Fire Sales and Debt Maturity*

Samuel Ligonnière †

BETA, University of Strasbourg

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Abstract

How does debt maturity structure affect fire sales? I show how debt maturity can trigger financial crises by introducing debt maturity in a Fisherian deflation model. In particular, using a stock/flow analysis, I find (i) that an excessive reliance on short-term debt exacerbates the risk of financial crises due to fire sales and (ii) that this risk is driven by a rise in the term premium. I confirm these two testable predictions with an empirical study of data from 69 emerging and developing countries from 1970 to 2017. This shows that debt maturity structure is a good early warning indicator of financial crises, which adds information compared with the level of external debt alone. Overall, this paper shows that the optimal policies against fire sales are determined by balancing current and future solvency concerns, as well as by liquidity concerns.

JEL classification: E44, E5, F34, G01, G28

Keywords: Fire sales, Debt maturity, Fisherian deflation, Stock-flow relationship.

1 Introduction

There is an unambiguous association between the level of private and public debt and financial crises (Schularick and Taylor, 2012; Mendoza and Terrones, 2012; Gourinchas and Obstfeld, 2012). Debt stock

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†BETA-CNRS, University of Strasbourg. Email: ligonniere@unistra.fr

is affected by inflows and outflows, which crucially depend on the balance between short and long-term debt. The former influences current and future debt flows through complete debt service in a given period, while the latter affects both debt flows and stocks in the long term. The current empirical and theoretical literature is rather silent however on stock-flow relationships in debt, with the notable exception of Drehmann et al. (2017) who focus on the lead-lag relationship in household debt between new borrowing and debt service.

This paper aims to fill this gap by answering the following three questions. First, in a Fisher (1933) model of financial crisis, how does debt maturity structure affect fire sales? Second, is the best predictor of a financial crisis the debt level or the debt maturity structure? Third, what is the optimal policy given the stock-flow relationship between debt level and debt maturity?

Fire sales occur when collateral constraints tighten. Collaterals are based on the market value of assets and determine the borrowing ability of economic agents. Agents sell their assets when they are unable to repay their debts and/or when they want to increase their consumption above their borrowing limit. However, if many borrowers act in the same way, this can lead to a well-known feedback loop between binding collateral constraints and decreasing asset prices and agent wealth, as described by Korinek and Mendoza (2014) and Bianchi and Mendoza (2018) among others. These so-called *Fisherian deflation* models consider occasionally binding financial constraints with a pecuniary externality, meaning that decentralized agents do not internalize the effects of their decisions on asset markets. There is therefore a wedge between the private and social marginal utilities of both assets and debt. The conventional result is that the gap can be filled by policy intervention via taxes and subsidies. However, these recent theoretical studies based on Fisher (1933) are mute on the effects of debt maturity structure.

In contrast to the existing literature, I show empirically that a prevalence of short-term debt is a good early-warning indicator of financial crises in developing countries over the period 1970-2017. This indicator has a higher predictive power than debt levels and complements the information obtained from country and year fixed effects. Because of endogeneity issues, I distinguish two cases on the basis of the level and movements in estimated US Treasury term premiums from Adrian et al. (2013). It turns out that debt maturity only affects the probability of crisis when term premiums are high. In other words, (i) debt maturity is a determinant of financial crises, (ii) probably via its effect on term premiums.[1]

I then integrate these two empirical insights into a *Fisherian deflation* model in which domestic

[1]This potentially creates a reverse causality problem, because it could be that debt maturity falls in countries when a crisis is expected. The identification strategy used here avoids this problem: a rise in US Treasury term premiums cannot be attributed to these idiosyncratic risks.

borrowers choose a mix of short and long-term debts, the balance of which can multiply the risk of fire sales because of binding collateral constraints. I show that the debt level and composition chosen by agents follow suboptimal paths, amplifying both liquidity risk (i.e. the rise in term premium) and solvency risk (i.e. the rise in risk premium), and then triggering fire sales. This differs from the social planner's optimal path of debt and more broadly, from the social planner's allocation including capital assets.

The main feature of the model is that the social planner can restore the optimal equilibrium via a set of taxes and subsidies, with all prices and term premiums still market-determined. Following Korinek and Dávila (2018), the social planner taxes debts and subsidizes capital but with two key differences. First, the taxes on debt are both *ex-ante* and *ex-post* policies, close to the results of Jeanne and Korinek (2013) and Bianchi and Mendoza (2018), who focus on moral hazard issues, while I specify the levels of taxes and subsidies at various times. Second, these policies are contingent on three key parameters: (i) the current and future risk of fire sales, (ii) the liquidity concern proxied by the term premium and (iii) the efficiency of capital investment.

Mechanism With only *one-period* debt, the standard literature result holds. Crucially, the decentralized agents are prone to overborrowing. They also underinvest in capital assets, making the collateral constraint more vulnerable to asset fire sales. This financial amplification mechanism works for public, household and firm borrowing, despite obvious differences in their roles. When the debt maturity structure is included, this mechanism still holds, and rational borrowers choose their paths of debt, while lenders distinguish between short and long-term bonds. The concerns about liquidity and solvency risks are indeed quite different. Lenders charge a higher term premium because excessive short-term debt causes liquidity problems and exacerbates the risk of default with a shorter amortization schedule.

Because of the pecuniary externality and the *unanticipated* shock on capital price, the decentralized agents' debt level can lead to both *flow* and *stock* binding collateral constraints. On the one hand, an overreliance on short-term debt tightens the current *flow* collateral constraint, leading to fire sales and an *unanticipated* term premium, which further reduces the agents' debt capacity. An excessive reliance on long-term debt on the other hand, while avoiding the risk of a current binding collateral constraint, generates future binding collateral constraints in the long term. In the worst case scenario with both binding collateral constraints, borrowers repeatedly pay a term premium (from the binding *flow* constraint) and a risk premium (from the binding *stock* constraint).

This stock-flow analysis of debt is key to understanding the likelihood of fire sales occurring. My findings complement those of Drehmann et al. (2017), who identify the relationship between new borrowing and debt service as a new transmission channel for financial crises. Using an empirical methodology close to the one presented in this paper and data from the Bank for International Settlements (BIS) on advanced economies over 1970-2015, the authors show that debt service is a good predictor of financial crises. In contrast, I show that debt maturity structure matters in the developing world. I develop a *Fisherian deflation* model with both short- and long-term debt that balances the benefits of new borrowing against future debt servicing problems. By focusing on low- and middle-income countries, this paper highlights the fact that the borrower is a price-taker on world financial markets, reinforcing the assumptions of the standard model.

Related Literature The model complements the findings of Jeanne and Korinek (2018) and Bianchi and Mendoza (2018), but differs in the channel through which fire sales are generated. The two cited studies do not consider debt maturity structure, probably because they focus on advanced economies (with good access to long-term loans), and identity determinants different from the three factors I describe in this paper: Jeanne and Korinek (2018) highlight the key roles of the collateral constraint parameter and of the vulnerability to a new bust, while Bianchi and Mendoza (2018) put forward the equity premium[2], and the lack of credibility of future policies. As surveyed by Mendoza (2017), recent theoretical investigations based on Fisher (1933) have followed different paths[3], but debt maturity structure has mostly been left unexplored. Jeanne and Korinek (2018) extend their framework by including variable debt maturities, but not multiple concurrent bonds. In contrast, I focus on the stock-flow relationship in debt where an excessive dependence on short- or on long-term debt is possible. This is in line with Zhou (2018). Her small open economy model generates time-varying term premiums through risk-averse international creditors and shocks in their discount factor, whereas I disentangle debt service and debt stock concerns. My results complement hers, as she introduces state-contingent and maturity-dependent capital inflow controls, while I focus on the simultaneous use of both *ex-ante* and *ex-post* policies.

This paper also contributes to the empirical literature on the key determinants of financial crises. The availability of different datasets and methodologies has drawn attention to multiple predictors, such as

[2] Defined as the *"expected excess return on assets relative to bonds"*.

[3] Some such as Bianchi and Mendoza (2018), Jeanne and Korinek (2018) and Korinek and Dávila (2018) link collateral constraint and asset prices, whereas Bianchi (2011), Benigno et al. (2016), Schmitt-Grohé and Uribe (2017), among others, consider collateral constraints that depend on real exchange rates, which in particular trigger sudden stop syndrome in emerging countries. The scope of policy intervention has also been widely discussed: see Benigno et al. (2013), Jeanne and Korinek (2013) and Bianchi and Mendoza (2018) on ex-ante versus ex-post policies; or Korinek and Sandri (2016) on the simultaneous use of capital controls and macroprudential regulation.

domestic credit growth (Schularick and Taylor, 2012; Mendoza and Terrones, 2012); domestic credit and real currency appreciation (Gourinchas and Obstfeld, 2012); the currency composition of debt (Bordo et al., 2010); the level and composition of foreign liabilities (Catão and Milesi-Ferretti, 2014); the relative size of the non-tradable sector (Kalantzis, 2015); domestic asset price bubbles (Jordà et al., 2015); private versus public debt (Jordà et al., 2016); domestic versus foreign credit growth (Cesa-Bianchi et al., 2019); and finally, debt service (Drehmann et al., 2017). The stock-flow relationship in debt is implicit in Catão and Milesi-Ferretti (2014), where the authors show that net external debt is a better predictor than gross external debt. An analogy can be drawn between this article and other recent studies of the determinants of external debt flows. Bianchi et al. (2018) and Qian and Steiner (2017) draw attention to the relation between external debt maturity and the level of international reserves. Focusing on 40 relatively well financially developed economies, Avdjiev et al. (2017a) examine whether external debt characteristics can trigger credit cycles. The authors show that the choice of debt instrument and the type of lender appear to be more important than the currency and the maturity of the external debt, but their sample is different from the one used in the present paper. In addition, my analysis includes global financial forces, whose effect on the risk of financial crises has been quantified by Avdjiev et al. (2017b) and Cerutti et al. (2017). According to Cerutti et al.'s (2019) sensitivity analysis, the foreign lenders' characteristics may be even more relevant that the borrower's fundamentals, and call for a time-varying premium.

