Sudden Stops and margin-based asset pricing*

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Abstract

Small open economy models with collateral constraints on foreign debt match the moments of key macroeconomic variables of emerging economies during Sudden Stops. However, they underestimate significantly the collapse of asset prices. We show that a model that a with state-contingent margins, which are inversely related to assets' market liquidity, can better explain the magnitude and the persistence of asset prices drop after a Sudden Stop event. In addition, procyclical margins constitute another externality with important implications for the optimal design of macroprudential policy.

Keywords: Financial crises; Margins; Macroprudential regulation.

JEL classification: F34, F38, F41, G12, G13, E44.

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1 Introduction

Small open-economy (SOE) models with financial frictions in the form of collateral constraints on foreign debt, have been widely used to interpret sudden stops, since their qualitative predictions are consistent with the empirics of these events. In order such models to match quantitatively the magnitude of the latter, the collateral-type financial frictions are imposed on multiple agents of domestic economy, e.g. households, firms and financial intermediaries, to capture both "demand-side" and "supply-side" effects of credit frictions. Furthermore, the borrowing limit fluctuates in parallel with the state of the economy, which makes distortions to persist and volatility to increase.

Mendoza (2002, 2010), developed SOE models with the aforementioned characteristics, to explain the Mexican sudden stop event (1994-95). In his models, the collateral constraints limit agent's borrowing ability to a fraction (ϕ) of the value of assets that can be used as a collateral. In other words, agents have to finance a fraction ($1 - \phi$) of their new investment with their own capital; this fraction is the "*margin*" or the "*haircut*" value of the asset. When the models were calibrated to the Mexican data, it produced a decline in consumption, investment and output similar to those observed in the data. However, it underestimated the collapse of asset prices.[1] A similar model, in which foreign investors trade the domestic equity and face trading costs, proposed by Mendoza and Smith (2006), generated larger drops in asset prices but required a high price elasticity of foreign asset demand.

A more recent literature that used this class of models to interpret the financial crisis of 2007-08, assumed that the ceiling on the leverage ratio, i.e. the fraction of collateralizable assets that determines the upper bound of the leverage ratio, is time-contingent.[2] Specifically, this ceiling was modelled by a stochastic process. Shocks on the latter, interpreted as financial shocks, could better match better the behavior of financial and real variables, that standard productivity shocks could only partially do. However, since the leverage limit is driven by an exogenous process, part of the credit crisis is exogenous as well.

In addition to this literature, there are several other studies that build models with endogenous leverage limits, based on the asymmetric information between borrowers and lenders and, in particular, the costly state verification problem, as first introduced by Townsend (1979).[3] However, in these models the leverage limit is an increasing function of both expected returns

[1] The model predicted a contraction of asset prices of about 1/3 of the actual size of the asset prices decline as observed in Mexican data.

[2] See, e.g. Jermann and Quadrini (2012), Boz and Mendoza (2014), Bianchi and Mendoza (2018) and Perri and Quadrini (2018).

[3] See e.g. Bernanke and Gertler (1989), Bernanke et al. (1999), Carlstrom and Fuerst (1997), Gertler and Kiyotaki (2011) and Gertler and Karadi (2011, 2013).

and the growth rate of net wealth. Furthermore, there is the Kocherlakota (2000) critique that amplification effects in Bernanke et al. (1999) and Kiyotaki and Moore (1997) are quantitatively not large enough to explain the data.

In this study, we build on the literature of models with endogenous margins and propose that a model with state-contingent margins embedded in the collateral constraint, could possibly do better at accounting for the stylized facts of sudden stops and, mainly, the contraction of asset prices. We differ from that literature by assuming that margins are inversely related to assets' market liquidity as in Brunnermeier and Pedersen (2009). The intuition is that a ceiling on the leverage ratio that depends positively on assets' market liquidity, and indirectly on asset prices, will amplify the magnitude, persistence and asymmetry of the responses of prices, as well as, of macro-variables to standard shocks that drive business cycles. Under this assumption, the loss of credit market access will remain endogenous (as in Mendoza, 2010), while the leverage limit will serve as an endogenous transmission mechanism, rather than a source of exogenous shocks.

