Fire Sales and Debt Maturity*

Samuel Ligonnière †

University of Lille LEM, Ecole Normale Supérieure Paris-Saclay

March 2019

Abstract

How does debt maturity structure affect fire sales? I show how debt maturity could trigger financial crises by introducing debt maturity in a *Fisherian deflation* model. In particular, using a stock/flows analysis, I find that (i) an excessive reliance on short-term debt exacerbates the risk of financial crises through fire sales and (ii) this risk is driven by a rise in the term premium. I confirm these two testable predictions with an empirical study based on 118 developing countries form 1970 to 2017. I highlight that debt maturity structure is a good early-warning indicator of financial crises, which provides information that adds up to the level of external debt. Overall, this paper shows that the optimal policies against fire sales mechanism are determined by the share of consumption in income, as well as term and risk premia.

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

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

1 Introduction

The level of private and public debt stock is unambiguously linked to financial crises (Schularick and Taylor, 2012; Mendoza and Terrones, 2012; Gourinchas and Obstfeld, 2012). This stock is both affected by debt inflows and outflows, which crucially depend on the choice between short and long-term debt. The

*I benefitted greatly from exchanges with Etienne Farvaque, Lionel Fontagné, Olena Havrylchyk, Jérôme Héricourt, Christophe Hurlin, Jean Imbs, Léa Marchal, Romain Rancière, Farid Toubal, Fabien Tripier, and seminar participants at the GSIE PSE, the CIRANO seminar, the 52nd Annual Conference of the Canadian Economics Association, and the 67th AFSE Annual Conference. I am very grateful for the insights of Maixing Dai and of Lise Patureau, as discussants at the 15th ACDD and at the RIEF 18th Doctoral Meetings. Any remaining errors are mine.

†Email: samuel.ligonniere@ens-paris-saclay.fr

former influences the current and future debt flows through complete debt service in one period, while the latter affects both debt flows and stock over long horizons. The current empirical and theoretical litterature is however quite silent on this stock-flow relationship of debt, with the notable exception of Drehmann et al. (2017) that focus on the lead-lag relationship of the household debt between new borrowing and debt service.

This paper aims to fill this gap by answering the following three questions. First, in light of the financial amplification mechanism *à la* Fisher (1933) that allows one to undesrtand financial crises, how does the debt maturity sturtuce affect fire sales ? Second, is the debt level or the debt maturity structure the best predictor of financial crises? Figure A.1 in the Appendix analyzes the relationship between these two predictors and the frequency of financial crises. At first glance, it suggests that both external debt stock over the gross national income and debt maturity structure play a role in the likelihood of future financial crises. Although there is no obvious relationship between the annual mean of debt maturity structure and this risk, the heterogeneous cases of debt maturity portfolios in Figure A.1, particularly in the 1980s, raise concerns. Third, what is the optimal policy according to the stock-flow relationship between the debt level and the debt maturity?

Fire sales appear when collateral constraint tightens. This collateral is based on the market value of assets that determines the borrowing ability of economic agents. When they are not able to repay their debt and/or when they want to increase their consumption above this borrowing limit, agents may sell their assets. However, if many borrower act in the same way, it may result in a well-known feedback loop between binding collateral constraints, a drop in asset prices and agents' wealth, as described by Korinek and Mendoza (2014) and Bianchi and Mendoza (2018), among others. These so-called *Fisherian deflation* models use occasionally binding financial constraints with pecuniary externality, which means that decentralized agents do not internalize the effect of their decisions on asset markets. Therefore, there is a wedge between private and social marginal utilities of both asset and debt. As a conventional result, policy intervention via taxes and subsidies could fill the gap. Nevertheless, these recent theoretical foundations of Fisher (1933) remain quite silent on debt maturity structure.

By constrast to the existing literature, I empirically show that a debt maturity structure essentially based on short-term debt is an appropriate early-warning indicator of financial crises for developping 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 four cases on the basis of joint movements in interest rates and changes in debt maturity.

There is one case in which interest rates are increasing even though debt maturity is falling: it *must* be one of an increasing term premium. It turns out that it is only in this case that debt maturity affects the probability of crisis. In other words, (i) debt maturity matters for financial crisis, and (ii) certainly via an increase in the term premium.[1]

I then rationalize these two empirical insights into a *Fisherian deflation* model in which domestic borrowers choose a mix of short and long-term debts. This debt maturity structure potentially multiplies the risk of asset fire sales due to the binding collateral constraints. I show that the level and the composition of the debt chosen by the agent follows a suboptimal path, which amplifies both liquidity risk (i.e. the rise in term premium) and solvency risk (i.e. the rise in risk premium), and then triggers fire sales. It differs from the social planner's optimal path of debt, and more broadly from the social planner allocation including the capital assets.

The main feature of the model lies in the fact that the social planner can replicate its optimal equilibrium via a set of taxes and subsidies, where all prices and term premium are still market-determined. Following Korinek and Dávila (2018), the social planner implements taxes on debts and subsidies on 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). The latter papers focus on moral hazard issues, while I specify the level of taxes and subsidies at various times. Second, these taxes on debts are contingent to three key elements: (i) the share of consumption good in total income, (ii) the liquidity concern and (iii) the solvency one. When the liquidity and/or solvency risks are high, the term and risk premia reduce the need to impose high taxes on debts.

Mechanism With only a *one-period* debt, the standard result of the literature holds. Crucially, the decentralized agent is prone to overborrowing. He also under-invests in capital assets that makes the collateral constraint more vulnerable to asset fire sales. This financial amplification mechanism works for public, household and firm borrowing, despite obivous differences in their role. Given the debt maturity structure, this mechanism is still valid and the rational borrower chooses his path of debt, while the lender distinguishes between short from long-term bonds. The concerns about liguidity and solvency risks are indeed quite different. The lender charges a term premium, since an excessive short-term debt causes liquidity troubles and exacerbates the risk of default with a lower debt amortization process.

Because of the pecuniary externality and their *unanticipated* shock on capital price, the level and

[1] It suggests that debt maturity must fall in countries where a crisis is expected, with two consequences: (i) it potentially creates a reverse causality issue and (ii) the debt maturity structure is not always a *free* choice. I can however not determine whether the rise in term premium is mostly driven by idiosyncratic risk or by foreign lender characteristics (degree of risk aversion and regional shocks) as suggested by Cerutti et al. (2017).

the structure of debt of the decentralized agent could bind one or two collateral constraints, i.e. *flows* and *stock* collateral constraints. On the one hand, if there is too much short-term debt, the current *flows* collateral constraint becomes tight. As a consequence, fire sales occur and an *unanticipated* term premium appears, thus further reducing the agents' debt capacity. On the other hand, the choice of too much long-term debt alleviates the risk of a current binding collateral constraint, but generates future binding collateral constraints over long horizons. When the borrower goes to the worst configuration with the two binding collateral constraints, it pays a term premium (from a binding *flows* constraint) and a risk premium (from a binding *stock* constraint) and suffers from multiple binding collateral constraints over time.