Studies of debt maturity are not new to the literature on the banking system (Chang and Velasco, 2000) or sovereign debt (Cole and Kehoe, 1996; Cole and Kehoe, 2000). However, while existing studies analyse how debt levels and debt maturity structure can generate self-fulfilling runs, I investigate an alternative channel. Arellano and Ramanarayanan (2012), Fernández and Martin (2015) and Debortoli et al. (2017), among others, discuss the role of debt maturity in sovereign debt crises. In contrast with the collateral constraint considered in the present paper, the source of financial friction in their study is a limited commitment to repayment. Following Broner et al. (2013), the sovereign debt literature on the trade-off between short- and long-term debt considers two main channels. Demand-side arguments emphasize the "disciplinary" role of short-term debt in reducing the incentive to dilute debt (Jeanne, 2009), while supply-side arguments stress the potential uncertainty and loss of information about default probabilities over longer timescales, requiring the inclusion of a positive term premium. Arellano and Ramanarayanan (2012) and Broner et al. (2013) confirm that emerging countries favor short-term debt, especially during crises, because of higher spreads. This is in line with the feedback loop between liquidity and solvency concerns, which is included in the theoretical model developed in this paper.

The remainder of the paper is structured as follows. Section 2 describes the empirical strategy and shows that debt maturity structure is a good predictor of financial crises. Section 3 presents the baseline model and describes debt maturity structure. Section 4 analyzes the social planner's optimal intervention policy. Section 5 concludes.

2 Empirical Analysis: the Role of Debt Maturity Structure

The purpose of this paper is to identify how debt levels and term structures affect the likelihood of financial crises at the country-level. This section first provides details on the data sources used, including on the various types of debt inflows and outflows. Second, I show how an excessively short-term oriented debt maturity structure can be a good early-warning indicator of financial crises.

The unbalanced panel database used for this analysis consists of 69 countries from 1970 to 2017 with 39 years per country on average.[4] Table A.1 in the Appendix lists the countries included, while Table A.2 and Table A.3 give the data sources and descriptive statistics. The long-time coverage is sufficient to identify regularities with various maturity mismatches. The sample covers almost all emerging countries and some relevant developing economies, in contrast with the existing literature that focuses mainly on advanced economies, as in Schularick and Taylor (2012) and Cesa-Bianchi et al. (2019). The use of specific control variables ensures that the fire sales mechanism is in play: I only consider countries with considerable private debt and in which the debt relationship works through market mechanisms. Another reason to include these control variables is that debt maturity structure should be more or less sensitive to international financial markets depending on the depth of domestic financial markets and the country's credibility.

2.1 Data

Financial Crises Defining precise dates for asset fire sales is quite challenging. Campbell et al. (2011) and Bian et al. (2018) use high-frequency microeconomic data, while the well-known dataset of Laeven and Valencia (2018) is widely used to assess systemic banking, currency and sovereign debt crises from 1970 to 2012. About 3.4% (92) of the sample are systemic banking crises. I assume that systemic banking crises are closely linked to the fire sales mechanism. Alternatively, I could have used banking crises, systemic banking crises and stock market crashes as defined by Reinhart and Rogoff (2009) and Reinhart

[4]This mean is for regressions that include the 5 year lag of each variable, following the baseline specification.

et al. (2016).

External Debt: Stock-Flow Relationship & Market Mechanisms I use the *International Debt Statistics* from the World Bank, as recently used by Qian and Steiner (2017). They provide a wide range of information. First, they distinguish public and publicly guaranteed debt (PPG), private non-guaranteed debt (PNG) and IMF credit. Second, they distinguish (i) stock and net flows, (ii) debt service and new debt, (iii) principal and interest payments. Third, the debt is also decomposed into short- and long-term components. I use the proportion of short-term external debt in the total stock of external debt as the main explanatory variable. Contrary to the ratio of short-term external debt relative to GDP as used by Gourinchas and Obstfeld (2012), this measure assesses debt structure directly.

I also use the ratio of debt stock over gross national income, distinguishing between PPG, PNG and IMF credit. This distinction allows the potential role of private debt, which is related to fire sales, to be investigated. In addition, the data from the World Bank include the stock of debt owed to multilateral creditors and the level of debt forgiveness grants, distinguishing between market mechanisms and multilateral processes.

The Global Financial Cycle Another key consideration for fire sales is international financial forces, because international lenders are susceptible to various shocks. International financial crises and even domestic economic crises may play a role through multiple channels, such as cross-border bank flows and volatile risk premia. Various measures could be used, such as the VIX (Rey, 2015), but Adrian et al.'s 2013 method is the most suitable for this analysis, as it provides a global risk premium from US Treasury bond yields. I generate a dummy to identify the threshold value of this risk premium that triggers the transmission channel. This dummy is equal to 1 if the risk premium is higher than the median of the distribution (i.e. 2).

2.2 Sources of Financial Instability: Debt Size & Debt Maturity

The empirical setting used follows the current literature on the early-warning indicators of financial crises, notably the seminal paper by Schularick and Taylor (2012) and more recently Cesa-Bianchi et al. (2019). I investigate debt maturity structure as a predictor for systemic banking crises, which sheds light on the causal link between debt maturity structure and fire sales. The dependent variable is a dummy equal to 1 when a systemic banking crisis occurs. I use a logit model of systemic banking crises with the following specification:

$$logit(p_{it}) = \sum_{s=1}^{5} \beta_{it-s} \frac{ST}{ST+LT}_{it-s} + \sum_{s=1}^{5} \delta'_{it-s} X_{it-s} + \alpha_i + \gamma_t + \epsilon_{it} \quad (1)$$

where $\frac{ST}{ST+LT}_{it}$ is the ratio of the short-term external debt stock over the total external debt stock, $logit(p) = ln(p/(1-p))$ is the log of the odds ratio and X_{it} is a vector of control variables that includes external debt stock, debt reduction and the share of multilateral creditors. Following formal lag selection procedures (AIC and BIC), I consider five annual lags for all variables, in keeping with Schularick and Taylor (2012), Drehmann and Juselius (2014) and Cesa-Bianchi et al. (2019). α_i denotes country fixed effects, and γ_t are year dummies. The presence of country fixed effects captures the specific behavior and reputation of particular developing countries. The global trend captured by year fixed effects, for both risk and term premia, clearly determines the likelihood of financial crisis, in line with Rey (2015), Cerutti et al. (2019) and Avdjiev et al. (2017b).

Table 1: External debt level and structure

	Dependent variable: Systemic Banking Crisis. Logit Estimates.							
							US Term Premium	
							> 2	< 2
Sum of 5 lags	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\frac{ST}{ST+LT}$	3.800*		3.602*	4.398**	4.274*		8.835**	-1.982
	(1.972)		(2.028)	(2.136)	(2.195)		(3.499)	(4.888)
$\frac{Debt\ Stock}{GNI}$		-0.190						
		(0.237)						
$\frac{Public\ (PPG)\ Debt\ Stock}{GNI}$			-0.460		-0.289	-0.287	-0.205	-1.712*
			(0.337)		(0.487)	(0.473)	(1.098)	(0.755)
$\frac{Private\ (PNG)\ Debt\ Stock}{GNI}$			3.854*		5.051**	4.772**	3.962	4.294
			(2.258)		(2.551)	(2.437)	(6.485)	(3.674)
$\frac{IMF\ Credit}{GNI}$				-3.390	-3.753	-4.366	-7.166	-3.015
				(5.258)	(6.277)	(6.180)	(12.04)	(10)
Multilateral Creditors (%)				-2.622	-2.202	-2.550	-1.632	-4.286
				(1.787)	(1.875)	(1.854)	(2.919)	(4.700)
$\frac{Debt\ Reduction}{GNI}$				19.73**	26.83**	25.48**		
				(8.122)	(10.72)	(10.45)		
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	2691	2691	2691	2691	2691	2691	913	772
Countries	69	69	69	69	69	69	43	39
Pseudolikelihood	-234.3	-240.8	-230.6	-225.3	-221.4	-226.9	-98.21	-66.76
R^2	0.260	0.239	0.272	0.288	0.301	0.283	0.311	0.471
AUROC	0.842	0.815	0.848	0.847	0.853	0.847	0.818	0.891
Standard error	0.0145	0.0156	0.0146	0.0133	0.0134	0.0137	0.0232	0.0165

Standard errors in parentheses. Following formal lag selection procedures, I consider five lags of all variables. Table A.4 gives the complete specification with all lags. *, ** and *** respectively indicate significance at the 10, 5 and 1% levels.

Table 1 reports the baseline logit specification. The explanatory variable for Column (1) is debt maturity structure, while column (2) analyzes the potential predictive ability of debt stock. Columns (3) to (5) go one step further by investigating multiple variables. Table 1 shows that debt maturity is a strong predictor of financial crisis: a reliance on short-term debt triggers financial vulnerability. The results are quantitatively similar whatever the specification used. I therefore adopt column (5) as the baseline model.

Regarding other control variables, Table 1 also reveals that the ratio of external private debt stock over gross national income is positively associated with the likelihood of financial crisis. This is in line with the recent literature (Schularick and Taylor, 2012; Cesa-Bianchi et al., 2019) but the focus here is on emerging countries and a set of sufficiently advanced developing countries. The share of debt owed to multilateral creditors and the ratio of debt reduction over gross national income help to effectively capture all non-market mechanisms.

The predictive power of the models were evaluated using receiver operating characteristic (ROC) curves. This has been a common approach in the field since Schularick and Taylor (2012). The area under the ROC curve (AUROC) varies between 0 and 1 and is a simple measure of the predictive power of the indicator. An AUROC equal to 0.5 means that the variable is completely uninformative, whereas an AUROC of 1 would mean here that the corresponding early-warning indicator is a perfect predictor of future financial crisis. The ROC results in Table 1 therefore show that debt maturity structure is a better early-warning indicator of financial crisis than debt level.

