0239	0.0213	-10.9%
σ_q	0.015	0.0144	-4.0%
σ_R	0.016	0.0143	-10.6%
$\sigma_{nx/y}$	0.0156	0.014	-10.3%
$\sigma_{ca/y}$	0.0922	0.0816	-11.5%
σ_d	0.0295	0.0261	-11.5%
Cross-correlations with Home GDP	$\rho_{LTV,A}=0.5$	$\rho_{LTV,A}=0$	**% difference**
$\rho_{x,y}$	0.9501	0.9523	0.2%
$\rho_{c,y}$	0.5789	0.6492	12.1%
$\rho_{q,y}$	0.9444	0.9439	-0.1%
$\rho_{R,y}$	0.2163	0.0381	-82.4%
$\rho_{nx/y,y}$	-0.088	-0.163	85.2%
$\rho_{ca/y,y}$	-0.1933	-0.0489	-74.7%
$\rho_{d,y}$	0.697	0.3398	-51.2%
Cross-correlations with equity prices	$\rho_{LTV,A}=0.5$	$\rho_{LTV,A}=0$	**% difference**
$\rho_{d,q}$	0.7151	0.4055	-43.3%
$\rho_{R,q}$	-0.0069	-0.1638	2273.9%
$\rho_{nx/y,q}$	0.1792	0.1102	-38.5%
$\rho_{ca/y,q}$	0.0391	0.1674	328.1%

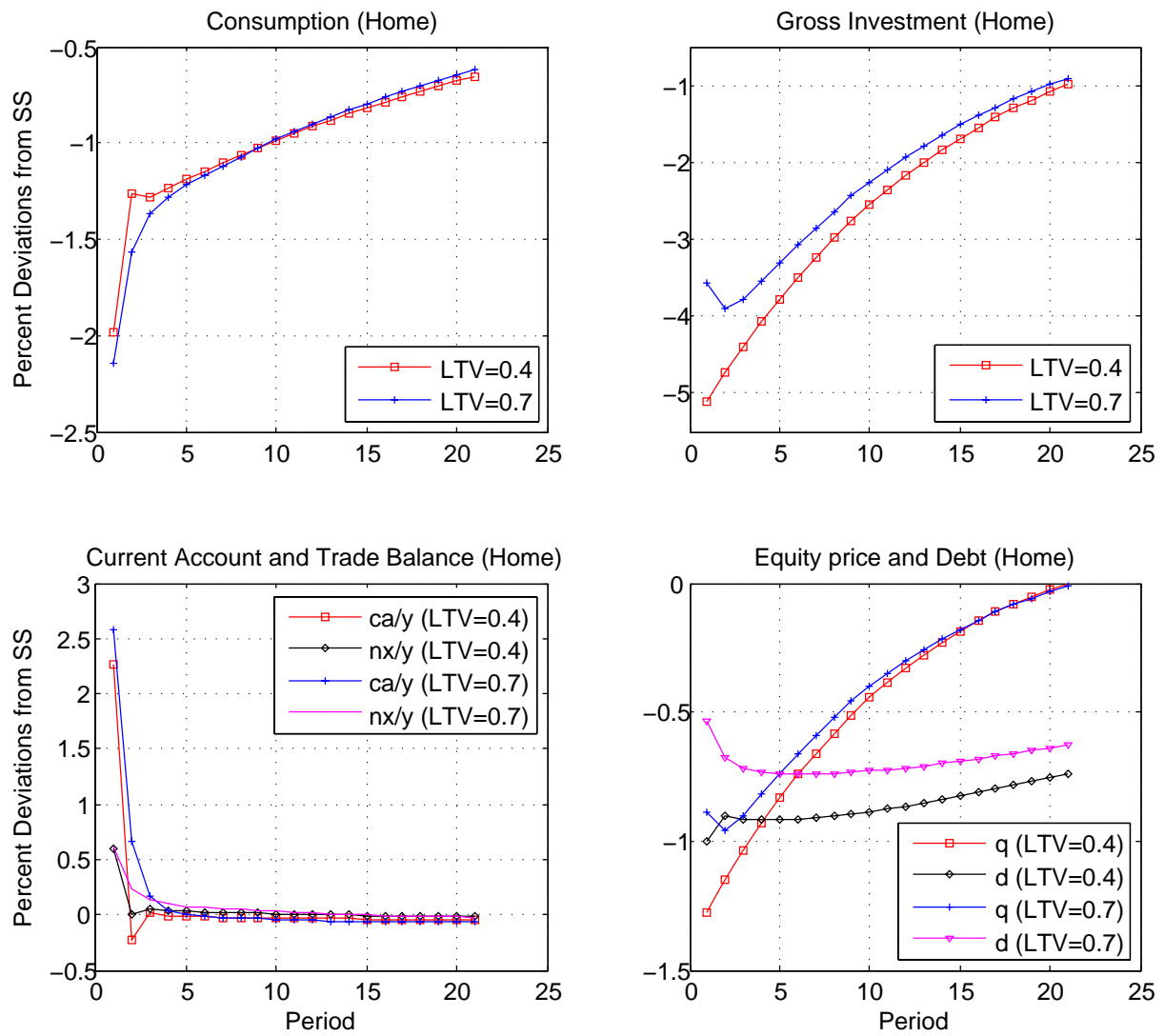**Table 5:** Policy Exercise Results (Average LTV = 0.7)