This stock-flow analysis of the debt is key to understand the likelihood of fire sales mechanism. My findings are complementary to those of Drehmann et al. (2017) who point out the relationship of new borrowing and debt service as a new transmission channel of financial crises. Using an empirical methodology close to the one presented in this paper and data of 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. By contrast, I highlight that the debt maturity structure matters for the developing world. I develop a *Fisherian deflation* model including both short and long-term debts which permits to balance the benefits of new borrowing and the future troubles generated by the debt service. By putting the focusing on low- and middle-income countries, this paper highlights that the borrower is a price-taker in world financial markets which makes more credible the standard model assumptions.

Related Literature The model complements the findings of Jeanne and Korinek (2018) and Bianchi and Mendoza (2018), but differs in the channel through which it generates fire sales. Focusing on advanced economies, these papers do not use debt maturity structure and they refer to other determinants than the three elements I describe in this paper: Jeanne and Korinek (2018) highlight the key role of the collateral constraint parameter and of the vulnerability to a new bust, while Bianchi and Mendoza (2018) put forward the equity premium[2], as well as the lack of credibility for future policies. As surveyed by Mendoza (2017), the recent theoretical foundations of Fisher (1933) investigate many different directions[3], but the

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

[3]Some papers such as Bianchi and Mendoza (2018), Jeanne and Korinek (2018) or Korinek and Dávila (2018) link collateral constraint and asset prices, whereas Bianchi (2011), Benigno et al. (2016), Schmitt-Grohé and Uribe (2017), among others, use a collateral constraint depending on real exchange rate and notably triggers sudden stop syndrome in emerging countries. The scope of policy intervention is also widely discussed: see Benigno et al. (2013), Jeanne and Korinek (2013) and Bianchi and Mendoza (2018) on ex-ante versus ex-post policies debate; or Korinek and Sandri (2016) on the simultaneous use of capital controls and macroprudential regulation.

debt maturity structure has been largely unexplored. Jeanne and Korinek (2018) extend their framework by including changes in the duration of debt. It is however only based on one sort of bond. By contrast, I focus on the stock-flow relationship of debt in which an excessive dependence on short or on long-term debt is possible. This is in line with the study of Zhou (2018). Her small open economy model generates time-varying term premium through risk-averse international creditors and shocks in their discount factor, whereas I disentangle debt service and debt stock concerns. My result is also complementary to their results, as she introduces a state-contingent and maturity-dependent capital inflow controls, while I focus on the simultaneous use of both *ex-ante* and *ex-post* policies. The optimal corrective policies can be globally designed using three statistics.

This paper also contributes to the empirical literature studying the key determinants of financial crises. Due to the availability of different datasets and various methodologies, multiple predictors have been discussed, such as the domestic credit growth (Schularick and Taylor, 2012; Mendoza and Terrones, 2012); the 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); the domestic asset price bubbles (Jordà et al., 2015); the private versus public debt (Jordà et al., 2016); the domestic versus foreign credit growth (Cesa-Bianchi et al., 2019) and lastly the debt service (Drehmann et al., 2017). The stock-flow relationship of debt is implicit in the study of Catão and Milesi-Ferretti (2014) in which they show that net external debt is a better predictor than gross external debt. By analogy, this peice of work is related to the recent academic papers analyzing the determinants of external debt flows. Bianchi et al. (2018) and Qian and Steiner (2017) draw attention to the relation between the external debt maturity and the level of international reserves. Focusing on 40 economies with relatively high financial development, Avdjiev et al. (2017a) study whether the characteristics of external debt could trigger credit cycles. The authors show that the choice of the debt instrument and the type of lenders appear to be more important than the currency and the maturity of external debt, but they focus on a different sample than in this paper. In addition, my analysis includes global financial forces, which are quantified by Avdjiev et al. (2017b) and Cerutti et al. (2017). According to the sensitivity analysis of Cerutti et al. (2015), the characteristics of the foreign lenders could be even more relevant than borrower's fundamentals, which call for a time-varying term premium.

The study of debt maturity is not new to the literature related to the banking system (Chang and Velasco, 2000) or to the severeign debt (Cole and Kehoe, 1996; Cole and Kehoe, 2000). Existing studies analyse how debt level and debt maturity structure could generate self-fulfilling runs, while 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 on sovereign debt crises. By contrast with the collateral constraint used in this paper, they focus on another financial friction, namely limited commitment for repayment.[4] Following Broner et al. (2013), the sovereign debt literature on the trade-off between short and long-term debt investigates two main channels. On the one hand, demand-side arguments put emphasis on the "disciplinary" role of short-term debt to reduce the incentive to dilute their debt (Jeanne, 2009). On the other hand, supply-side arguments stress the role of the potential uncertainty and the loss of information on the default probability over longer horizons, which calls for the modelling of a posititve term premium.[5] Arellano and Ramanarayanan (2012) and Broner et al. (2013) confirm that emerging countries promotes 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 the debt maturity structure is a good predictor of financial crises. Section 3 presents the baseline model and describes the debt maturity structure. Section 4 analyzes the optimal social planner intervention. Section 5 concludes.

2 Empirical Analysis: the Role of Debt Maturity Structure

The purpose of this paper is to identify how debt level and term structure affect the likelihood of financial crisis at the country-level. This section first provides details on data sources, including details on various types of debt inflows and outflows. Second, I underline how a debt maturity structure too short-term oriented could play the role of a good early-warning indicator of financial crises.

The unbalanced panel database consists of 118 countries from 1970 to 2017 with 32.7 years per country on average.[6] Table A.1 in Appendix provides a list of the countries, while Table A.2 gives the data sources. The long time coverage is sufficient to catch regularities with various cases of currency and maturity mismatches. The sample covers almost all emerging and developing economies, which contrasts with

[4]By introducing two financial frictions (i.e. limited commitment for repayment and for fiscal policy) in their framework, Debortoli et al. (2017) demonstrate that optimal maturity structure of debt is nearly flat.

[5]Going into more details, various mechanisms inducing more short-term debt coexist. As developed by Aguiar et al. (2016), the government incentives to deleverage depend on the debt maturity structure since the larger the share of short-term debt, the more able to compute the probability of sovereign default. Another mechanism reverts to consumption smoothing benefits from the debt. Niepelt (2014) compares them to the revenue effect from new debt issuance.

[6]This mean is for regressions including the 5 years-lag of each variable, following the baseline specification.

the current literature largely focused on advanced economies such as Schularick and Taylor (2012) and Cesa-Bianchi et al. (2019). Another motive is that sensitivities of debt maturity structure to international financial markets should depend on the depth of domestic financial markets and the country's credibility.

2.1 Data

Financial Crises The definition of precise dates for asset fire sales is quite challenging. Campbell et al. (2011) and Bian et al. (2018) use high-frequency microeconomic data. By contrast, the well-known dataset of Laeven and Valencia (2018) is used to assess systemic banking, currency and sovereign debt crises during the period 1970-2012. Over 3.9 percent (79) of the sample represents a systemic banking crisis. I assume that systemic banking crises are closely linked to the fire sales mechanism. Alternatively, I could use banking crises, systemic banking crises and stock market crashes as defined by Reinhart and Rogoff (2009) and Reinhart et al. (2016).