Endogeneity Issues Since the information contents of debt level and debt maturity structure differ, there is an endogeneity problem in identifying the underlying mechanism linking debt maturity to financial crises. If the term premium is too high because of world or country-specific factors, the country is more likely to borrow short-term. In other words, the mechanism works differently if a country is unwilling or unable to access long-term debt. Columns (7) and (8) treat this endogeneity problem specifically by controlling for the US Treasury term premium (Adrian et al., 2013). The two columns compare subsamples with high and low values of the term premium. Debt maturity structure only drives the dynamics of financial vulnerability if the estimated term premium is > 2. To sum up, Table 1 indicates that debt maturity structure is associated with financial crisis, which is predicted by a high proportion of short-term debt. This result creates a reverse causality problem if it is the prospect of a financial crisis that constrains the borrowing countries to short-term debt, rather than the other way round. However, using the US treasury term premium sharply reduces this concern.

Table 1 is globally consistent with the theoretical framework that generates a wedge between the decentralized equilibrium and the social planner's allocation. The former involves too much borrowing, which generates a term and risk premia, whereas the social planner aims for the optimal path of debt.

Quantification To document the role of debt maturity structure in financial crises, I estimated the predicted probability of the baseline model (column (5)) with all the control variables.[5] Table 2 provides this probability by differentiating between true-positive and false-positive signals of financial crisis. Out of the 92 financial crises the average probability is around 11 percent. This is four times higher than for cases in which no financial crisis occurred.

Table 2 also reports the results of a counterfactual exercise similar to Kalantzis's 2015. I compare the predicted probabilities of the models with and without the debt maturity structure variable (column (5) and column (6), respectively). Debt maturity structure significantly improves the probability of predicting a financial crisis, by 0.9 percentage points on average. In contrast, the false-positive rates with the two models are identical.[6] Looking into specific cases, Table 2 lists the true and false positives with the highest predicted probabilities of financial crisis. Omitting the debt maturity structure substantially reduces the accuracy of the predictions. The gap between the predicted and counterfactual probabilities is as high as 16 percentage points, and about 10 percentage points in four other cases.

[5] An alternative approach, used by Catão and Milesi-Ferretti (2014), would have been to maximize the ratio of true to false positives to define an optimal threshold.

[6] Figure A.1 in the Appendix shows the difference for all cases.

Table 2: Counterfactual probability of crises without the debt maturity structure

	Nb.	Predicted	Counterfactual	|Difference|
True-Positive Signal	92	0.106	0.097	0.025
False-Positive Signal	2599	0.023	0.023	0.006

Country	Year	Predicted	Counterfactual	Difference
		True-Positive Signal		
Nicaragua	2000	0.852	0.831	0.021
Kazakhstan	2008	0.39	0.42	-0.04
Ukraine	2014	0.364	0.379	-0.015
Guyana	1993	0.325	0.234	0.091
Russia	2008	0.308	0.182	0.126
Paraguay	1995	0.302	0.232	0.07
Ukraine	2008	0.291	0.167	0.124
Niger	1983	0.27	0.107	0.163
Moldova	2014	0.252	0.154	0.098
Costa Rica	1994	0.181	0.145	0.036
		False-Positive Signal		
Swaziland	1998	0.653	0.359	0.294
Romania	1995	0.61	0.384	0.226
Yemen	1995	0.512	0.441	0.071
Moldova	1998	0.408	0.461	-0.053
Mongolia	1997	0.34	0.272	0.068
Russia	1997	0.314	0.276	0.038
Sierra Leone	1994	0.306	0.295	0.011
Bulgaria	1998	0.287	0.232	0.055
Romania	1994	0.279	0.195	0.084
Mongolia	1998	0.275	0.283	-0.08

The sample covers 92 financial crises. The second part of this table only reports the 20 cases with the highest probability of financial crisis.

Furthermore, the high predicted probability for false-positive signals does not necessarily imply model failure, for three reasons. First, the dates in the country-year pairs can be misleading, with a financial crisis occurring in Yemen and Romania respectively one year and three years later than listed in Table 2. Second, some of these cases are likely driven by year fixed effects; indeed, Rey (2015) and Cesa-Bianchi et al. (2019) suggest that the probability of financial crises in emerging countries increases substantially with the strength of the global financial cycle. Third, it could be that the model also predicts currency and/or sovereign debt crises, as occurred in Mongolia and Yemen. These three types of crises are closely intertwined, which leads to false positives.[7]

Robustness Tests The robustness of these results is investigated in the appendix. Table A.5 controls for the duration of the crisis,[8] and Table A.6 includes additional control variables. The results are unaffected

[7]The mechanism linking debt maturity structure to financial crisis may also play a role in other types of crises. The analyses with currency and debt crises as additional control variables and as alternative dependent variables are shown in the appendix.

[8]Caggiano et al. (2016) highlight a *crisis duration bias* in the literature.

by controlling for (i) the level of international reserves, (ii) other types of crises (currency and debt crises), (iii) GDP growth and (iv) a proxy for currency mismatch problems. Finally, Table A.7 presents sensitivity analyses to different measures of financial crises. While the dating of banking crises is likely to have a first order effect on the results, the same results are obtained when alternative data (Laeven and Valencia, 2018; Reinhart et al., 2016) are used. The currency crisis variable is used as a falsification test, since the underlying mechanism is more related to banking crises.[9]

3 Baseline Model

The model borrows from previous *Fisherian deflation* models of financial crises, notably Korinek and Dávila's (2018). I consider a small open economy in which the agents, i are either domestic borrowers (B) or international savers (S)[10] ($i \in B, S$). Borrowers are potentially more productive than savers in their use of capital but are subject to collateral constraints that may lead to fire sales. As is common in this literature, market failure generates a difference between the decentralized equilibrium and the social planner's choice, which justifies policy intervention. While most studies of *Fisherian deflation* consider one-period debt, this model includes debt maturity structure.

3.1 Economic Environment

I consider a discrete time framework with three periods: $t = 0, 1, 2$. Each agent i's consumption of homogeneous goods, c_t^i, varies according to a time separable utility function

$$U^i = \mathbb{E}_0 \sum_{t=0}^{2} \beta^t u^i(c_t^i) \tag{2}$$

where the utility function $u^i(.)$ is a standard concave twice-continuously differentiable function that satisfies the Inada condition and β is the time-discount factor. Agents receive an endowment of consumption goods in each period, with e_t^i the endowment of consumption goods received by agent i in period t. Both sets of agents consume the homogeneous good, which serves as numeraire and can be transformed into a capital asset at price q_t. At date 0, agent i receives a stock of capital assets k_0^i and decides how much to invest or disinvest in the new period at price q_0. At date 1, all the current capital, k_1^i, is used to

[9]I expected the reliance on short-term debt to be associated with the likelihood of stock market crashes, but this is not the case, maybe because of the year dummies or the limited sample size.

[10]This could be extended to the framework used by Korinek and Sandri (2016), with domestic borrowers, domestic savers and a large set of international agents who trade bonds with both types of domestic agents. In both cases, the economy is a price taker on world financial markets.

produce $F_1^i(k_1^i)$ units of consumption good, where F is a concave, strictly increasing and continuously differentiable production function that satisfies $F^i(t) = 0, \forall t$. Following the literature on fire sales, I assume that borrowers have better production technology than savers. The agents decide how much to invest or disinvest in the new period at price q_1. At date 2, agent i's capital k_2^i produces $F_2^i(k_2^i)$ units of consumption goods. Capital is worthless after this date and fully depreciates.

The two agents trade bonds. At date 0, they have access to two bonds b_{01} and b_{02} denominated in terms of the homogeneous good, where $b < 0$ corresponds to borrowing. They also have initial bond holdings b_0^i.[11] The short-term bond b_{01} matures in period 1 with a gross interest rate R_{01}, while the long-term bond b_{02} matures in period 2 with a gross interest rate R_{02}. At date 1, the agents have access to a new short-term bond b_{12} with a gross interest rate R_{12}.

Agent i's budget constraints are given by

$$c_0^i + q_0(k_1^i - k_0^i) + \frac{b_{01}^i}{R_{01}} + \frac{b_{02}^i}{R_{02}} = e_0^i + b_0^i \quad (3)$$

$$c_1^i + q_1(k_2^i - k_1^i) + \frac{b_{12}^i}{R_{12}} = e_1^i + b_{01}^i + F_1^i(k_1^i) \quad (4)$$

$$c_2^i = e_2^i + b_{02}^i + b_{12}^i + F_2^i(k_2^i) \quad (5)$$

Collateral Constraints: Flows and Stocks Financial market imperfections that constrain borrowers' choices are commonly represented by occasionally binding financial constraints that link bond stocks and capital prices. Financial friction has to be included in the model because of moral hazard problems between lenders and borrowers. Lenders have inexact knowledge of borrowers' ability to repay their debts and I assume that lenders can only access a fraction Φ of the value of their capital asset holdings in periods 0 and 1. The current literature links one-period debt and current collateral, whereas I explicitly include the debt maturity structure and the stock-flow relationship. To avoid defaults, lenders impose the following *stock* collateral constraints

$$\frac{b_{01}^B}{R_{01}} + \frac{b_{02}^B}{R_{02}} > -\Phi q_0 k_1^B \quad (6)$$

$$\frac{b_{02}^B}{R_{02}} + \frac{b_{12}^B}{R_{12}} > -\Phi q_1 k_2^B \quad (7)$$

Because of potential differences in moral hazard, lenders generally distinguish short and long-term bonds,

[11] The endowments and the initial bond holdings are distributed in such a way that in periods 0 and 1, borrowers find it optimal to borrow and savers find it optimal to save.

for which the concerns about liquidity and solvency risks differ. At date 0, lenders anticipate that the current value q_0 of the borrowers' capital assets and their current accumulated capital k_1^B act as collateral if the borrowers default on their short-term debt. Thus, I assume that lenders also impose the following *flow* constraint

$$\frac{b_{01}^B}{R_{01}} > -\kappa q_0 k_1^B \tag{8}$$

Tightening of the stock constraints (6)-(7) yields a risk premium, while tightening of the liquidity constraint (8) yields a positive term premium between the two interest rates R_{01} and R_{02}. Lenders charge a term premium because excessive short-term debt creates liquidity problems and exacerbates the risk of default with a shorter amortization period. There is no such liquidity constraint at date 1 because all debts (i.e. short-term bonds issued at date 1 and long-term bonds issued at date 0) are repaid at date 2. κ and Φ are pledgeability parameters that determine the level of market incompleteness, with $(\kappa, \Phi) \in [0,1]^2$. The set of parameters $\{\kappa, \Phi\}$ allows the distinction between short and long-term debt.[12] For each feasible $\{\kappa, \Phi\}$ combination, there are four possibilities: (i) none of the constraints are binding; (ii) only the debt flow constraint is binding; (iii) only the debt stock constraint is binding; (iv) both constraints are binding.