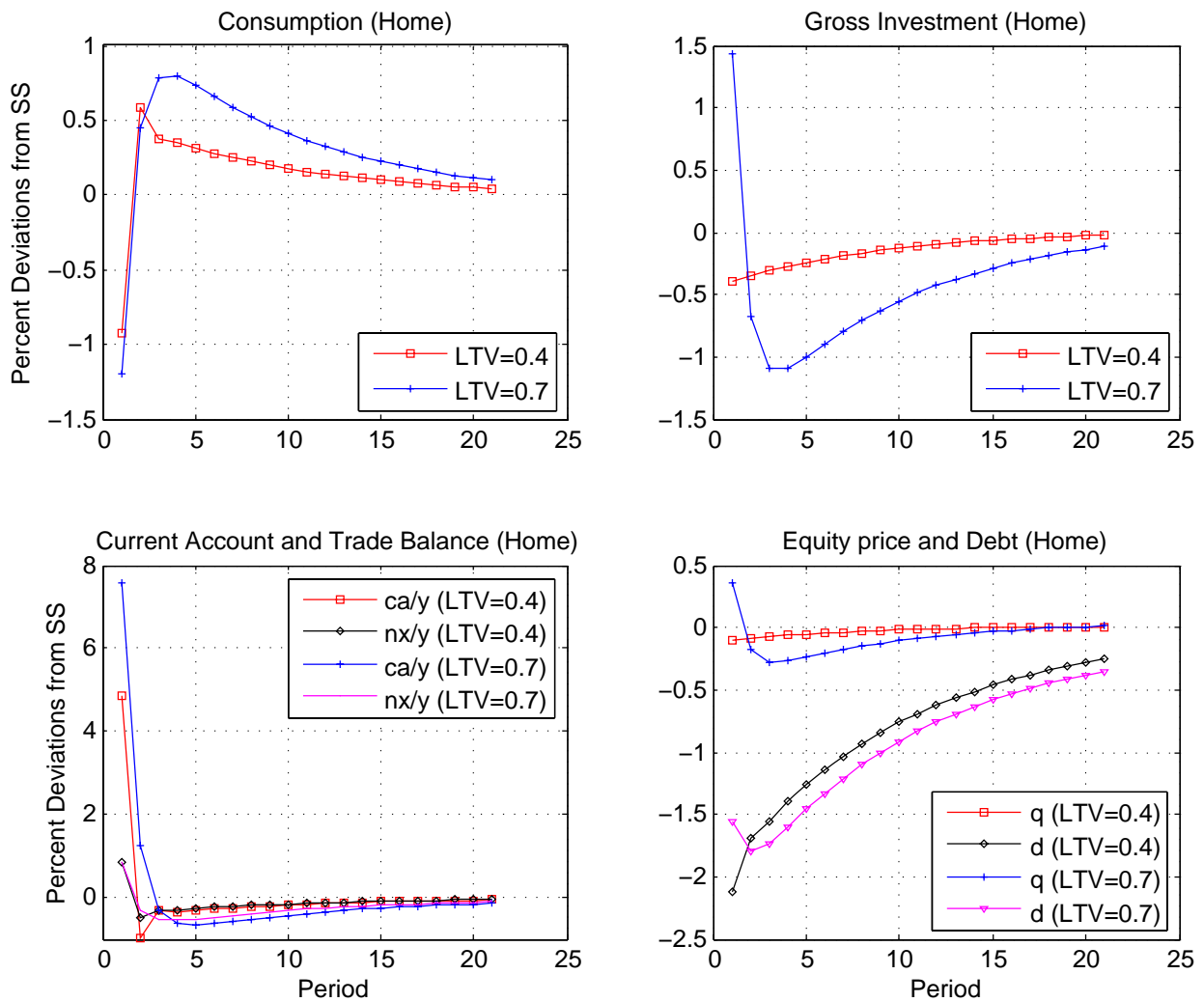**Figure 8:** IRFs to a Negative Productivity Shock under Alternative Leverage Levels