External Debt: Stock-Flow Relationship I use the *International Debt Statistics* from the World Bank. This data has been recently employed by Qian and Steiner (2017). They provide a wide range of information. First, they distinguish (i) stock and net flows, (ii) debt service and new debt, (iii) principal and interest payments. Second, they are again decomposed into short and long-term. They also offer the average interest and average maturity on new external debt commitments. As the main explanatory variable, I employ their measure of short-term external debt over total stock of external debt. This measure directly assesses debt structure, whereas Gourinchas and Obstfeld (2012) use the ratio of short-term external debt relative to GDP. I also rely on ratios of debt stock (or debt service) over gross national income, both with the distinction between short and long-term.[7]

Currency versus Maturity Mismatches Given that exchange rate volatility is a potential source of financial distress (Schmitt-Grohé and Uribe, 2017; Bianchi and Mendoza, 2018), this paper investigates the relative influence of both currency and maturity mismatches on the likelihood of financial crisis. Four potential measures of currency mismatch emerge from the literature, namely (i) the ratio of foreign currency external debt over total external debt (Bordo et al., 2010), (ii) the ratio of debt service or debt flows over the net exports of a country (Kuruc et al., 2016), (iii) the ratio of foreign currency liabilities

[7] This distinction and all other measures do not provide a better fit as a early-warning indicator of financial crises. For the same reason, I do not use the information relative to the potential publicly guaranteed debt and the distinction between public and private debt.

to foreign currency assets of the banking sector (Arteta, 2005; Tobal, 2018) and (iv) foreign currency denominated net unhedged liabilities (Rancière et al., 2010). As emphasized by Rancière et al. (2010), the first one completely ignores the asset side of the balance sheet, and the second one, the potential sectoral imbalances. In addition, the third one assumes that all foreign claims in the foreign currency assets are hedged, whereas unhedged debtors represent an *indirect exchange rate risk*. Due to data dearth, currency mismatch will be assessed through one measure: I use ratio of net debt flows over net exports of the country provided by the World Bank.[8]

2.2 Sources of Financial Instability: Debt Size & Debt Maturity

The empirical setting used follows the current literature on 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 the predictive ability of debt maturity structure on the likelihood of systemic banking crisis, which shed light on the causal link between the debt maturity structure and fire sales. The dependent variable is a dummy equal to 1 when systemic banking crisis occurs. I consider a logit model of systemic banking crisis event with the following specification:

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

where $\frac{ST}{ST+LT}_{it}$ is the ratio of 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 including external debt stock, debt service and proxy of currency mismatch. Following formal lag selection procedures (AIC and BIC), I consider 5 annual lags for all variables, which is consistent with Schularick and Taylor (2012), Drehmann and Juselius (2014) and Cesa-Bianchi et al. (2019). α_i denotes country fixed effects, and α_t represents year dummies. The presence of country fixed effects catches the specific behavior and reputation of some developing countries. The global trend captured by year fixed effects, concerning both risk and term premia, clearly determines the likelihood of financial crisis, in line with Rey (2015), Cerutti et al. (2015) and Avdjiev et al. (2017b).[9]

[8] Another proxy of currency mismatch is the aggregate foreign currency exposure (FXAGG), a measure developed in Bénétrix et al. (2015). They estimate currency composition of foreign assets and liabilities through geographic exposures. Unfortunately, they provide few data on emerging world: the use of this measure drops around 80% of the baseline sample.

[9] A burgeoning literature discusses the role of the VIX and of the tightening of US monetary policy on the frequency and the magnitude of financial crises. Following a two-step approach proposed by Ligonnière (2018), the estimated year fixed effect from equation (1) could be treated as a dependent variable in a new model including these global variables but it is beyond the scope of this paper.

Table 1: External debt level and structure

	Dependent variable: Systemic Banking Crisis. Logit Estimates.								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\frac{ST}{ST+LT}$	3.885*				4.194*	4.199*	3.986*	5.517**	
Sum of lags	(2.30)				(2.345)	(2.351)	(2.343)	(2.527)	
$\frac{Debt\ Stock}{GNI}$		−0.759*			−0.739*			−1.317***	−1.163**
Sum of lags		(0.417)			(0.419)			(0.502)	(0.483)
$\frac{Debt\ Service}{GNI}$			0.927			3.866		14.25**	9.638
Sum of lags			(5.517)			(5.712)		(7.005)	(6.643)
$\frac{Net\ Debt\ Flows}{Net\ Exports}$				0.0299			0.0217	0.0259	0.0302
Sum of lags				(0.0420)			(0.0422)	(0.0426)	(0.0419)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	2029	2029	2029	2029	2029	2029	2029	2029	2029
Countries	62	62	62	62	62	62	62	62	62
Pseudolikelihood	-193.2	−197.8	-199.6	-198.7	-190.6	-192.3	-191.4	-185.4	-194
R^2	0.258	0.24	0.234	0.237	0.268	0.262	0.265	0.288	0.255
AUROC	0.836	0.801	0.805	0.804	0.831	0.836	0.837	0.831	0.809
Standard error	0.0169	0.0186	0.0176	0.0183	0.0174	0.0161	0.0171	0.0173	0.0183

Standard errors in parentheses. Following formal lag selection procedures, I consider 5 lags of all variables. Table A.3 provide complete specification with all lags. *, ** and *** denote respectively significance at the 10, 5 and 1% levels.

Table 1 reports the baseline logit specification. Column (1) relies on the debt maturity structure, while columns (2) to (4) analyze the potential predictive ability of other debt variables. Columns (5) to (9) go one step further by investigating multiple models. Table 1 shows that the debt maturity is a strong predictor of financial crisis: a reliance on short-term debt triggers financial vulnerabilities. The results remains quantitatively identical, whatever the specification used. Thus, I adopt column (8) as the baseline specification.

Table 1 also reveals that the ratio of external debt stock over gross national income is negatively associated with the likelihood of financial crisis. It is at odds with the recent literature (Schularick and Taylor, 2012; Cesa-Bianchi et al., 2019), but they focus on advanced economies or some emerging countrries displaying a sufficient level of development. By contrast, the sample here includes low-income and middle-income countries. This counterintuitive finding on debt level is more likely explained by a rise in idiosyncratic risk premium when foreign lenders expect a domestic financial crisis.

Regarding other control variables, debt service and proxy of currency mismatch have the expected sign, but are generally insignificant. Two complementary explanations are conceivable for currency mismatch. On the one hand, this could reflect the inefficiency of this proxy to capture currency mismatches, following Rancière et al. (2010). On the other hand, the crises that are caused by maturity or currency mismatches tend to happen in batches. It is in line with Bussiere et al. (2006) that analyze the procyclical relationship between them. The "effect" of currency mismatch on crises is perhaps knocked out by maturity mismatch.[10]

Finally, the predictive power of this model is evaluated by the Receiver Operating Characteristic (ROC) curve. Since Schularick and Taylor (2012), this methodology is common in this literature. It generates a statistic AUROC, namely *area under the curve ROC*. This statistic between 0 and 1 provides a simple information to assess the predictive power of the indicator. An AUROC equal to 0.5 means that it is completely uninformative. Symmetrically, an AUROC equal to 1 means that the early-warning indicator perfectly anticipates future financial crisis. Table 1 reports ROC statistics for each model and reveal that the debt maturity structure is a better early-warning indicator of financial crises than debt level.