The borrowers' mix of short and long-term bonds contributes to financial amplification. Figure 1 summarizes the feasible states, with a term premium at date 0 and risk premia at dates 0 and 1. If one or more of the collateral constraints in period 0 are binding, the stock collateral constraint in period 1 is generally binding but not necessarily. Indeed, the production borrowers' production function F_1^B and the endowment e_1^B may be large enough to avoid additional overborrowing and/or fire sales.

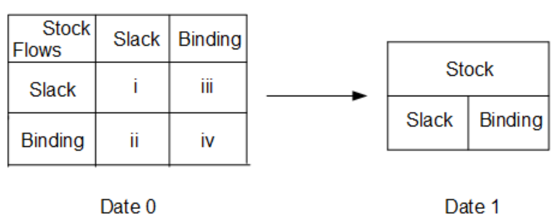

Figure 1: Set of possible states

[12] If $\kappa > \Phi$, the choice between the two types of debt is not really *free*. The high availability of short-term debt reduces access to long-term debt.

3.2 Decentralized Equilibrium

The decentralized equilibrium consists of the set of allocations $(c_0^i, c_1^i, c_2^i, k_1^i, k_2^i, b_{01}^i, b_{02}^i, b_{12}^i)$ and prices $(q_0, q_1, R_{01}, R_{02}, R_{12})$ in which each agent $i \in \{B, S\}$ solves his optimization problem and all markets clear[13]

$$\sum_i b_{01}^i = \sum_i b_{02}^i = \sum_i b_{12}^i \tag{9}$$

Following Korinek and Sandri (2016) and Korinek and Dávila (2018), the decentralized equilibrium is solved by backward induction. The impact of uncertainty on the economy (i.e. on potential binding flow and stock collateral constraints) is fully captured by the financial net worth n_0^i in period 0 and by the financial net worth n_1^i and the capital holdings k_1^i in period 1, which are given by

$$n_0^i = e_0^i + b_0^i + k_0^i \tag{10}$$

$$n_1^i = e_1^i + b_{01}^i + b_{02}^i + F_1^i(k_1^i) \tag{11}$$

In other words, there is no shock but agents suffer a pecuniary externality. If either or both of the collateral constraints are binding because of these fire sales, they will not be perfectly anticipated at decision time by the borrowers, who will not make the correct decisions.

Date 2 Equilibrium All agents consume the homogeneous good and settle their bond positions, regardless of any previous binding collateral constraint.

Date 1 Equilibrium The problem solved by the agents, who behave competitively and take prices as given, is as follows

$$V^i(n_1^i, k_1^i) = max\ u^i(c_1^i) + \beta u^i(c_2^i) \quad \text{subject to} \quad (4), (5) \text{ and } (7) \tag{12}$$

where λ_1^i, λ_2^i and μ_2^i respectively denote the Lagrange multipliers on the budget constraints (4), (5) and on the collateral stock constraint (7). By construction, μ_2^S is equal to zero.

As is often the case in the field, the resulting Euler equation for bonds and the optimal capital

[13] I assume that this equilibrium is unique. See Schmitt-Grohé and Uribe (2016) and Jeanne and Korinek (2018) on the possibility of multiple equilibria.

accumulation decisions are

$$\lambda_1^i = R_{12}\lambda_2^i + \mu_2^i \quad \text{with} \quad \lambda_1^i = U_1^{\prime i} \quad \text{and} \quad \lambda_2^i = \beta U_2^{\prime i} \tag{13}$$

$$q_1 = \frac{\lambda_2^i F_2^{\prime i}(k_2^i)}{\lambda_1^i - \Phi\mu_2^i} = \frac{F_2^{\prime i}(k_2^i)}{R_{12} + \frac{\mu_2^i}{\lambda_2^i}(1-\Phi)} \tag{14}$$

Equation (13) is the standard Euler equation weighing up the marginal benefit of higher consumption today against the marginal cost of lower consumption tomorrow. The additional term μ^i is always equal to 0 for lenders, whereas borrowers may be subject to a binding stock collateral constraint. As usual in this literature, this term increases the marginal benefit of higher current consumption of the capital good, which relaxes the collateral constraint. Equation (14) characterizes capital price. If the collateral constraint is slack, the price q_1 is given by a standard Euler equation for assets whereby it equals the marginal product of capitaldiscounted by the marginal rate of substitution. In turn, this provides a relationship between capital price and interest rate. If instead, the collateral constraint is binding, the effect on capital prices is ambiguous. Looking at the middle expression in equation (14), which is close to Korinek and Mendoza (2014), while on the one hand, the marginal rate of substitution falls, on the other, the denominator is reduced by the extra term. This reduces the borrowers' disutility $U_2^{\prime B}$ by relaxing the collateral constraint. In the right-hand expression in equation (14), the balance of these two effects is quantified by the parameter Φ, which reflects the strength of financial amplification. At equilibrium, the optimal conditions (13) and (14) yield the capital price q_1 and the interest rate R_{12}.

Date 0 Equilibrium In the same way, agent i takes prices as given, and solves

$$max \ u^i(c_0^i) + \beta\mathbb{E}_0 V^i(n_1^i, k_1^i) \quad \text{subject to} \quad (3), (6) \text{ and } (8) \tag{15}$$

where λ_0^i, μ_1^i and η_1^i are the Lagrange multipliers on the budget constraint (3), on the stock collateral constraint (6) and on the flow collateral constraint (8), respectively. Again, by construction, μ_1^S and η_1^S are equal to zero.

As in Korinek and Dávila (2018), the term $V_{n1}^i := \frac{\partial V^i}{\partial n_1^i}$ represents the private marginal utility of wealth and likewise V_{k1}^i for capital goods. Using the envelope conditions $V_{n1}^i = \lambda_1^i$ and $V_{k1}^i = \lambda_1^i q_1$, maximisation yields

$$\lambda_0^i = \beta R_{01}\mathbb{E}_0(\lambda_1^i) + \mu_1^i + \eta_1^i \quad \text{with} \quad \lambda_0^i = U_0^{\prime i} \tag{16}$$

$$\lambda_0^i = \beta R_{02}\mathbb{E}_0(\lambda_1^i) + \mu_1^i \tag{17}$$

$$q_0 = \frac{\beta\mathbb{E}_0\left[\lambda_1^i(F_1^{\prime i}(k_1^i) + q_1)\right]}{\lambda_0^i - \Phi\mu_1^i - \kappa\eta_1^i} \tag{18}$$

These conditions are similar to the previous ones, with equations (16) and (17) for the two types of bonds and equation (18) for capital. Two differences are apparent compared with the equilibrium for period 1. First, the two Euler equations for bonds can only be combined to deliver the no-arbitrage condition if the flow collateral constraint is binding.

$$R_{02} = R_{01} + \frac{\eta_1^i}{\beta\mathbb{E}_0(\lambda_1^i)} \tag{19}$$

Second, the Euler equation (18) at date 0 includes the remaining amount of capital q_1 as an additive term. It also includes the benefit of relaxing both the stock and the flow collateral constraints.

Proposition 1 *From a positive perspective, the model provides two main theoretical predictions that are in line with the previous empirical exercise: (i) that excessive levels of debt trigger fire sales through binding collateral constraints; (ii) that the bulk of the impact of debt on fire sales comes from short-term debt. A tightening of the flow collateral constraint generates a positive term premium in equation* (19)*, which reinforces the feedback loop between equations* (16) *and* (18)*.*

4 Normative Analysis

The pecuniary externality generated by the presence of the capital price in the collateral constraints may result in fire sales, which generally lead to a suboptimal decentralized equilibrium. The benevolent social planner internalizes this pecuniary externality in periods 0 and 1. First, he chooses allocations for date 0 and date 1, recognizing that all prices are market-determined. The optimal allocation is then restored in the decentralized equilibrium through a set of taxes on short and long-term debts and subsidies for capital.

4.1 Social Planner's Allocation

The outcome of the social planner problem is close to the decentralized equilibrium at date 0, with two key exceptions. First, the planner directly includes the pecuniary externality in the form of two implementability constraints at dates 0 and 1, namely the Euler equations for capital (14) and (18). This allows him to internalize the interdependencies between dates 0 and 1. For instance, excessively contracting long-term bonds at date 0 avoids fire sales at date 0 but generates them at date 1. As a result, the planner chooses the optimal allocation for dates 0 and 1, which in turn provides the one for date 2, in contrast with Korinek and Sandri (2016) and Korinek and Dávila (2018).[14]

Because the savers are unconstrained and hence behave optimally[15], I focus on the borrowers' behavior, which is another difference between this study and the two previous ones.

$$max\ u^B(c_0^B) + \beta\mathbb{E}_0 V^B(n_1^B, k_1^B) = u^B(c_0^B) + \beta u^B(c_1^B) + \beta^2 u^B(c_2^B) \quad \text{subject to (3)-(8), (14) and (18)} \tag{20}$$

where λ_t^{SP}, μ_t^{SP}, η_1^{SP} and ξ_t^{SP} are the Lagrange multipliers in period t for the social planner on the budget constraints, on the stock and flow collateral constraints and on the implementability constraints, respectively. The social planner's optimum differs from the decentralized equilibrium in several ways.