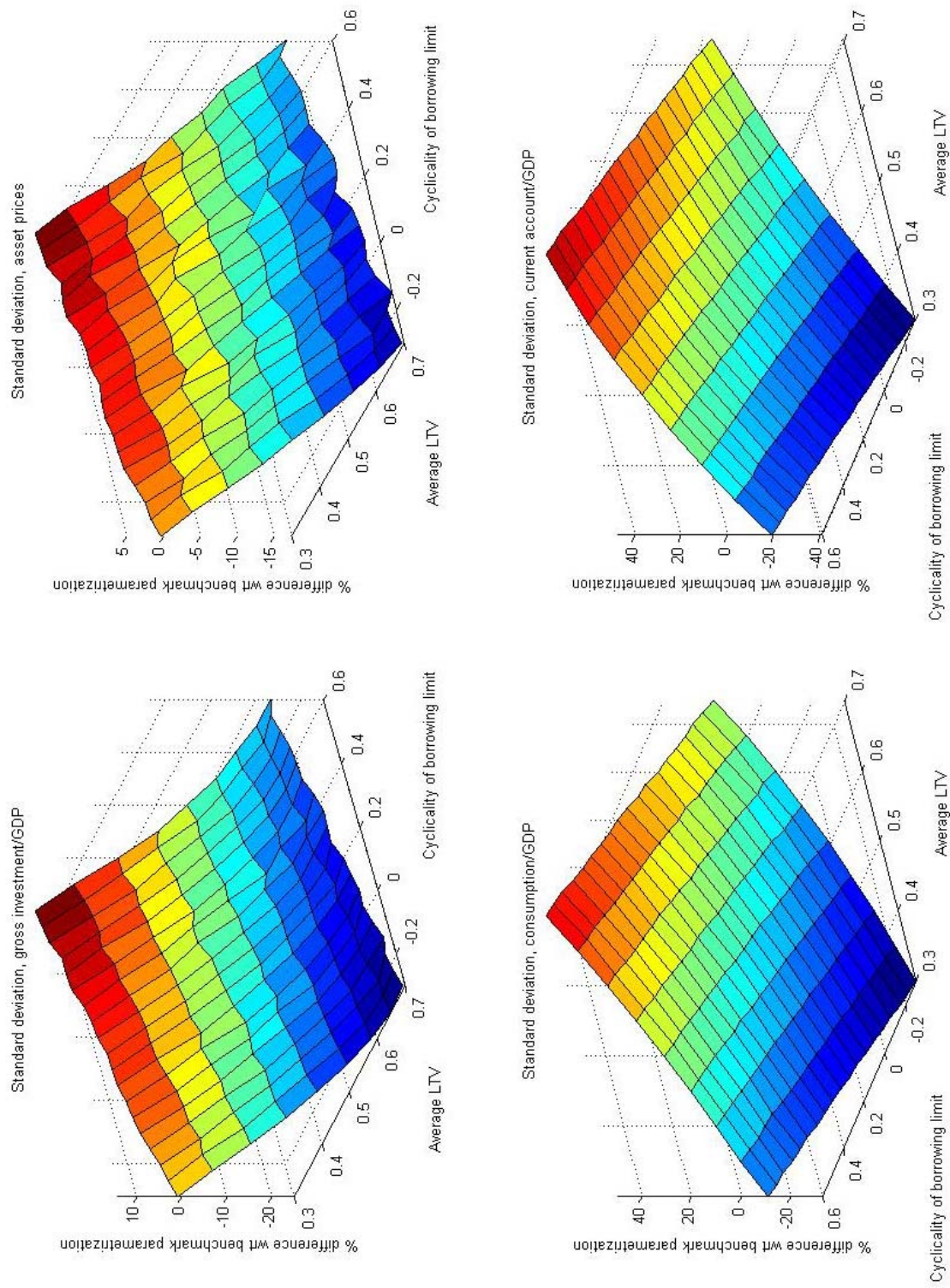**Figure 9:** IRFs to a Negative Shock to Lending Standards under Alternative Leverage Levels