To put the same thing differently, we suggest that what the models have failed to capture so far is the presence of a negative relationship between margins and asset prices.[4] The countercyclical behavior of margins, or similarly the procyclical behavior of leverage limit, has been thoroughly documented by a growing literature.[5] The increase in margins of many asset classes after the financial crisis of 2007-8, was a result of the increase in uncertainty, the deterioration in credit quality, as well as, the inability of particular asset to be used as collateral by levered financial institutions.[6]

In addition, the fact that the value of collateral is a market price introduces a pecuniary externality, as first pointed out in the theoretical work of Korinek (2007). Procyclical margins constitute another externality with important implications for the optimal design of macroprudential policy. When "ex-post" policies are considered, margins have been used by central bankers as an additional monetary policy tool, in order to decrease spreads and facilitate the supply of credit during the recent crisis.[7]

To study the amplification effects of state-contingent margins on the performance of macroag-

[4] See e.g. Holmström and Tirole (2001), Gârleanu and Pedersen (2009) and Brunnermeier and Sannikov (2014) for theoretical models of asset pricing based on leverage ratios.

[5] See e.g. Adrian and Shin (2009), Gârleanu and Pedersen (2009), Brunnermeier and Pedersen (2009), Gorton and Metrick (2010) and Boz and Mendoza (2014), among others.

[6] See, also, Fostel and Geanakoplos (2008, 2014) on how the value of an asset depends on its ability to be used as a collateral, the "collateral value".

[7] The role of margins as another channel of monetary policy transmission has been highlighted by Brunnermeier and Pedersen (2009), Adrian and Shin (2009) and Ashcraft, Gârleanu and Pedersen (2011).

gregates, and particularly on prices, we add state-varying margins in the model of an open endowment economy of Korinek and Mendoza (2014). Specifically, we make the simplistic assumption that the upper bound of the leverage ratio is a linear function of assets' market liquidity as defined in Brunnermeier and Pedersen (2009). We solve the model with, and without, state-contingent margin requirements, using the gridpoints bifurcation method proposed by the authors, and compare equilibrium prices. We find that in the model with state-contingent margins, the credit effects on consumption and prices are more severe. In particular, prices respond vastly to the non-linear margin effects, the distortion of the intertemporal marginal rate of substitution and the cut of investment. On the other hand, in the unconstrained regime, both models deliver similar dynamics.

Our analysis is closely related to literature on sudden stops and the basic papers by Mendoza (2002, 2010) and Korinek and Mendoza (2014). Also, it is related to the to the large literature on equilibrium with multiple agents and borrowing constraints that shows the importance of the collateral value of assets (e.g. Bernanke and Gertler, 1989, Kiyotaki and Moore, 1997, Caballero and Krishnamurthy, 2001, 2004, Lustig and Van Nieuwerburgh, 2005, Fostel and Geanakoplos, 2008, 2014, etc.). In addition, it is related to the literature that studies the linkages between margins and market liquidity (e.g. Gromb and Vayanos, 2002, Brunnermeier and Pedersen, 2009, Adrian and Shin, 2009, Gârleanu and Pedersen, 2009, Brunnermeier and Sannikov, 2014, etc.), as well as, between the latter and asset prices (e.g. Amihud and Mendelson, 1986, Acharya and Pedersen, 2005, Duffie, Gârleanu, and Pedersen, 2007, etc.). Finally, it is related to the literature on macroprudential policy (e.g. Choi and Cook, 2004, Korinek, 2007, Jeanne and Korinek, 2019a, b, Korinek and Mendoza, 2014, Schmitt-Grohé and Uribe, 2018, Ashcraft, Gârleanu and Pedersen, 2011, etc.).

The rest is organized as follows. Section 2 sets up the model and section 3 conducts the quantitative analysis. Section 4 discusses policy implications. Section 5 concludes.

2 A model with margin-based asset pricing and collateral constraints

2.1 Model setup

In this section we extend the asset pricing model by Korinek and Mendoza (2014, Section 5) (referred to as KM) to allow for state-contingent margin requirements in borrowing constraints. The model describes an open endowment economy and follows the Fisherian debt deflation approach.