First of all, the optimal conditions with respect to consumption of the homogeneous good become

$$\lambda_0^{SP} = U_0^{'B} - \underbrace{\xi_0^{SP} q_0 \Omega_0 U_0^{''B}}_{Intra.\ arbitrage} \tag{21}$$

$$\lambda_1^{SP} = \beta\mathbb{E}_0(U_1^{'B}) - \underbrace{\xi_1^{SP}\mathbb{E}_0\left[q_1\Omega_1 U_1^{''B}\right]}_{Intra.\ arbitrage} + \underbrace{\xi_0^{SP}\beta\Omega_0\mathbb{E}_0\left[U_1^{''B}(F_1^{'B}(k_1^B) + q_1)\right]}_{capital\ accumulation} \tag{22}$$

$$\lambda_2^{SP} = \beta^2\mathbb{E}_0(U_2^{'B}) + \underbrace{\xi_1^{SP}\beta\mathbb{E}_0\left[\Omega_1 U_2^{''B} F_2^{'B}(k_2^B)\right]}_{capital\ accumulation} \tag{23}$$

with $\Omega_0 = \frac{1}{U_0^{'B} - \Phi\mu_1^B - \kappa\eta_1^B}$ and $\Omega_1 = \frac{1}{U_1^{'B} - \Phi\mu_2^B}$. At date 0, there is a wedge between the optimal private (16) and social (21) conditions that reflect the marginal utility of consumption because the social planner accounts for the risk of potential fire sales and values capital assets more than the consumption good.

[14] Korinek and Sandri (2016) and Korinek and Dávila (2018) include the pecuniary externality by distinguishing between individual state variables (n^i, k^i) and sector-wide aggregate state variables (n^i, k^i). However, this approach is difficult for the debt maturity structure. This paper introduces the pecuniary externality through implementability constraints, an approach close to Bianchi and Mendoza (2018) and Schmitt-Grohé and Uribe (2017).

[15] Nevertheless, fire sales could potentially lead to wealth redistribution between the two types of agents through *distributive externalities* as described by Korinek and Dávila (2018). For simplicity, I leave this question and the associated potential distortions aside. See Jeanne and Korinek (2013) for ex-post policies financed by savers.

This effect is conditional on the degree of concavity of the consumption function. Because $U_t''^B < 0$ and $\xi_t^{SP} > 0$ for $t \in \{0,1\}$, goods consumption is lower at date 0 in the social planner's allocation than in the decentralized equilibrium if $\xi_t^{SP} > 0$. Lastly, goods consumption is also reduced by the potentially binding stock and flow collateral constraints through Ω_0 and the capital price q_0 (equation (18)). Positive term and risk premia at date 0 effectively increase the risk of immediate fire sales.

Consider now the differences between the private (13) and social (22) conditions. Consumption at date 1 as defined by the social planner includes two new terms.[16] The first term follows from the same considerations as in the previous period and includes the risk of potential fire sales at date 1 through the capital price q_1 and Ω_1. The second term represents the positive role of previous capital accumulation for current consumption as well as for sales and in the production function. It reduces the wedge in goods consumption between the decentralized equilibrium and the social planner's allocation. Finally, the net effect of these two terms on consumption at date 1 is uncertain and depends on intertemporal arbitrage. Rearranging (22) sheds light on the sign of the shadow values ξ_1^{SP} and ξ_0^{SP}.

$$\lambda_1^{SP} = \beta \mathbb{E}_0(U_1'^B) - \underbrace{(\xi_1^{SP}\Omega_1 - \xi_0^{SP}\beta\Omega_0)\mathbb{E}_0\left[q_1 U_1''^B\right]}_{\textit{Inter. arbitrage}} + \xi_0^{SP}\beta\Omega_0\mathbb{E}_0\left[U_1''^B F_1'^B(k_1^B)\right] \tag{24}$$

where the difference $\xi_1^{SP}\Omega_1 - \xi_0^{SP}\beta\Omega_0$ compares how highly the social planner values the potential risk of fire sales in the two periods. If the difference is negative, the term that reflects this intertemporal arbitrage has the same effect as capital accumulation. Goods consumption in period 1 is therefore higher in the social planner's allocation. However, if the inequality is positive, the net impact of these terms is ambiguous and depends on the relative strength of the effects of the risk of fire sales and previous capital accumulation. It is also useful to contrast the date 2 conditions (13) and (23), which highlight the social benefit of higher capital accumulation at date 1.

Furthermore, the optimal capital accumulation decisions according to the social planner's allocation are

$$q_0 = \frac{\mathbb{E}_0 \overbrace{\left[\lambda_1^{SP}(F_1'^B(k_1^B) + q_1)\right]}^{\textit{Externality term}} + \overbrace{\xi_0^{SP}\beta\Omega_0\mathbb{E}_0\left[U_1'^B F_1''^B(k_1^B)\right]}^{\textit{Decreasing returns}}}{\lambda_0^{SP} - \Phi\mu_1^{SP} - \kappa\eta_1^{SP}} \tag{25}$$

$$q_1 = \frac{\mathbb{E}_0\left[\lambda_2^{SP} F_2'^B(k_2^B)\right] + \xi_1^{SP}\beta\mathbb{E}_0\left[\Omega_1 U_2'^B F_2''^B(k_2^B)\right]}{\lambda_1^{SP} - \Phi\mu_2^{SP}} \tag{26}$$

[16] Substituting (16) into (13) makes the first term in (13) the same as the one in (22). Both reflect the private marginal utility of consumption and are discounted in the same way.

Again, comparing the private (14)-(18) and social decisions (25)-(26) highlights differences in the two periods. First, the social planner induces redistribution between consumption of goods and capital through the term labeled *Externality term* in equation (25). This mechanism normally supports capital prices but depends on the values of the shadow prices. Second, this effect in favor of capital is balanced by decreasing returns to scale in the production function. These two competing effects can generate lower capital prices in the social planner's allocation than in the decentralized equilibrium, as suggested by Korinek and Dávila (2018). Because of the focus on inefficient fire sales, I assume that the social planner's allocation reduces the risk of overborrowing and generates an higher capital price than in the decentralized equilibrium.

Proposition 2 *From a normative perspective, the social planner evaluates the potential risk of fire sales in the current and future periods. The level of debt and the balance between consumption goods and capital depend on (i) the current risk of fire sales, (ii) the risk of fire sales in the next period and (iii) the level and effectiveness of previous capital accumulation.*

Finally, the optimal Euler conditions for bonds are close to those in the decentralized equilibrium, the difference coming from the wedge between the Lagrange multipliers (13)-(16) for the decentralized equilibrium and (21)-(22)-(23) for the social planner.

$$\lambda_0^{SP} = R_{01}\mathbb{E}_0(\lambda_1^{SP}) + \mu_1^{SP} + \eta_1^{SP} \tag{27}$$

$$\lambda_0^{SP} = R_{02}\mathbb{E}_0(\lambda_1^{SP}) + \mu_1^{SP} \tag{28}$$

$$\lambda_1^{SP} = R_{12}\lambda_2^{SP} + \mu_2^{SP} \tag{29}$$

4.2 Implementation via Taxes

I show based on these differences that the social planner's allocation can be recovered using a set of taxes and subsidies. The debt level is taxed at dates 0 and 1 to avoid overborrowing and capital investments are subsidized. Tipping the balance between consumption and capital assets toward the latter reduces the risk of fire sales. The social planner implements (i) taxes on short-term bonds, τ_0^{ST} and τ_1^{ST}, (ii) a tax on long-term bonds, τ_0^{LT} and (iii) subsidies for capital investments, τ_0^k and τ_1^k. $\tau^{ST} > 0$ and $\tau^{LT} > 0$ represent taxes, while $\tau^k > 0$ represents a subsidy. The intervention policy assumes that the government budget is balanced in each period t, with lump-sum transfers T_t.[17]

[17] I also assume that there is no time inconsistency problem. The potential break between policies under commitment and under discretion is widely debated, see Bianchi and Mendoza (2018) and Jeanne and Korinek (2018).

The borrower's budget constraints at date 0 and 1 are now

$$c_0^B + q_0(1-\tau_0^k)(k_1^B - k_0^B) + \frac{b_{01}^B}{R_{01}}(1-\tau_0^{ST}) + \frac{b_{02}^B}{R_{02}}(1-\tau_0^{LT}) + T_0 \;=\; e_0^B + b_0^B \tag{30}$$

$$c_1^B + q_1(1-\tau_1^k)(k_2^B - k_1^B) + \frac{b_{12}^B}{R_{12}}(1-\tau_1^{ST}) + T_1 \;=\; e_1^B + b_{01}^B + F_1^B(k_1^B) \tag{31}$$

Interest rates paid by borrowers increase with the level of the corresponding tax in line with the framework of Schmitt-Grohé and Uribe (2017). The corresponding lump-sum transfers/taxes for borrowers are

$$T_0 \;=\; \tau_0^k q_0 k_1^B + \tau_0^{ST}\frac{b_{01}^B}{R_{01}} + \tau_0^{LT}\frac{b_{02}^B}{R_{02}} \tag{32}$$

$$T_1 \;=\; \tau_1^k q_1 k_2^B + \tau_1^{ST}\frac{b_{12}^B}{R_{12}} \tag{33}$$

Taxes on Debt At dates 0 and 1, the Euler equations for bonds become

$$\lambda_0^B(1-\tau_0^{ST}) \;=\; \beta R_{01}\mathbb{E}_0(\lambda_1^B) + \mu_1^B + \eta_1^B \tag{34}$$

$$\lambda_0^B(1-\tau_0^{LT}) \;=\; \beta R_{02}\mathbb{E}_0(\lambda_1^B) + \mu_1^B \tag{35}$$

$$\lambda_1^B(1-\tau_1^{ST}) \;=\; R_{12}\lambda_2^B + \mu_2^B \quad \text{with} \quad \lambda_1^B = U_1'^B \quad \text{and} \quad \lambda_2^B = \beta U_2'^B \tag{36}$$