Quantification To document the impact of debt maturity structure in financial crisis, I estimate the predicted probability of the baseline specification (column (8)) with all control variables.[11] Table 2 compares them by differentiating between true-positive signal and false-positive signal of financial crisis. Out of the total 79 observations of financial crises, the average probability is around 11 percent. This is four times higher than the one of the regular cases, without any financial crises.

In addition, Table 2 reports the results of a counterfactual exercise close to Kalantzis (2015). I compare the probability of the baseline specification with the role of debt maturity structure (column (8)) to those without debt maturity structure (column (9)). Overall, the debt maturity structure significantly improves the probability of financial crisis by 2 percentage point on average. It contrasts with the false-positive rate in which the debt maturity structure does not really change the likelihood of financial crisis. The same holds for the difference between the predicted and the counterfactual probabilities expressed in absolute terms.[12] Going into more details, Table 2 also highlights specific cases with the highest probability of financial crisis for both true and false alarms. Without the debt maturity structure, the loss of accuracy could be quite substantial. The extreme gap is roughly 20-40 percentage points for Niger in 1983 or for central European countries.

Furthermore, the high probability of false-positive signals does not necessarily imply a model failure for three reasons. First, the timing for country-year pairs could be misleading. In other words, the financial crisis appears one year later in Yemen and three years later in Romania than pairs listed in Table 2.

[10] The horse race between debt maturity and currency mismatch does not necessarily mean that maturity mismatch is a more important cause.

[11] Alternatively, Catão and Milesi-Ferretti (2014) maximize the ratio of true-positive to the false-positive in order to define an optimal threshold.

[12] Figure A.2 in Appendix reports the difference for all cases.

Second, some specific cases are likely driven by year fixed effects. As a matter of fact, the probability of financial crisis in emerging world substantially increases with the strength of the global financial cycle, as suggested by Rey (2015) and Cesa-Bianchi et al. (2019). Third, the model could also predict currency and/or sovereign debt crises like Kazakhstan, Mongolia and Nigeria. These three types of crises are closely intertwined, which in turn hurt model predictions.[13]

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

	Nb.	Predicted	Counterfactual	|Difference|
True-Positive Signal	79	0.113	0.095	0.040
False-Positive Signal	1950	0.027	0.028	0.009

Country	Year	Predicted	Counterfactual	|Difference|
		True-Positive Signal		
Niger	1983	0.502	0.097	0.405
Russia	2008	0.471	0.264	0.207
Ukraine	2014	0.412	0.391	0.021
Ukraine	2008	0.378	0.202	0.176
Moldova	2014	0.329	0.138	0.191
Macedonia, FYR	2003	0.301	0.256	0.045
Guinea-Bissau	2014	0.267	0.215	0.052
Mongolia	2008	0.219	0.164	0.055
Kazakhstan	2008	0.220	0.164	0.056
Costa Rica	1987	0.196	0.107	0.089
		False-Positive Signal		
Swaziland	1998	0.688	0.149	0.539
China	1990	0.603	0.458	0.145
Nigeria	1982	0.523	0.101	0.422
Yemen	1995	0.479	0.326	0.153
Romania	1994	0.459	0.241	0.215
Romania	1995	0.450	0.163	0.287
Mongolia	1997	0.435	0.315	0.120
Kazakhstan	2014	0.363	0.403	-0.040
Macedonia, FYR	2008	0.338	0.469	-0.131
Nicaragua	2008	0.307	0.217	0.090

The sample covers 79 financial crises. The second part of this table only reports the 20 cases with the highest probability of financial crisis.

The Spread Channel: Endogeneity issues The debt level and debt maturity structure provide different informational contents. Then, endogeneity is a major issue in the proper identification of the underlying mechanism from debt maturity to financial crises. If the term premium is too high because of world or country-specific factors, country (i.e. both public and private agents) is more likely to borrow short-term. In other words, the mechanism works differently depending on whether a country is unwilling or unable to choose more long-term debt.

I provide an explicit treatment for this endogeneity issue by controlling for term premium. Data avail-

[13] The potential mechanism related to financial crisis could probably play a role in other types of crisis. Thus, I will use these currency and debt crises as an alternative dependent variable rather than treating them as control variables.

ability for developing world and comparability troubles across countries make the precise term premium estimation impossible. Alternatively, I develop a strategy based on the first difference of average maturity and average interest rate on new external debt at the country-level. The *unwanted* rise in term premium is caught by cases with a simultaneous rise in interest rates and a decrease in maturity, assuming little composition effects of debt portfolio. Figure 1 illustrates the four possible regions that are labeled with a red dashed line.

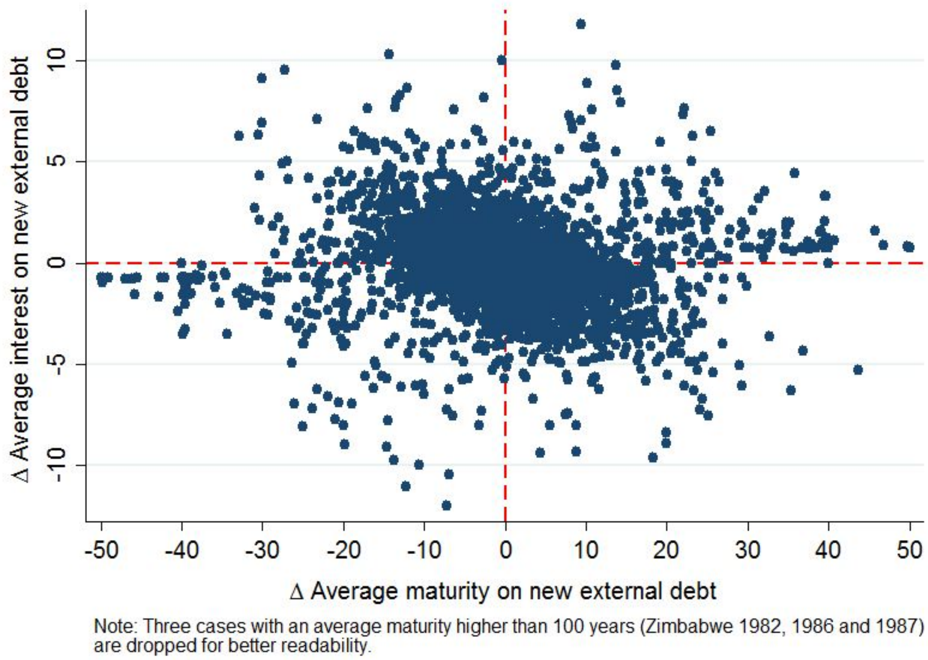

Figure 1: Illustration of estimated term premia regions

The lower left and upper right sides of Figure 1 clearly fit the basic message of yield curve but do not provide information on the term premium dynamics. By contrast, the upper left side likely captures an increasing term premium, while the opposite holds for the lower right ones. Table 3 explores the new information content across subsamples by distinguishing the four regions. When the estimated term premium is on the upper left side, the debt maturity structure drives the dynamics of financial vulnerability. Conversely, no such effect can be observed for all other sides. To sum up, Table 3 predicts that debt maturity structure is associated with a financial crisis through unwanted excessive reliance on short-term debt. This result does create a reverse causality issue if it is the prospect of a financial crisis that constrains the borrowing countries to short-term debt, rather the other way round. But I cannot determine if the rise in term premium is mostly driven by idiosyncratic risk or by foreign lender characteristics (degree of risk aversion and regional shocks) à la Cerutti et al. (2017).