Specifically, we consider a small open economy in infinite discrete time $t = 1, 2, \ldots$. The economy is inhabited by a large number of identical and infinitely lived households with preferences described by the utility function:

$$U = E \sum_{t=0}^{\infty} \beta^t \left[u(c_t) \right] \tag{1}$$

where c_t denotes consumption, $u(c_t)$ denotes a standard continuously differentiable, strictly increasing and concave utility function and $\beta \in (0, 1)$ is the discount factor.

Each period, domestic households receive an endowment income, e_t, and have the ability to invest in an infinitely-lived asset, α_t, which pays a stochastic dividend, d_t, is traded at price, p_t, and it is in fixed unit supply each period. Households can, also, invest in a risk-free internationally traded bond, b_t, which pays the world gross real interest rate R_t.[8] The latter is assumed to be exogenous and, for simplicity, constant over time ($R_t = R$). The budget constraint of the household is given by:

$$c_t + p_t \alpha_{t+1} + \frac{b_{t+1}}{R} = e_t + \alpha_t (p_t + d_t) + b_t \tag{2}$$

International financial markets are imperfect. Specifically, if domestic agents go bankrupt, foreign lenders can seize a fraction φ of the market value of the collateralized assets. In other words, domestic agents could borrow up to a fraction φ of the market value of their capital or, alternatively, should finance a fraction $(1 - \varphi)$, the margin, of the new capital investment with their own funding. The collateral constraint is:

$$\frac{b_{t+1}}{R} \geq -\varphi p_t \alpha_{t+1} \tag{3}$$

Equations (2) and (3) are like equations (9) and (10) in KM. Note that b_{t+1} comes with a positive sign at the LHS of households' balance sheet and could be considered as the value of bond purchases carried as savings into the next period.

Up to this point, the model set-up is exactly as in KM. We will differ from the latter by assuming that the upper bound of the leverage ratio, φ, is not fixed and exogenous, but it is state-contingent and, in fact, an increasing function of asset's market liquidity. Brunnermeier and Pedersen (2009) define asset's market liquidity as the difference between the current price and the fundamental value. As a proxy for the latter we use the steady state value of prices. In particular, for our numerical solutions, we use the following linear functional:

[8] See Bianchi and Mendoza (2010) and Jeanne and Korinek (2019 a,b) for a similar set up.

$$\varphi_t = \varphi \frac{p_t}{p} \tag{4}$$

where $0 \leq \varphi \leq 1$ is a parameter and the variable without the time subscript denotes the steady state value of prices. Thus, we assume that φ_t is an increasing function of the deviation of asset prices from their steady state value and in that way we capture the negative relationship between margins and asset prices, as has been documented by the empirical literature. Also, please note, that this model will deliver the same steady equilibrium as KM model. We do not attempt to match moments of an aggregate economy at the business cycle frequency.

The choice of the above functional form is very ad hoc. However, our aim here is not to match moments of an aggregate economy during a sudden stop event; our aim is to assess the amplification effects of state-contingent margins, when the latter are negatively correlated with prices as has been documented by the empirical literature.

Each household chooses sequences of consumption, asset and bond holdings, $\{c_t, \alpha_{t+1}, b_{t+1}\}_{t=0}^{\infty}$, so as to maximize their utility function (1) subject to the budget constraint (2) and the collateral constraint (3). The Euler equation of foreign bonds and the asset pricing equation are:

$$u'(c_t) = \beta R E_t[u'(c_{t+1})] + \lambda_t \tag{5a}$$

$$p_t = \frac{\beta E[u'(c_{t+1})(d_{t+1} + p_{t+1})]}{u'(c_t) - \varphi_t \lambda_t} \tag{5b}$$

where λ_t denotes the non-negative Lagrange multipliers on the collateral constraint (3). Combining the Euler and the asset pricing equation, and rearranging the terms we get the following expression for the equity premium:

$$E[(R^k_{t+1} - R)] = \frac{(1 - \varphi_t)\lambda_t}{\beta E[u'(c_{t+1})]} \tag{6}$$

where $R^k_{t+1} = \frac{d_{t+1}+q_{t+1}}{q_t}$ is the asset return. Under a binding credit constraint, the required return on asset holdings, i.e. the spread between the latter and the risk-free interest rate, co-moves with the haircut value.[9]

Looking at equations (5a) and (6), we observe the two endogenously generated premia relative to the world interest rate; the external financing premium and the equity premium.