Combining these new equations, the risk premium (19) and the social planner's optimal conditions for consumption in periods 0 and 1, (21) and (22), gives

$$\tau_0^{ST} \;=\; -\overbrace{\frac{\xi_1^{SP}R_{01}\mathbb{E}_0\left[q_1\Omega_1 U_1''^B\right]}{U_0'^B}}^{Ex-ante} + \overbrace{\frac{\xi_0^{SP}q_0\Omega_0U_0''^B}{U_0'^B}}^{Ex-post} + \overbrace{\frac{\xi_0^{SP}R_{01}\Omega_0\mathbb{E}_0\left[U_1''^B(F_1'^B(k_1^B)+q_1)\right]}{U_0'^B}}^{Ex-post:\ capital\ accumulation\ date\ 0} \tag{37}$$

$$\tau_0^{LT} \;=\; -\frac{\xi_1^{SP}\overbrace{R_{02}}^{Key\ diff.}\mathbb{E}_0\left[q_1\Omega_1U_1''^B\right]}{U_0'^B} + \frac{\xi_0^{SP}q_0\Omega_0U_0''^B}{U_0'^B} + \frac{\xi_0^{SP}\overbrace{R_{02}}^{Key\ diff.}\Omega_0\mathbb{E}_0\left[U_1''^B(F_1'^B(k_1^B)+q_1)\right]}{U_0'^B} \tag{38}$$

$$\tau_1^{ST} \;=\; -\overbrace{\frac{\xi_0^{SP}\Omega_0\mathbb{E}_0\left[U_1''^BF_1'^B(k_1^B)\right]}{U_1'^B}}^{Ex-post\ capital\ accumul.\ date\ 0} + \overbrace{\frac{(\xi_1^{SP}\Omega_1-\xi_0^{SP}\Omega_0)\,\mathbb{E}_0\left[q_1U_1''^B\right]}{U_1'^B}}^{Inter.\ arbitrage} + \overbrace{\frac{\xi_1^{SP}R_{12}\mathbb{E}_0\left[\Omega_1U_2''^BF_2'^B(k_2^B)\right]}{U_1'^B}}^{Ex-post:\ capital\ accumul.\ date\ 1} \tag{39}$$

The set of taxes on short (37) and long-term (38) bonds at date 0 are increased by the first (*ex-ante*) component and reduced by the two other (*ex-post*) components. Through the previous condition (22) and the associated benefits of capital accumulation for consumption, sales and production, the *ex-ante* component pushes up both taxes on bonds, which in turn limits the risk of future binding collateral constraints. This argument is in line with the countercyclical policies proposed by Korinek and Sandri (2016) and Jeanne and Korinek (2018). But the *ex-post* components have the opposite effect on the taxes. First, the risk of current fire sales (at date 0) reduces the optimal level of the taxes, because they may amplify the fire sales mechanism. Second, the impact of the taxes is limited by the effectiveness of the production function: investments at date 0 may generate a substantial amount of capital, which would protect against future fire sales.

The taxes on short (37) and long-term (38) bonds are equivalent if and only if the short and long-term interest rates are the same, the *"key difference"* in equation (38). Because flow collateral constraint tightening is the key factor in (19) for interest rate parity, the existence of a term premium introduces a difference between the taxes. In other words, if the optimal level of the taxes is positive, liquidity concerns lead to higher taxes for long-term bonds than for short-term bonds. The social planner internalizes the market mechanism driven by the term premium.

Finally, the tax on short-term bonds (39) at date 1 depends on the size of three terms. The first term, labeled *"ex-post: capital accumul. date 0"*, increases the tax. It depends on the efficiency of capital accumulation at date 0 and how it acts against the risk of fire sales at date 1. The second term is related to the time preference of the social planner and depends on the relative value assigned to fire sales at both times. This decides the balance between ex-ante and ex-post policies in each period. The last term plays the same role as the one for the taxes at date 0: it reflects the effectiveness of the production function for investments at date 1.

Subsidies on Capital By using the decentralized equilibrium conditions (14)-(18) with the subsidies and the social planner's capital accumulation allocations (25)-(26), the tax/subsidy on capital is defined at dates 0 and 1 by

$$\tau_0^k = \frac{\overbrace{\mathbb{E}_0\left[(\lambda_1^{SP} - \lambda_1^B)(F_1'^B(k_1^B) + q_1)\right]}^{Externality\ diff.}}{q_0\lambda_0^{SP}} + \frac{\overbrace{\xi_0^{SP}\beta\Omega_0\mathbb{E}_0\left[U_1'^B F_1''^B(k_1^B)\right]}^{Decreasing\ returns}}{q_0\lambda_0^{SP}} \tag{40}$$

$$\tau_1^k = \frac{\overbrace{\mathbb{E}_0\left[(\lambda_2^{SP} - \lambda_2^B)F_2'^B(k_2^B)\right]}^{Externality\ diff.}}{q_1\lambda_1^{SP}} + \frac{\overbrace{\xi_1^{SP}\beta\mathbb{E}_0\left[\Omega_1 U_2'^B F_2''^B(k_2^B)\right]}^{Decreasing\ returns}}{q_1\lambda_1^{SP}} \tag{41}$$

These policies on capital complement the taxes on debt to ensure that decentralized agents have no incentive to sell too much of their capital. This mechanism crucially depends on the inequality $\lambda_t^{SP} > \lambda_t^B$ with $t = 1, 2$, meaning that consumption in the social planner's allocation is lower than in the decentralized equilibrium. In addition, the mechanism depends on the efficiency of the production function because of decreasing returns to scale. To sum up, the social planner should provide a subsidy on capital ($\tau^k > 0$) if and only if the first term is sufficiently large and $\lambda_t^{SP} > \lambda_t^B$. This means that the planner subsidizes capital when capital accumulation is the key to avoiding current and future fire sales.

Proposition 3 *From a normative perspective, the optimal allocation is restored in the decentralized equilibrium by a set of taxes on short and long-term debts and subsidies for capital, both at date 0 and date 1. As summarized in table 3, these policy instruments are contingent on various determinants, in particular the risk of current and future fire sales, the efficiency of capital investments and the term premium.*

Table 3: Policy Intervention - Summary

Policy Intervention	Increase	Decrease
τ_0^{ST} and τ_0^{LT}	risk of overconsumption at date 1	risk of overconsumption at date 0 efficiency of the capital acccumulation at date 0
τ_0^{LT}	positive term premium (i.e. liquidity concerns)	
τ_1^{ST}	Intertemporal arbitrage between date 0 and date 1 efficiency of the capital acccumulation at date 0	risk of overconsumption at date 1 efficiency of the capital acccumulation at date 1
τ_0^k and τ_1^k	efficiency of the capital acccumulation	Decreasing returns to scale

5 Conclusion

This paper highlights predictive value of debt maturity structure as an early-warning indicator of financial crises in the developing world. An excessive reliance on short-term debt exacerbates the risk of financial crises by increasing the term premium. These predictions are tested in a theoretical model. I introduce debt maturity structure into a *Fisherian deflation* model and show that the mix of debts chosen by decentralized agents follows a suboptimal path, amplifying both liquidity risk (i.e. the rise in term premium) and solvency risk (i.e. the rise in risk premium), and then triggering fire sales. This makes policymaking decisions harder and calls for both ex-ante and ex-post policies. Nevertheless, the optimal corrective policies can be designed using three statistics, namely the risk of current and future fire sales, the efficiency of capital investments and the term premium.

This framework can be extended by including global financial forces, referred to as the global financial cycle by Rey (2015). Clearly, the spillover effects of US monetary policy are large, because they drive global liquidity and this adds to the high levels of comovement in asset prices, credit, and risk aversion around the world. The global financial cycle can be seen as having two phases: (i) booms when US interest rates are low and global liquidity is high and (ii) busts when US interest rates are high and global liquidity is low. Bianchi et al. (2016) include these regime shifts in their *Fisherian deflation* model. The framework proposed here with debt maturity structure can be enhanced to include these regime shifts. This would affect the mix of short and long-term bonds chosen by agents, which in turn may amplify the risk of asset fire sales. More precisely, if the world goes from a high-liquidity regime to a low-liquidity regime and if the borrower has previously accumulated too much long-term debt, the likelihood of a financial crisis and its amplitude both increase.

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Appendix 1: List of Countries and Data Sources

Table A.1: List of countries

	Time Coverage		Time Coverage		Time Coverage
Algeria	1975-2017	Ghana	1975-2017	Niger	1975-2017
Argentina	1975-2016	Guinea	1991-2017	Nigeria	1975-2017
Bangladesh	1978-2017	Guinea-Bissau	1979-2017	Paraguay	1975-2017
Belize	1975-2017	Guyana	1975-2017	Peru	1975-2017
Bolivia	1975-2017	Haiti	1975-2017	Philippines	1975-2017
Brazil	1975-2012	India	1975-2017	Romania	1994-2017
Bulgaria	1986-2017	Indonesia	1975-2017	Russia	1997-2017
Burkina Faso	1975-2017	Ivory Coast	1975-2017	Sao Tome	1982-2017
Burundi	1975-2017	Jamaica	1975-2017	Senegal	1975-2017
Cameroon	1975-2017	Jordan	1975-2017	Sierra Leone	1975-2017
Cape Verde	1986-2017	Kazakhstan	1998-2017	Sri Lanka	1975-2017
Central African Rep.	1975-2017	Kenya	1975-2017	Swaziland	1975-2017
Chad	1975-2017	Lebanon	1975-2017	Thailand	1975-2017
China	1986-2017	Madagascar	1975-2017	Togo	1975-2017
Colombia	1975-2017	Malaysia	1975-2017	Tunisia	1975-2017
Congo, Dem. Rep.	1975-2017	Mali	1975-2017	Turkey	1975-2017
Congo, Rep.	1975-2017	Mauritania	1975-2017	Uganda	1975-2017
Costa Rica	1975-2017	Mexico	1975-2017	Ukraine	1997-2017
Djibouti	1975-2017	Moldova	2000-2017	Venezuela	1975-2015
Dominican Rep.	1975-2017	Mongolia	1997-2017	Vietnam	1994-2017
Ecuador	1975-2017	Morocco	1975-2017	Yemen	1995-2017
Egypt	1975-2017	Nepal	1975-2017	Zambia	1975-2017
El Salvador	1975-2017	Nicaragua	1994-2017	Zimbabwe	1975-2017

Note: this table corresponds to the sample of 69 countries with 2691 points including the 5 years-lag.