Table 3 is globally consistent with the theoretical framework that generates a wedge between decentralized equilibrium and social planner allocation. The former borrows too much, which will then generate a term premium, whereas the latter is looking for optimal path of debt.

Table 3: The spread channel - Endogeneity issues

	Upper left		Upper right		Lower right		Lower left	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\frac{ST}{ST+LT}$	39.28***	50.41***	14.37	32.14	3.806	4.108	-0.701	4.348
Sum of lags	(13.71)	(18.93)	(23.10)	(10.30)	(3.526)	(3.720)	(5.804)	(9.680)
$\frac{Debt\ Stock}{GNI}$		1.704		-0.505		0.165		1.309
Sum of lags		(1.880)		(1.501)		(0.881)		(1.571)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Optimal lag nb.	5	5	1	1	5	5	1	1
Obs.	312	312	104	104	387	387	112	112
Countries	25	25	13	13	32	32	12	12
Pseudolikelihood	-24.72	-20.73	-6.760	-4.930	-50.72	-48.44	-9.735	-9.051
R^2	0.593	0.673	0.750	0.818	0.414	0.441	0.632	0.657
AUROC	0.891	0.887	0.955	0.959	0.858	0.868	0.935	0.928
Standard error	0.0216	0.0228	0.0193	0.0183	0.0232	0.0224	0.0240	0.0278

Subsample regressions. Dependent variable: Systemic Banking Crisis. Logit Estimates. Standard errors in parentheses. Following formal lag selection procedures, I consider 1 lag or 5 lags of all variables.
*, ** and *** denote respectively significance at the 10, 5 and 1% levels.

Robustness Tests The Appendix investigates the robustness of my results. First, Table A.4 replaces logit model by OLS linear probability model for the baseline specification. Even if the latter suffers from various limits, such as the unbonded predicted probabilities, this specification provides similar results with positive and statistically significant effects of short-term external debt as a ratio of all external debt. Quantitatively, it means that a one-unit increase in the five-year average of the ratio of short-term external debt over all external debt (on a [0-1] scale) is associated with an 6 percentage point increase in the probability of financial crisis. It is clearly important, because the sample's frequency of financial crises is around 2.3 percent.

Second, Table A.5 includes additional control variables. The results are globally unaffected by controlling for (i) the level of international reserves, (ii) the level of domestic credit provided by the private sector and (iii) the use of IMF credit. Finally, Table A.6 provides some sensitivity analysis to different measures of financial crises. On the one hand, the dating of banking crises is likely to have a first order effect on the results, but they hold for alternative sources of information (Laeven and Valencia, 2018; Reinhart et al., 2016). On the other hand, I use currency crises from Laeven and Valencia, 2018 as a falsification test, since the underlying mechanism is more related to banking crises.[14]

[14] I expect that the reliance of short-term debt is asssociated with the likelihood of sovereign debt crisis or of stock market

3 Baseline Model

The model borrows from *Fisherian deflation* models of financial crises, more precisely from Korinek and Dávila (2018). I consider a small open economy model where agents i belong to one of the two following types, named domestic borrowers B or international savers S[15] ($i \in B, S$). Borrowers are potentially more productive than savers at using capital but are subject to collateral constraints that may lead to fire sales. As common in this literature, the market failure generates a difference between the decentralized equilibrium and the social planner, which justifies policy intervention. I introduce the debt maturity structure into this *Fisherian deflation* model, whereas most of the literature uses one-period debt.

3.1 Economic Environment

I resort to a discrete time framework with 3 time periods: $t = 0, 1, 2$. The agent i values consumption of homogenous good c_t^i 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 the time-discount factor. At each period, agents receive an endowment of consumption good. I denote by e_t^i the endowment of consumption good received by the agent i in period t. The two agents consume this homogenous good, which serves both as numeraire and can be transformed into a capital good at price q_t. At date 0, he receives a stock of capital goods k_0^i and he decides how much to invest or disinvest in the new period at price q_0. At date 1, all the current capital denoted by k_1^i is employed to produce $F_1^i(k_1^i)$ units of consumption goods, where F is a concave, strictly increasing and continuously differentiable production function which satisfies $F^i(t) = 0, \forall t$. Following the literature on fire sales, I assume that borrowers have a better production technology than savers. Again, agents decide how much to invest or disinvest in the new period at price q_1. At date 2, the current capital denoted by 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

crash, but it is not the case. It could be explained by the year dummies or restricted samples.

[15] This could be extended to the framework of Korinek and Sandri (2016): their economy is described by domestic borrowers, domestic savers and a large set of international agents, the latter who trade bonds with both domestic agents. In all cases, the economy is price taker in world financial markets.

terms of homogenous good, where $b < 0$ corresponds to borrowing. They also have an initial level of bonds denoted by b_0^i.[16] The short-term bond b_{01} pays back in period 1 at the gross interest rate R_{01}, while the long-term bond b_{02} pays back in period 2 at the gross interest rate R_{02}. At date 1, they have access to a new short-term bond b_{12} with the gross interest rate R_{12}.

The agent i's budget constraints are given by

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

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

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

Collateral Constraints: Flows and Stock Financial market imperfections that constrain borrowers' choice are commonly depicted as an occasionally binding financial constraint linking bond stock and capital price. It is necessary to include financial frictions in the model because of moral hazard issues between lenders and borrowers. Lenders do not exactly know the household's ability to repay their debt and I assume that lenders can seize up only 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-flows relationship. To avoid defaults, lenders impose to borrowers the following *stock* collateral constraints

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

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

Because of potential differences in terms of moral hazard problems, lenders generally distinguish short from long-term bonds. Indeed, the concerns about liquidity and solvency risks are not the same. At date 0, lenders anticipate that the current value q_0 of the capital good and the current accumulation capital k_1^B of the borrower directly play the role of collateral if the borrower defaults for the short-term debt. Thus, I assume that lenders impose to borrowers the following additional *flows* constraint

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

[16] The endowments and the initial level of bonds are distributed such that in periods 0 and 1 borrowers find it optimal to borrow and savers find it optimal to save.