[9] Based on a similar equation, Gârleanu and Pedersen (2011), explained the CDS-bond basis and other deviations from the Law of One Price due to different margins.

Furthermore, as KM discuss, the fact that the borrowing limit is a market price has two important implications: first, there is a feedback loop as described by the Fisherian debt-deflation mechanism. When constrained agents cut investment to meet the margin requirement, the collateral value decreases and a downward spiral between investment, asset prices and debt is generated. Second, there is a pecuniary externality, because agents fail to internalize the effects that their borrowing decisions have on the price of the collateral and total foreign debt. This is what Uribe (2006) characterizes as *overborrowing*. This central-market failure could be offset by macro-prudential policy intervention, implemented via a tax on foreign borrowing, as discussed by KM. A state-contingent margin that varies inversely relative to prices, is related to both aforementioned arguments; the spiral effects are reinforced and margins constitute another instrument of policy.

2.2 Macroeconomic equilibrium

To define and solve the equilibrium system we follow the same assumptions as in KM. In particular, we assume that the dividend income and endowment income are both a constant fraction of the same exogenous output process y_t. Specifically, $d_t = \alpha y_t$, is interpreted as income from pledgeable assets, and $e_t = (1-\alpha)y_t$, is interpreted as income from non-pledgeable assets, where $0 \leq \alpha \leq 1$ is a parameter. Thus, in each period, the economy can be summarized into the state vector of bond holdings and the realization of output (b, y). Finally, we assume that only domestic agents can hold the asset tree, i.e. in equilibrium $\alpha_{t+1} = 1$.

The equilibrium system can be summarized 4 equations, namely the budget constraint, the collateral constraint, the Euler equations and the asset pricing condition, equations (2), (3), (5a) and (5b) respectively, in $\{c_t, b_{t+1}, p_t, \lambda_t\}_{t=0}^{\infty}$, given the stochastic output process $\{y_t\}_{t=0}^{\infty}$ and the initial asset position b_0. To solve the model we reformulate the above equilibrium in recursive form.

3 Quantitative Results

Under the parameterization borrowed from KM (Table 1), we solve the model numerically using the gridpoints bifurcation method as proposed by the authors.

Table 1: Calibrated parameters

β	σ	ϕ	R	α	Δy
0.96	2	1/5	0.38	0.0.5	0.03

Source: Korinek and Mendoza (2014).

Figure 1 plots the policy functions of debt, consumption and prices, $\{c, b', p\}$, as a function of current wealth b. In the same figure we, also, indicate the 45^o line by a dotted line. If $b' > b$, i.e. b' lies above the 45^o line, households accumulate savings and the economy runs a current account surplus and vice versa.