Table A.2: Data sources

Variable	Description	Source
	Crises	
Banking Crises	Systemic banking crises. Dummy equal to 1 if crisis.	Laeven and Valencia (2018)
Currency Crises	Currency crises. Dummy equal to 1 if crisis.	Laeven and Valencia (2018)
Debt Crises	Sovereign debt crises. Dummy equal to 1 if crisis.	Laeven and Valencia (2018)
Reinhart Banking Crises	Alternative measure of banking crises. Dummy equal to 1 if crisis.	Reinhart et al. (2016)
Reinhart Systemic Banking Crises	Alternative measure of systemic banking crises. Dummy equal to 1 if crisis.	Reinhart et al. (2016)
Stock Market Crash	Large drop in equity prices. Dummy equal to 1 if crisis.	Reinhart and Rogoff (2009)
	International Debt Securities	
$\frac{ST}{ST+LT}$	Ratio of short-term external debt stock to all external debt stock. Short-term means disbursed outstanding debt with an original maturity of one year or less.	World Bank
$\frac{Debt\ Stock}{GNI}$	Ratio of external debt stock to gross national income. External debt stock decomposed into three blocs: (i) public and publicly guaranteed debt (PPG) (ii) private nonguaranteed debt (PNG) (iii) IMF credit, provided by the IMF Treasurer's Department.	World Bank
$\frac{Debt\ Reduction}{GNI}$	Debt forgiveness grants from bilateral and multilateral creditors.	World Bank
Multilateral Creditors	Ratio of the stock of debt owed to multilateral creditors to external debt. Multilateral creditors are international financial institutions, and other multilateral and intergovernmental agencies whose lending is administered on a multilateral basis.	World Bank
	Endogeneity issues, term premium	
US Term Premium	US Treasury term premium estimates.	Adrian et al. (2013)
	Other Control Variables	
$\frac{Reserves}{Debt\ Stock}$	Ratio of international reserves to external debt stock, including its reserve position in the IMF, its holdings of foreign exchange, and its holdings of gold. resources provided to the private sector by financial corporations.	World Bank
log(GDP)	GDP, current US dollars.	World Bank
	Currency Mismatch Measure	
$\frac{Net\ Debt\ Flows}{Net\ Exports}$	Ratio of net debt flows to net exports of goods, services and primary income.	World Bank

Table A.3: Descriptive Statistics

Variable	Mean	First Quartile	Median	Third Quartile	SD
Crises					
Banking Crises	0.034	0	0	0	0.182
Currency Crises	0.048	0	0	0	0.214
Debt Crises	0.016	0	0	0	0.125
Reinhart Banking Crises	0.204	0	0	0	0.403
Reinhart Systemic Banking Crises	0.173	0	0	0	0.378
Stock Market Crash	0.321	0	0	1	0.467
International Debt Securities					
$\frac{ST}{ST+LT}$	0.123	0.053	0.104	0.175	0.112
$\frac{PPG\ Debt\ Stock}{GNI}$	0.496	0.186	0.326	0.597	0.562
$\frac{PNG\ Debt\ Stock}{GNI}$	0.056	0	0.009	0.06	0.124
$\frac{IMF\ Credit}{GNI}$	0.03	0.004	0.015	0.04	0.053
$\frac{Debt\ Reduction}{GNI}$	0.006	0	0	0	0.045
Multilateral Creditors	0.283	0.116	0.224	0.417	0.211
Endogeneity issues, term premium					
US Term Premium	1.795	0.711	1.962	2.51	1.232
Other Control Variables					
$\frac{Reserves}{Debt\ Stock}$	0.476	0.078	0.19	0.393	2.067
log(GDP)	23.26	21.82	23.02	24.59	2
Currency Mismatch Measure					
$\frac{Net\ Debt\ Flows}{Net\ Exports}$	-0.25	-0.59	-0.26	-0.05	12.75

Appendix 2: Additional Tests

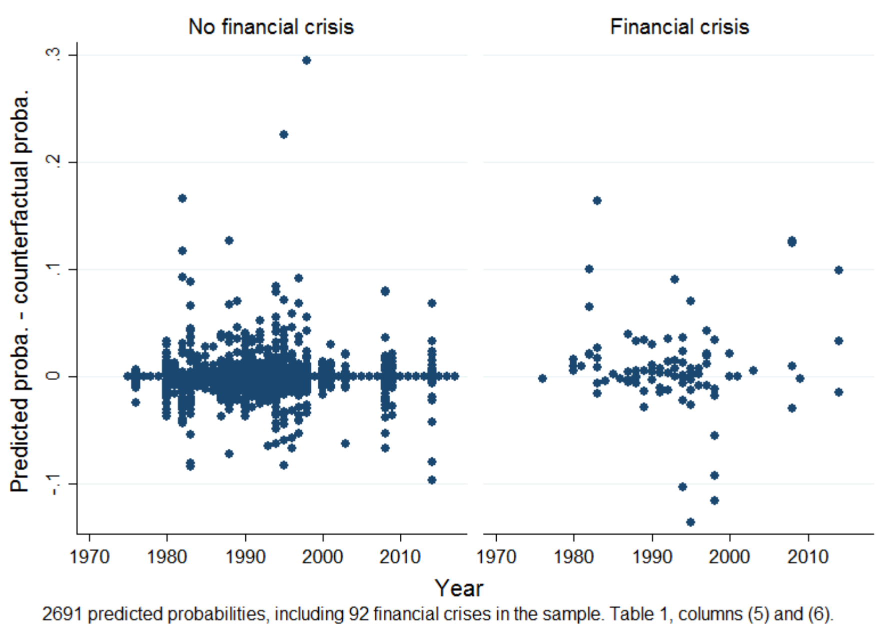

Figure A.1: Difference between predicted and counterfactual probabilities

Table A.4: Full set of results with individual lags - Table 1

	Dependent variable: Systemic Banking Crisis. Logit Estimates.								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
L.$\frac{ST}{ST+LT}$	6.190**		6.346**	5.540*	6.487**		23.69***	-4.068	
	(2.683)		(2.723)	(3.116)	(3.222)		(6.173)	(4.937)	
L2.$\frac{ST}{ST+LT}$	-5.856		-6.269	-5.769	-6.477		-23.11***	-0.0756	
	(3.773)		(3.847)	(4.177)	(4.301)		(7.468)	(7.663)	
L3.$\frac{ST}{ST+LT}$	-1.097		-1.602	-0.566	-0.999		-0.228	-1.366	
	(3.697)		(3.791)	(3.906)	(4.037)		(5.887)	(7.329)	
L4.$\frac{ST}{ST+LT}$	-1.221		-0.726	0.173	0.520		1.837	3.895	
	(3.364)		(3.447)	(3.553)	(3.627)		(5.308)	(6.576)	
L5.$\frac{ST}{ST+LT}$	5.783**		5.853**	5.020**	4.743*		6.654*	-0.368	
	(2.307)		(2.392)	(2.423)	(2.504)		(3.598)	(4.891)	
L.$\frac{Debt\ Stock}{GNI}$		-0.118							
		(0.408)							
L2.$\frac{Debt\ Stock}{GNI}$		0.204							
		(0.548)							
L3.$\frac{Debt\ Stock}{GNI}$		-0.293							
		(0.614)							
L4.$\frac{Debt\ Stock}{GNI}$		0.0636							
		(0.538)							
L5.$\frac{Debt\ Stock}{GNI}$		-0.0463							
		(0.420)							
L.$\frac{Public\ (PPG)\ Debt\ Stock}{GNI}$			-0.283		0.296	0.192	0.173	1.758	
			(0.568)		(0.750)	(0.728)	(1.710)	(1.707)	
L2.$\frac{Public\ (PPG)\ Debt\ Stock}{GNI}$			0.0599		-0.416	-0.209	-0.369	-2.041	
			(0.726)		(1.065)	(1.041)	(2.740)	(2.286)	
L3.$\frac{Public\ (PPG)\ Debt\ Stock}{GNI}$			-0.229		0.373	0.555	2.402	-2.066	
			(0.777)		(0.997)	(0.973)	(2.478)	(2.240)	
L4.$\frac{Public\ (PPG)\ Debt\ Stock}{GNI}$			0.664		0.151	0.131	-1.054	0.353	
			(0.788)		(1.131)	(1.109)	(3.121)	(1.129)	
L5.$\frac{Public\ (PPG)\ Debt\ Stock}{GNI}$			-0.671		-0.693	-0.955	-1.357	0.285	
			(0.646)		(0.852)	(0.851)	(1.991)	(0.704)	
L.$\frac{Private\ (PNG)\ Debt\ Stock}{GNI}$			5.906		7.734	4.883	9.017	1.846	
			(4.832)		(4.851)	(4.242)	(8.557)	(8.314)	
L2.$\frac{Private\ (PNG)\ Debt\ Stock}{GNI}$			-2.310		-4.251	-1.572	-16.33	-0.968	
			(7.638)		(7.977)	(7.277)	(15.81)	(9.692)	
L3.$\frac{Private\ (PNG)\ Debt\ Stock}{GNI}$			0.0785		1.890	2.972	17.64	6.995	
			(7.852)		(8.328)	(8.144)	(15.53)	(14.89)	
L4.$\frac{Private\ (PNG)\ Debt\ Stock}{GNI}$			-7.176		-7.713	-7.240	-16.43	-12.45	
			(8.320)		(8.471)	(8.542)	(14.97)	(17.48)	
L5.$\frac{Private\ (PNG)\ Debt\ Stock}{GNI}$			7.356		7.392	5.729	10.07	8.875	
			(5.331)		(5.589)	(5.573)	(9.851)	(9.147)	
L.$\frac{IMF\ Credit}{GNI}$				-14.50	-17.57	-17.20*	-9.450	-33.34*	
				(9.644)	(10.70)	(10.36)	(22.18)	(18.87)	
L2.$\frac{IMF\ Credit}{GNI}$				17.12*	19.86	20.21*	9.872	31.58	
				(10.22)	(12.14)	(11.60)	(32.02)	(26.60)	
L3.$\frac{IMF\ Credit}{GNI}$				-12.63	-13.24	-15.27	-25.46	-6.577	
				(9.794)	(10.87)	(10.65)	(30.32)	(21.21)	
L4.$\frac{IMF\ Credit}{GNI}$				14.04	14.97	15.39	51.69*	10.31	
				(9.177)	(10.94)	(10.61)	(29.96)	(18.76)	
L5.$\frac{IMF\ Credit}{GNI}$				-7.428	-7.771	-7.492	-33.83	-4.995	
				(7.433)	(9.190)	(8.815)	(20.92)	(17.39)	
L.$Multilateral\ Creditors$ (%)				-1.543	0.237	-4.379	3.910	-10.25	
				(4.445)	(4.595)	(3.924)	(7.653)	(6.717)	
L2.$Multilateral\ Creditors$ (%)				-0.901	-1.912	4.246	-5.285	2.525	
				(6.169)	(6.307)	(5.296)	(9.546)	(10.32)	
L3.$Multilateral\ Creditors$ (%)				3.850	3.483	3.243	9.807	8.673	
				(5.079)	(5.197)	(4.710)	(7.415)	(9.021)	
L4.$Multilateral\ Creditors$ (%)				0.238	0.897	-0.388	0.819	-6.657	
				(4.673)	(4.740)	(4.414)	(6.541)	(8.999)	
L5.$Multilateral\ Creditors$ (%)				-4.266	-4.907	-5.272	-10.88*	1.424	
				(3.924)	(3.973)	(3.794)	(5.832)	(7.377)	
L.$\frac{Debt\ Reduction}{GNI}$				1.363	3.127	2.258			
				(2.118)	(2.544)	(2.465)			
L2.$\frac{Debt\ Reduction}{GNI}$				0.614	1.878	2.300			
				(3.492)	(3.808)	(4.380)			
L3.$\frac{Debt\ Reduction}{GNI}$				5.454*	7.372**	7.817**			
				(2.960)	(3.369)	(3.420)			
L4.$\frac{Debt\ Reduction}{GNI}$				5.339*	6.599*	6.138*			
				(2.987)	(3.863)	(3.712)			
L5.$\frac{Debt\ Reduction}{GNI}$				6.955*	7.858	6.970			
				(4.025)	(5.233)	(5.028)			
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Obs.	2691	2691	2691	2691	2691	2691	913	772	
Countries	62	62	62	62	62	62	62	62	62