The tightening of the stock constraint (6) yield a risk premium, while that 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 an excessive short-term debt creates liquidity troubles and exacerbates the risk of default with lower debt amortization process. There is no similar liquidity constraint at date 1 because all debt (i.e. short-term bond issued at date 1 and long-term bond issued at date 0) is repaid in date 2. κ and Φ appear as pledgeability parameters that determine the level of the market incompleteness, where $(\kappa, \Phi) \in [0,1]^2$. The set of parameters $\{\kappa, \Phi\}$ allow a distinction between short and long-term debt.[17] For each combination of feasible $\{\kappa, \Phi\}$, there are four possibilities: (i) no constraint binds; (ii) only the debt flows constraint binds; (iii) only the debt stock constraint binds; (iv) both debt flows and stock constraints bind.

The mix of short and long-term bonds for borrowers plays a role in financial amplification. Figure 2 summarizes the feasible states, with term premium at date 0 and risk premia at dates 0 and 1. If one or more collateral constraints in period 0 are binding, the stock collateral constraint in period 1 is not generally slacking but that is not automatic. Indeed, the production function of borrowers F_1^B and the endowment e_1^B may be large enough to avoid another overborrowing case and/or asset fire sales.

Flows \ Stock	Slack	Binding
Slack	i	iii
Binding	ii	iv

date 0

Stock	
Slack	Binding

date 1

Figure 2: Set of possible states

3.2 Decentralized Equilibrium

A decentralized equilibrium consists of a 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, where all markets clear[18]

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

[17] If $\kappa > \Phi$, there is no real *free* choice between these two types of debt and it is at the expense of long-term debt.

[18] I assume the uniqueness of the equilibrium. See Schmitt-Grohé and Uribe (2016) and Jeanne and Korinek (2018) on the possibility of multiple equilibria.

Following Korinek and Sandri (2016) and Korinek and Dávila (2018), the decentralized equilibrium is solved via backward induction. The impact of uncertainty on the economy (i.e. on potential binding flows 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 from the pecuniary externality. If one or two collateral constraint are binding because of these fire sales, they are not perfectly anticipated at the moment of decisions by the borrower, and the decisions will not be correct.

Date 2 Equilibrium Each agent consumes homogenous good and settles their bond positions, regardless of whether one previous collateral constraint is binding or not.

Date 1 Equilibrium The problem solved by each agent, who behaves competitively and takes prices as given, is as follows

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

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 common in this literature, the resulting Euler equation for bonds and the optimal capital 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 weighting 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 improves the marginal benefit of higher current consumption of the capital good, that relaxes the collateral constraint. Equation (14) characterizes capital price. If the collateral constraint is slack, the price q_1 reduces to a standard Euler equation for assets whereby it equals the marginal product of capital discounted 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 quite ambiguous if I look the middle-hand side of the equation (14), close to Korinek and Mendoza (2014). On the one hand, the marginal rate of substitution falls. On the other hand, the denominator of this equation is reduced by the extra-term. It reduces the borrowers' disutility of $U_2'^B$ by relaxing the collateral constraint. The right-hand part of equation (14) highlights that the result of these two effects is rationalized by the parameter Φ, that reflects the strength of financial amplification. At the equilibrium, these optimal conditions (13) and (14) provide the capital price q_1 and the interest rate R_{12}.

Date 0 Equilibrium Following the same way, the agent i takes prices at given, and solves

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

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

As in Korinek and Dávila (2018), I denote the term $V_{n1}^i := \frac{\partial V^i}{\partial n_1^i}$ as the private marginal utility of wealth. In the same way, the term V_{k1}^i holds for capital good. Using the envelope conditions $V_{n1}^i = \lambda_1^i$ and $V_{k1}^i = \lambda_1^i q_1$, the maximisation problem yields

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

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

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

These conditions are similar to the previous ones, with equations (16) and (28) for the two types of bonds and equation (18) for capital. Two differences appear compared to the period 1 equilibrium. First, the two Euler equations for bonds can be combined to deliver the no-arbitrage condition with a positive term premium if and only if the flows collateral constraint is binding.

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

Second, the Euler equation (18) at date 0 adds the remaining value q_1 of the capital. It includes the benefit of relaxing not only the stock collateral constraint but also the flow ones.

Proposition 1 *Following a positive approach, the model provides two main theoretical predictions that are in line with the previous empirical exercise: (i) the excessive level of debt triggers fire sales through the binding collateral constraints; (ii) the bulk of the impact of debt on fire sales is driven by 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 asset price in collateral constraints may result in asset fire sales, which generally induces a suboptimal decentralized equilibrium. The benevolent social planner internalizes this pecuniary externality in periods 0 and 1. First, he chooses date 0 and date 1 allocations, respecting that all prices are market-determined. Then, the optimal allocation is restored in the decentralized equilibrium by a set of taxes on short and long-term debts and subsidies on capital.

4.1 Social Planner Problem

The social planner problem is close to the date 0 decentralized equilibrium, with two key exceptions. First, the planner directly includes the pecuniary externality through two implementability constraints at dates 0 and 1, namely the Euler equations for capital (14) and (18). Second, thanks to the previous point, he internalizes the interdependencies between dates 0 and 1. For instance, too many long-term bonds contracted at date 0 could avoid asset fire sales at date 0 but generates them at date 1. As a consequence, the planner not only chooses the optimal date 0 allocation but also the optimal date 1 allocation, which in turn directly provides the same for date 2, in contrast to Korinek and Sandri (2016) and Korinek and Dávila (2018).[19]

[19] Korinek and Sandri (2016) and Korinek and Dávila (2018) look for the distinction between individual state variables (n^i, k^i) and sector-wide aggregate state variables (n^i, k^i), which can be used to include the pecuniary externality. But this approach does not easily allow for debt maturity structure. This paper introduces the pecuniary externality through implementability constraints. This another approach is close to Bianchi and Mendoza (2018) and Schmitt-Grohé and Uribe (2017).

Because the saver is unconstrained and hence behaves optimally[20], I focus on the behavior of the borrower that constitutes another difference between the paper and the two previous ones.

$$max U^B(c_0^B) + \beta \mathbb{E}_0 V^B(n_1^B, k_1^B) \quad \text{subject to (3), (4), (5), (6), (7), (8), (14) and (18)} \tag{20}$$

where λ_t^{SP}, μ_t^{SP}, η_1^{SP} and ξ_t^{SP} denote the Lagrange multipliers for the social planner on the budget constraints, on the stock and flows collateral constraints and on the implementability constraints in period t, respectively. The optimal conditions for the social planner differ from the decentralized equilibrium in various ways.

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

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

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

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

About the consumption at date 0, there is a wedge between the private (16) and social (21) conditions that the reflect marginal utility of consumption because the social planner includes the risk of potential asset fire sales and values more the capital good. Because $U_t''^B < 0$ for $t \in \{0, 1\}$, the consumption of homogenous good at date 0 is lower in the social planner allocation than in the decentralized equilibrium if $\xi_t^{SP} > 0$. The value of this implementability condition ξ_t^{SP} is generally non-zero and will be specified later.