Figure 1: Policy functions and equilibrium prices with state-contingent margins

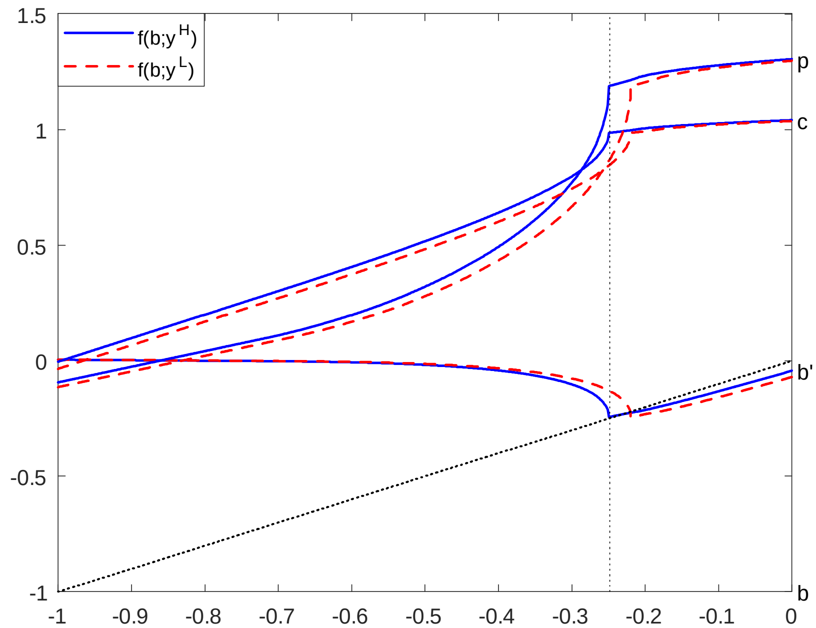
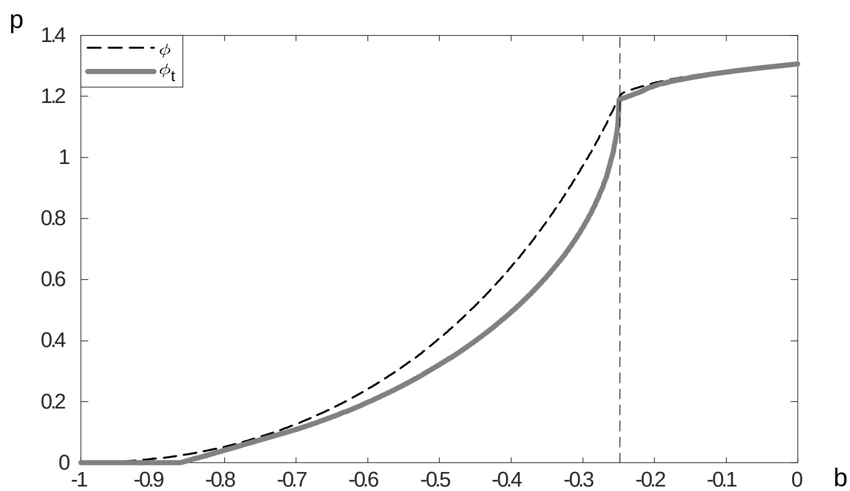


Figure 1 depicts two regimes separated by the vertical line, which indicates the level of debt at which the constraint binds. Thus, to the left of the vertical line the collateral constraint is binding and to the right of the vertical line the constraint is loose. The first thing to observe is the non-monotonic behavior of b'. When the financial constraint binds, b' is a decreasing function of the current wealth, as less wealth today tights more the constraint and limits the debt carried over in the next period, whereas when the constraint is loose, it is an increasing function of the latter. Regarding consumption and asset prices, they both are a steeply increasing function of the current wealth in the constrained regime, while, in the unconstrained regime, they respond rather mildly to its changes. Unconstrained agents are able to smooth wealth and consumption over time.

In order to asses the magnitude of the amplification effects stemming from state-contingent margins, we, first, compare the asset prices of the above model to the prices generated by a model with fixed margins, as in KM. We consider only the case where $y = y^H$. Results are reported in Figure 2. As above, prices are a function of current wealth and the vertical line, indicates the level of debt at which the constraint binds.

Figure 2: Equilibrium prices with and without state-contingent margins



Not surprisingly, since we have ex-ante assume that margins are a function of prices, the comparison between asset prices in two models imply that the state-varying margins amplify the macro-effects of funding crises. In the model with state-contingent margins prices respond strongly to changes of current wealth. On the other hand, in the unconstrained regime, both models deliver almost identical equilibrium prices.