Standard errors in parentheses. Following formal lag selection procedures, I consider five lags of all variables.

*, ** and *** respectively indicate significance at the 10, 5 and 1% levels.

Table A.5: Crisis years (not only the outbreak of the crisis) - Sensitivity analysis

Dependent variable: Systemic Banking Crisis (All Years). Logit Estimates.							US Term Premium	
							> 2	< 2
Sum of 5 lags	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\frac{ST}{ST+LT}$	3.940***		3.678***	3.945***	3.758***		10.10***	-1.472
	(1.216)		(1.247)	(1.281)	(1.310)		(2.321)	(2.848)
$\frac{Debt\ Stock}{GNI}$		-0.0644						
		(0.170						
$\frac{Public\ (PPG)\ Debt\ Stock}{GNI}$			−0.433*		-0.435	-0.448	0.859	−1.897***
			(0.255)		(0.307)	(0.303)	(0.742)	(0.488)
$\frac{Private\ (PNG)\ Debt\ Stock}{GNI}$			4.145***		4.561***	4.385***	10.09**	5.135***
			(1.301)		(1.429)	(1.371)	(4.430)	(1.853)
$\frac{IMF\ Credit}{GNI}$				0.0809	1.420	0.863	−15.87**	8.490
				(3.200)	(3.559)	(3.457)	(7.856)	(5.802)
$Multilateral\ Creditors$ (%)				−1.917*	-1.161	-1.503	−3.693*	-1.773
				(1.106)	(1.190)	(1.164)	(2.204)	(2.371)
$\frac{Debt\ Reduction}{GNI}$				7.339	14.36**	13.34**		
				(5.411)	(6.145)	(6.213)		
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	2691	2691	2691	2691	2691	2691	1021	1066
Countries	69	69	69	69	69	69	51	53
Pseudolikelihood	-517.7	-518	-502.4	-508.3	-494.3	-500.4	-197	-160.9
R^2	0.253	0.252	0.275	0.266	0.286	0.278	0.335	0.455
AUROC	0.816	0.812	0.831	0.824	0.837	0.834	0.797	0.851
Standard error	0.0113	0.0119	0.0109	0.0106	0.0104	0.0106	0.0162	0.0153

Standard errors in parentheses. Following formal lag selection procedures, I consider five lags of all variables. 261 points of crisis regime, including 92 first year crisis regime. *, ** and *** respectively indicate significance at the 10, 5 and 1% levels.

Table A.6: Other control variables - Sensitivity analysis

	Dependent variable: Systemic Banking Crisis. Logit Estimates.								
								US Term Premium	
								> 2	< 2
Sum of 5 lags	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\frac{ST}{ST+LT}$	4.235*	4.6445**	4.647**	4.856*	5.537**	6.933**	6.555*	50.07***	-197.9
	(2.187)	(2.249)	(2.240)	(2.494)	(2.583)	(3.017)	(3.391)	(15.94)	(164.8)
$\frac{Public\ (PPG)\ Debt\ Stock}{GNI}$	-0.311	-0.261	-0.286	-1.139	-1.278^{*}	-0.978	-1.471	-0.571	57.07
	(0.485)	(0.495)	(0.490)	(0.739)	(0.761)	(0.960)	(1.096)	(4.132)	(44.52)
$\frac{Private\ (PNG)\ Debt\ Stock}{GNI}$	5.058**	5.5085**	5.504**	5.119*	5.832**	4.852	6.662*	14.24	-19.96
	(2.536)	(2.589)	(2.590)	(2.826)	(2.921)	(3.232)	(3.954)	(17.88)	(94.03)
$\frac{IMF\ Credit}{GNI}$	-3.901	-3.471	-3.917	-5.525	-6.728	-7.243	-11.93	-12.59	-586
	(6.305)	(6.368)	(6.378)	(7.708)	(7.780)	(9.144)	(10.49)	(41.71)	(523.8)
$Multilateral\ Creditors$ (%)	-2.259	-1.921	-1.955	-2.484	-2.189	-2	-1.011	0.173	-106.4
	(1.886)	(1.895)	(1.901)	(2.166)	(2.246)	(2.513)	(2.859)	(9.081)	(105.3)
$\frac{Debt\ Reduction}{GNI}$	26.55**	27.485**	27.04**	32.46**	36.04**	44.72**	47.82**	-4399	3162
	(10.60)	(11.18)	(11)	(13.16)	(14.18)	(17.94)	(20.99)	(751864)	(2755)
$Currency\ Crisis$	-0.157		0.586		0.508	2.310	3.169	8.062	145.9
	(1.472)		(1.516)		(1.639)	(1.811)	(2.019)	(6.977)	(131.8)
$Debt\ Crisis$		-51.02	-51.45		-60.01	-63.34	-61.14	-95.64	175.3
		(4244)	(4180)		(11965)	(19616)	(11813)	(107986)	(219122)
$\frac{Reserves}{Debt\ Stock}$				-2.793^{**}	-3.386^{***}	-4.981^{***}	-4.315^{***}	-8.080^{**}	-21.68
				(1.148)	(1.245)	(1.553)	(1.618)	(3.732)	(26.06)
$Log(GDP)$						1.426	1.482	-0.0126	108.7
						(0.905)	(1.138)	(3.791)	(90.08)
$\frac{Net\ Debt\ Flows}{Net\ Exports}$							0.0191	1.575**	-3.797
							(0.0496)	(0.790)	(3.583)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	2691	2691	2691	2511	2511	2284	1869	617	560
Countries	69	69	69	65	65	62	60	35	35
Pseudolikelihood	-220.5	-215.3	-213.9	-197.5	-187.9	-170.6	-148.6	-39.72	-21.29
R^2	0.304	0.320	0.324	0.343	0.375	0.402	0.404	0.633	0.789
AUROC	0.8547	0.8628	0.8641	0.8649	0.8757	0.8250	0.8077	0.8758	0.6553
Standard error	0.0134	0.0123	0.0125	0.0136	0.0128	0.0169	0.0195	0.0219	0.0456

Standard errors in parentheses. Following formal lag selection procedures, I consider five lags of all variables.

*, ** and *** respectively indicate significance at the 10, 5 and 1% levels.

Table A.7: Other dependent variable - Sensitivity analysis

	Dependent variable: Various types of crisis. Logit Estimates.				
	(1)	(2)	(3)	(4)	(5)
Dependent variable:	CurrencyLV	SoverDebtLV	BankRR	SystemicBankRR	StockCrash
$\frac{ST}{ST+LT}$	1.379	-1.291	4.009***	4.593***	1.308
	(1.276)	(2.576)	(1.397)	(1.510)	(1.739)
$\frac{Public\ (PPG)\ Debt\ Stock}{GNI}$	-0.270	0.801	1.014**	0.667	1.334
	(0.357)	(1.033)	(0.404)	(0.427)	(1.026)
$\frac{Private\ (PNG)\ Debt\ Stock}{GNI}$	-0.780	-1.726	5.186**	4.419*	3.867
	(1.580)	(3.205)	(2.280)	(2.423)	(3.128)
$\frac{IMF\ Credit}{GNI}$	-6.469^{*}	-17.68^{**}	1.565	9.623*	-6.769
	(3.446)	(9.001)	(4.505)	(5.227)	(5.729)
$Multilateral\ Creditors$ (%)	0.633	-8.670^{**}	1.383	0.208	1.896
	(1.127)	(3.405)	(1.394)	(1.529)	(2.198)
$\frac{Debt\ Reduction}{GNI}$	-19.10	-500.1	-1.149	-17.31	-6.711
	(15.19)	(596.4)	(9.748)	(11.42)	(24.70)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Obs.	3215	1737	1413	1275	713
Countries	86	43	38	33	21
Pseudolikelihood	-431.7	-116.8	-449.5	-378.5	-265.1
R^2	0.172	0.395	0.225	0.229	0.289
AUROC	0.743	0.889	0.781	0.793	0.802
Standard error	0.0185	0.0152	0.0153	0.0162	0.0171

"LV" refers to Laeven and Valencia (2018) while "RR" refers to Reinhart et al. (2016). Standard errors in parentheses.
Following formal lag selection procedures, I consider five lags of all variables.
*, ** and *** respectively indicate significance at the 10, 5 and 1% levels.