Consider now the differences between private (13) and social (22) conditions. The consumption at date 1 as defined by the social planner includes two new terms.[21] The first term follows the same logic as the ones defining the previous period. The second term represents the positive role of previous capital accumulation on the current consumption as well as in sales and in the function production. It reduces the wedge between good consumption for decentralized equilibrium and social planner allocation. This effect is conditional on the degree of concavity in consumption. Finally, the net effect of these two terms on the

[20] Nevertheless, the potential asset fire sales could lead to redistribute wealth among the two types of agents, which are called *distributive externalities* and described in Korinek and Dávila (2018). For simplicity, I put aside this question and the associated potential distortions. See Jeanne and Korinek (2013) about ex-post policies financed by savers.

[21] Substituting (16) into (13) yields the same first term in (22) and in (13). They reflect the private marginal utility of consumption and are discounted in the same way.

consumption at date 1 is uncertain and clearly depends on an intertemporal arbitrage. Rearranging (22) sheds light on the sign of the shadow values ξ_1^{SP} and ξ_0^{SP} on this issue.

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

where $\xi_1^{SP} - \xi_0^{SP}$ means how the social planner relatively values the potential risk of asset fire sales in the two periods. If $\xi_1^{SP} < \xi_0^{SP}$, then the term that reflects this intertemporal arbitrage has the same sign as the effect of capital accumulation. Therefore, the social planner allocation increases the good consumption in period 1. But, if $\xi_1^{SP} > \xi_0^{SP}$, then the net impact of these terms is ambiguous, depending on the potential risk of asset fire sales versus the previous capital accumulation. It is also useful to contrast date 2 conditions (13) and (23), because of the social benefit due to higher capital accumulation at date 1.

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

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

$$q_1 = \frac{\lambda_2^{SP}\left[F_2^{\prime B}(k_2^B) + \xi_1^{SP} F_2^{\prime\prime B}(k_2^B)\right]}{\lambda_1^{SP} - \Phi\mu_2^{SP}} \tag{26}$$

Again, the comparison between private (14)-(18) and social decisions (25)-(26) provides some differences in the two periods. First, the social planner creates some redistribution between consumption of good and capital, underlined as *Externality term* in equation (25). Second, this effect in favor of capital is balanced with decreasing returns to scale of the production function.

Finally, the Euler optimal conditions for bonds are close to those obtained in decentralized equilibrium.

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

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

$$\lambda_1^{SP} = R_{12}\lambda_2^{SP} + \mu_2^{SP} \quad \text{with} \quad \lambda_2^{SP} = \beta U_2^{\prime SP} \tag{29}$$

But the social planner allocation generates striking differences through changes in the Lagrange multipliers. So it affects the term premium denoted by $\rho^j := R_{02}^j - R_{01}^j$ where the superscript $j \in \{DE, SP\}$

distinguishes decentralized equilibrium (from condition (19)) from social planner.

$$\rho^{DE} = \frac{\eta_1^B}{\beta \mathbb{E}_0(\lambda_1^B)} \lesseqgtr \rho^{SP} = \frac{\eta_1^{SP}}{\beta \mathbb{E}_0(\lambda_1^{SP})} \tag{30}$$

where λ_1^{SP} is defined in equation (24). When the flow collateral constraint is slack, there is no risk premium in both cases. If I suppose a sufficient amount of short-term bonds, the risk premium between decentralized equilibrium and social planner is different, but with an ambiguous sign. For the above-mentioned reasons and with $\xi_1^{SP} > \xi_0^{SP}$ as a necessary condition, the risk premium of the social planner allocation could shrink down. The intuition is that if the flow collateral constraint is potentially binding at date 0 with too much short-term bonds, the planner analyzes the risk of asset fire sales and forces the borrower to increase his position on long-term bonds. In other words, the social planner decides how to reallocate debt portfolio in order to avoid positive term premium.

4.2 Implementation via Taxes

Based on these differences, I highlight that a set of taxes and subsidies replicates the social planner allocation. They affect the debt level at date 0 and 1, in order to avoid an overborrowing case. They also provide capital good subsidies on the capital good. In fact, tipping the balance between consumption and capital goods in favor of the latter leads to reduced potential asset 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 on capital good τ_0^k and τ_1^k, where $\tau > 0$ (< 0) reflects a tax (subsidy). The policy intervention assumes that government budget constraint is balanced at each period t, with the presence of lump-sum transfers T_t.[22]

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

$$c_0^B + q_0(1+\tau_0^k)(k_1^B - k_0^B) + \frac{b_{01}^B}{R_{01}}(1-\tau_0^{ST}) + \frac{b_{02}^B}{R_{02}}(1-\tau_0^{LT}) + T_0 = e_0^B + b_0^B \tag{31}$$

$$c_1^B + q_1(1+\tau_1^k)(k_2^B - k_1^B) + \frac{b_{12}^B}{R_{12}}(1-\tau_1^{ST}) + T_1 = e_1^B + b_{01}^B + F_1^B(k_1^B) \tag{32}$$

Interest rates paid by borrowers increases with the level of the corresponding tax in line with the framework

[22] I also assume that there is no time inconsistency problem. The potential break between policymaker's action under commitment and under discretion is widely debated. See Bianchi and Mendoza (2018) and Jeanne and Korinek (2018).

of Schmitt-Grohé and Uribe (2017). The corresponding lump-sum transfers/taxes only for borrowers are

$$T_0 = \tau_0^k q_0 k_1^B + \tau_0^{ST} \frac{b_{01}^B}{R_{01}} + \tau_0^{LT} \frac{b_{02}^B}{R_{02}} \tag{33}$$

$$T_1 = \tau_1^k q_1 k_2^B + \tau_1^{ST} \frac{b_{12}^B}{R_{12}} \tag{34}$$

Taxes on Debt At date 0, the Euler equations for bonds become

$$\lambda_0^B (1 - \tau_0^{ST}) = \beta R_{01} \mathbb{E}_0(\lambda_1^B) + \mu_1^B + \eta_1^B \tag{35}$$

$$\lambda_0^B (1 - \tau_0^{LT}) = \beta R_{02} \mathbb{E}_0(\lambda_1^B) + \mu_1^B \tag{36}$$

By combining these new equations, the risk premium (19) and the social planner allocation conditions (21) and (22) on the consumption in periods 0 and 1, I obtain

$$\tau_0^{ST} = \tau_0^{LT} = 1 - \beta R_{01} \mathbb{E}_0 \left[\frac{\beta U_1'^B - (\overbrace{\xi_1^{SP}}^{Date\ 1} \overbrace{- \xi_0^{SP}) q_1 U_1''^B + \xi_0^{SP} \beta U_1''^B F_1'^B (k_1^B)}^{Inter.\ arbitrage:\ pecu.\ externality}}{U_0'^B \underbrace{- \xi_0^{SP} q_0 U_0''^B}_{Intra.\ arbitrage}} \right] - \underbrace{\frac{\eta_1^B}{\lambda_0^{SP}}}_{Term\ prem.} - \underbrace{\frac{\mu_1^B}{\lambda_0^{SP}}}_{Risk\ prem.}$$

The set of taxes on short and long-term bonds are both *ex-ante* and *ex-post* policies. The *ex-ante* component is represented by a large part of the numerator in the main fraction, underlined as *inter-temporal arbitrage*. Following the previous condition (22) and the associated benefits of capital accumulation as well as in sales and function production, this pushes up both taxes on bonds, which in turn limits the risk of further binding collateral constraint. This argument is in line with countercyclical policies as proposed by Korinek and Sandri (2016) and Jeanne and Korinek (2018). The *ex-post* component of these taxes, close to Bianchi and Mendoza (2018) and underlined as *intra-temporal arbitrage*, reduces the risk of a current binding collateral constraints due to overconsumption. As suggested by condition (21), it supports high-level taxes and leads to a decrease in the good consumption in period 0.