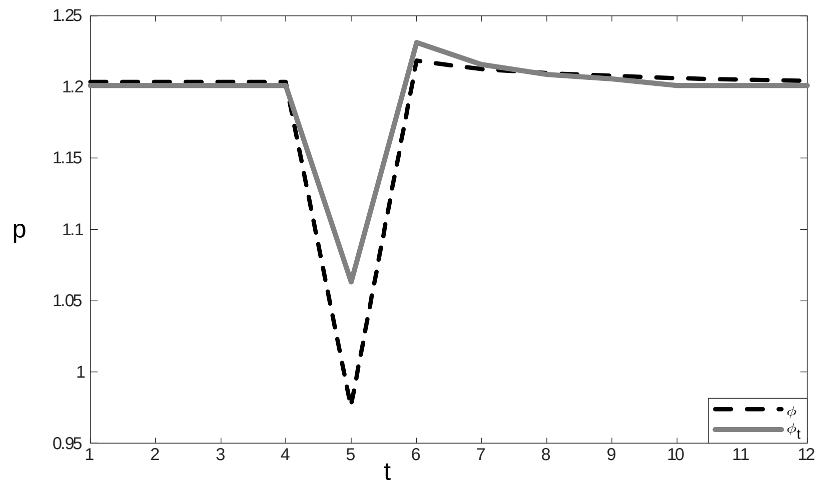
In addition, we compare the response of prices to a one-time adverse shock y^L, under the two margin specifications.[10] The transition paths are presented in Figure 3. Under state-contingent margins, prices exhibit a higher decrease on impact and a lower increase in the next period. Quantitatively, in KM model when income decreases by 3%, prices drop by approximately 11.5%, while in the model with endogenous margins, prices drop by 19%.

Summing up, state-contingent margins could possibly enable SOE models with collateral constraints to account for the asset prices dynamics during the sudden stop events. In particular, when the sudden stops of emerging economies are considered, procyclical margins could do better in explaining two stylized facts observed in the data: *i*) the magnitude and the persistence of asset prices drop after a Sudden Stop event, *ii*) the strong appreciation before a

[10] This graph is similar to Figure 7 in Korinek and Mendoza (2014).

Sudden Stop event, if agents choose to borrow up to their limit.[11]

Figure 3: Path of asset prices



4 Policy implications

The severity of the macro-finance implications of international flows reversal, call economists to suggest and policy makers to design and implement efficient macroeconomic policies. Such policies could be either macroprudential "ex-ante" policies,[12] mitigating the magnitude of the foreign capital cycle, or "ex-post", ensuring a "soft landing" when flows subside.[13]

As described above, the fact that the collateral is priced at market values induces the Fisherian amplification mechanism. At the same time, it introduces a pecuniary externality, as first pointed out in the theoretical work of Korinek (2007). Households acquire higher debt than would be optimal if they were able to internalize the effects that current borrowing decisions have on future prices. Higher debt implies lower aggregate demand, and thus lower prices, in the constrained regime. This central market failure justifies macroprudential policy by a *prudential social planner,* who chooses savings allocation while taking that externality into account. Thus, the planner borrows less than optimally in the periods predating the binding

[11] See Korinek and Mendoza (2014, Section 2) for the dynamics of Sudden Stops of both advanced and emerging economies.

[12] See e.g. Bianchi (2011), Bianchi and Mendoza (2016, 2018), Mendoza and Rojas (2018), Korinek (2018) and Jeanne and Korinek (2019a,b).

[13] See e.g. Shleifer and Vishny (2010), Benigno et al. (2013, 2016), Bocola and Lorenzoni (2017) and Schmitt-Grohé and Uribe (2018).

financial constraints. If there is eventually a negative shock in the economy and the constraint binds, then, the planner relaxes the constraint ensuing welfare benefits for the economy.

The approach followed in the literature on macroprudential policies is to compare the allocations of the decentralized competitive equilibrium to the allocations of social planner. In a similar exercise Jeanne and Korinek (2019a, b) and Korinek and Mendoza (2014), propose a Pigouvian tax on foreign borrowing that could address the externality associated with the leverage cycle.[14] The authors show how a Pigouvian state-contingent tax on debt, which its rate is equal to the wedge between the social and private Euler equations and its revenues are rebated as a lump-sum transfer to households, could alleviate the deviations between the competitive and social planner equilibria.[15] Our analysis above proposes that the optimal design of such prudential taxation should also consider the effects of state-contingent margin requirements on equilibrium allocations and, mainly, on prices.

Specifically, in the asset pricing model of KM, where they assume that prices are an increasing function of the aggregate state of the economy as captured by aggregate consumption, the optimal tax on borrowing that can attain the planner's allocation, is given by:

$$\tau = \frac{\beta R E_t[\lambda_{t+1} \phi p'(c_{t+1})]}{u'(c_{t+1})}$$

In the model with state-contingent margins of section 2, the above expression takes the form, $\tau = \frac{\beta R E_t[\lambda_{t+1}\left(\frac{2\phi}{p}\right) p(c_{t+1}) p'(c_{t+1})]}{u'(c_{t+1})}$; the level of the optimal tax is affected by both expected price changes and levels.