Figure 10: Sensitivity of Volatility to Different Degrees of Cyclicality in Lending Standards Under Alternative Leverage Levels

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Scenario :	Benchmark		$\psi = 0.3$		$B_{12} = B_{21} = 0.08$		$\gamma = \gamma^* = 0.75$		$\sigma = 2$	
$\rho_{LTV,A}$:	Bench	% diff.	Bench	% diff.	Bench	% diff.	Bench	% diff.	Bench	% diff.
σ_y	0.0285	-0.4%	0.0307	-1.6%	0.0272	-0.7%	0.0286	-1.0%	0.0264	-1.9%
σ_x	0.0674	-3.6%	0.0711	-4.1%	0.0634	-4.3%	0.0649	-3.5%	0.0715	-3.8%
$\sigma_{x/y}$	0.0396	-6.1%	0.0411	-6.1%	0.0368	-6.8%	0.0367	-5.7%	0.0458	-4.8%
σ_c	0.0256	-4.3%	0.024	-3.3%	0.0248	-5.2%	0.0269	-2.2%	0.0184	0.0%
σ_{c/p^H}	0.0286	-1.7%	0.0276	-0.7%	0.0273	-3.3%	0.0274	-0.4%	0.0216	1.9%
$\sigma_{(c/p^H)/y}$	0.0163	-13.5%	0.0161	-13.7%	0.0159	-11.3%	0.0134	-14.9%	0.0107	-14.0%
σ_q	0.017	-3.5%	0.0179	-3.9%	0.016	-4.4%	0.0164	-3.7%	0.018	-3.3%
σ_R	0.022	-14.1%	0.0198	-13.6%	0.0219	-13.7%	0.023	-15.7%	0.0247	-14.6%
$\sigma_{nx/y}$	0.0144	-13.2%	0.0131	-13.7%	0.0139	-12.2%	0.0103	-13.6%	0.0084	-11.9%
$\sigma_{ca/y}$	0.0642	-14.0%	0.0581	-14.1%	0.0633	-13.4%	0.0611	-15.9%	0.0642	-14.8%
σ_d	0.033	-13.9%	0.0327	-13.5%	0.0323	-12.7%	0.0336	-14.9%	0.034	-14.1%
σ_ζ	0.0026	0.0%	0.0028	-3.6%	0.0024	0.0%	0.0096	-8.3%	0.0024	0.0%
$\rho_{x,y}$	0.9843	0.2%	0.9876	0.2%	0.9864	0.1%	0.9926	0.0%	0.9828	0.2%
$\rho_{c,y}$	0.6995	8.3%	0.7064	8.2%	0.7042	4.6%	0.7988	6.4%	0.8018	5.4%
$\rho_{q,y}$	0.9694	0.4%	0.9724	0.3%	0.9745	0.2%	0.9811	-0.1%	0.9685	0.3%
$\rho_{R,y}$	0.1772	-62.5%	0.0404	-238.6%	0.2457	-56.3%	0.2302	-43.0%	0.1823	-50.7%
$\rho_{nx/y,y}$	-0.0939	48.6%	0.0424	-148.8%	-0.0801	-3.4%	-0.128	65.6%	-0.0717	161.5%
$\rho_{ca/y,y}$	-0.1575	-51.4%	-0.019	-348.9%	-0.2095	-54.7%	-0.2133	-34.0%	-0.1688	-41.2%
$\rho_{d,y}$	0.7244	-42.0%	0.7183	-39.8%	0.7222	-44.6%	0.7785	-33.9%	0.7609	-35.4%
$\rho_{d,q}$	0.7721	-37.5%	0.7651	-36.2%	0.7561	-38.8%	0.7921	-31.3%	0.7958	-32.4%
$\rho_{R,q}$	0.3361	-39.3%	0.1794	-66.6%	0.3973	-38.0%	0.2266	-43.5%	0.3324	-33.7%
$\rho_{nx/y,q}$	-0.2455	6.1%	-0.0879	36.1%	-0.2277	-13.5%	-0.1097	68.3%	-0.2258	37.4%
$\rho_{ca/y,q}$	-0.3161	-32.8%	-0.1574	-57.6%	-0.3618	-36.0%	-0.2075	-35.4%	-0.321	-28.0%

<div align="center">Sensitivity Analysis - LTV=0.4</div>

Table 6: Sensitivity Analysis.