Quantitative results on the optimal magnitude and the effects of a Pigouvian tax could be found in the work of Bianchi and Mendoza (2010, 2018) and Jeanne and Korinek (2019a, b). In their models, taxes are positively correlated with leverage in the unconstraint regime of the economy and reduce once the constraint binds. Calibrated to the surge of capital outflows experienced by the US economy in 2008, they showed that the macro-prudential taxation decreases the probability of capital outflows and also increase the equilibrium asset prices. On the other hand, Schmitt-Grohé and Uribe (2018) in a similar set-up with flow collateral constraints, they show that the optimal policy calls for capital controls to be countercyclical, i.e. to be lowered during expansions and to be increased during recessions.

In addition, complementary "ex-post" policies have been frequently implemented during

[14] Other types of Pigouvian taxes, or with the broader definition of *prudential capital controls*, include the unremunerated reserve requirements (URRs) and capital requirements.

[15] Taxation, as an indirect way of regulating the markets, stems from the idea of Holmstrom and Tirole (1998) that the government has a comparative advantage in providing liquidity, which arises from its unique regalian taxation power.

sudden stop events. Since, agents' borrowing capacity depends on asset prices, the prominent objective of such policies would be to break the spiral effect between debt and asset prices, by mitigating the decrease of the latter.

As some examples of "ex-post" policy interventions, Calvo (2002) proposed asset price guarantees for emerging economies (EMs)[16] and Choi and Cook (2004) proposed a government subsidy that could dampen the feedback loop generated between the procyclical behavior of the recovery rates, used in the valuation of the collateralized assets.

In addition, quantitative easing policies, like the large-scale asset purchase programs or direct capital injections, which were implemented by most central banks during the recent financial crisis, though costly and risky, could directly prop up prices and stimulate real activity.[17] Furthermore, aside to higher supply of assets to indirectly control their prices, central banks could also affect the latter through the margins. Central Bank's lending facilities with low haircuts (e.g. the TALF program) can reduce the required returns of the affected assets and ease the corresponding funding constraints.[18] Ashcraft, Gârleanu and Pedersen (2011) discuss how haircuts has been proved monetary policy tool, as powerful as the interest rates. It is worth adding here that the specification of the collateral constraint is key to evaluate the efficacy of such policies. For example, in a similar environment with credit frictions, Caballero and Farhi (2017) showed that low interest rate and forward guidance policies, the most frequently monetary policy measures to a slowing economy, can stimulate the economy during liquidity traps. On the other hand, Ashcraft, Gârleanu and Pedersen (2011) argued that an interest rate cut may increase the excess return for margin-based asset prices, and, thus amplify the deleverage cycle.

Since both type of policies have being criticized, "ex-post" policies for being time-inconsistent, while "ex-ante" policies for inducing moral hazard and higher risk-taking, researchers are now looking for the optimal policy mix.[19] In any case, policy makers should not neglect the fact that margins, the upper limit of the leverage ratio, is a market price.

[16] Such guarantees allow foreign investors to sell EM's equity holdings either to other agents at the equilibrium market price or to an international agency at the guaranteed price. See, e.g. Durbu and Mendoza (2006).

[17] See e.g. the QE1, QE2 and QE3 programs by FED and the corporate sector purchase programs by ECB.

[18] Ashcraft et al. (2011) showed that after the introduction of the TALF lending facility the yields of the affected securities dropped by 5%.

[19] See e.g. Caballero and Lorenzoni (2014), Dogra (2015) and Jeanne and Korinek (2019a, b).

5 Conclusions

We extended the Korinek and Mendoza (2014) SOE model with collateral constraints by allowing for state-contingent margins. When the margins are negatively related to assets' market liquidity, the model can generate an additional drop of approximately 7% relative to the model with fixed margins. In addition, an optimal macroprudential tax on borrowing would depend both on future price changes and levels.

As a natural extension, we will calibrate the model to the Mexican sudden stop (1994-95) and evaluate its ability to match the moments of asset prices as observed in the data.

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