These taxes at date 0 are also negatively correlated to the shadow value ξ_1^{SP} of the next period's implementability constraint, underlined as *date 1*. It is related to the time preference of social planner and reflects the interest of ex-post policies in the next period. This balances the choice between ex-ante and ex-post policies period-by-period.

In addition, these policy interventions are state-contingent, because they are reduced in overborrowing cases, when one or two collateral constraints are binding.[23] Specifically, the social planner alleviates the fiscal pressure on both short and long-term bonds when the *flow* collateral constraint is binding (i.e. a positive *term* premium appears) and/or when the *stock* collateral constraint is binding (i.e. a positive *risk* premium appears). In other words, there is no need to introduce a wedge between the two taxes. That does not mean that the bond maturity structure chosen by the agent is irrelevant, but he internalizes the set of taxes and chooses carefully the optimal mix between short and long-term bonds. The role of premia in these policy instruments reflects the private self-insurance mechanism, acccording to Jeanne and Korinek (2018). In their setup, the level of optimal *ex-ante* policies relies on changes in parameter values, such as the likelihood of a financial crisis, whereas I develop a model in which the policies are explicitly linked to the term and risk premia.

At date 1, the process is similar with the new Euler equation for bond

$$\lambda_1^B(1-\tau_1^{ST}) \quad = \quad R_{12}\lambda_2^B + \mu_2^B \quad \text{with} \quad \lambda_1^B = U_1^{\prime B} \quad \text{and} \quad \lambda_2^B = \beta U_2^{\prime B} \tag{37}$$

which provides the following tax on short-term bonds at date 1

$$\tau_1^{ST} \quad = \quad 1 - \mathbb{E}_1 R_{12}\left[\frac{\beta^2 U_2^{\prime B} + \overbrace{\xi_1^{SP}\beta U_2^{\prime\prime B}F_2^{\prime B}(k_2^B)}^{\textit{Interest next capital accumul.}}}{\beta U_1^{\prime B} - \underbrace{\xi_1^{SP}q_1 U_1^{\prime\prime B}}_{\textit{Pecu. Externality}} - \underbrace{\xi_0^{SP}q_1 U_1^{\prime\prime B} + \xi_0^{SP}U_1^{\prime\prime B}F_1^{\prime B}(k_1^B)}_{\textit{Date 0: capital accumul.}}}\right] - \underbrace{\frac{\mu_2^B}{\lambda_1^{SP}}}_{\textit{Risk prem.}} \tag{38}$$

Comparing the tax with the similar one in the previous period yields some similarities and calls for a *ex-post* policy intervention, because of two arguments: (i) the current risk of overconsumption, which in turn triggers overborrowing and asset fire sales, and (ii) the benefits of further capital accumulation.

The binding stock collateral constraint related to risk premium at date 1 cuts the level of the tax. Furthermore, this tax includes a new negative term, that is related to the previous capital accumulation at date 0 due to the ex-ante policy.

Subsidies on Capital By using decentralized equilibrium condition (25) and the new optimal capital accumulation decision with the social planner policies, the tax/subsidy on the capital at date 0 is defined

[23] The relevant values of μ and η from relaxing the collateral constraints are those of decentralized equilibrium and not of the social planner, because the set concerns a decentralized equilibrium with taxes and subsidies.

by

$$\tau_0^k = \frac{\mathbb{E}_0 \left[(F_1^{'B}(k_1^B) + q_1) \left(\overbrace{(\xi_1^{SP} - \xi_0^{SP}) q_1 U_1^{''B}}^{Inter.\ arbitrage} - \overbrace{\xi_0^{SP} U_1^{''B} F_1^{'B}(k_1^B)}^{Intra.\ arbitrage} \right) - \overbrace{\xi_0^{SP} \beta \lambda_1^{SP} F_1^{''B}(k_1^B)}^{Decreasing\ returns} \right]}{q_0 \lambda_0^{SP}} \tag{39}$$

and the tax/subsidy at date 1 is

$$\tau_1^k = \frac{\mathbb{E}_1 \left[\beta U_2^{''B} F_2^{'B}(k_2^B) \left(\overbrace{F_2^{'B}(k_2^B)}^{Capital\ accumulation} + \overbrace{\xi_1^{SP} F_2^{''B}(k_2^B)}^{Decreasing\ returns} \right) + \beta^2 U_2^{'B} F^{''B}(k_2^B) \right]}{q_1 \lambda_1^{SP}} \tag{40}$$

These policies on capital complement taxes on debt to ensure that decentralized agents have no incentives to sell too much of their capital. At date 0, the equation (39) may be decomposed into three parts, following close previous arguments. First, this policy depends on the preference of the social planner for the two-periods risk of asset fire sales, which is measured by $\xi_1^{SP} - \xi_0^{SP}$. Second, this policy is affected by the degree of concavity in consumption. Finally, it is weighted by the production function and the efficiency limits due to decreasing returns to scale. To sum up, equation (39) generates a subsidy on capital ($\tau^k < 0$) if and only if the first term is sufficiently large and $\xi_1^{SP} > \xi_0^{SP}$. This means that the planner provides subsidies on capital when the capital accumulation is the key to avoid current and further asset fire sales. It is conditional on the function production efficiency and the agent's preference, while taxes on debt potentially sharply reduce the risk of fire sales. The same mechanism holds for subsidy at date 1 in equation (40).

Proposition 2 *Following a normative approach, the optimal allocation is restored in the decentralized equilibrium by a set of taxes on short and long-term debts and subsidies on capital, both at date 0 and date 1. As summarized in table 4, these policy instruments are contingent to various determinants, especially the share of consumption in total income, the term premium and the risk premium.*

5 Conclusion

This paper underlines the role of debt maturity structure as a key early-warning indicator of financial crises for the developing world. An excessive reliance on short-term debt exacerbates the risk of financial

Table 4: Policy Intervention - Summary

Policy Intervention	Increase	Decrease
τ_0^{ST} and τ_0^{LT}	risk of overconsumption at date 0 risk of overconsumption at date 1 benefits of further capital accumulation	positive term premium at date 0 positive risk premium at date 0
τ_1^{ST}	risk of overconsumption at date 1 benefits of further capital accumulation	positive risk premium at date 1 benefits of *previous* capital accumulation
τ_0^k and τ_1^k	benefits of further capital accumulation	Decreasing returns to scale

crises through a rise in the term premium. These testable predictions are then brought to the model. I introduce debt maturity structure in a *Fisherian deflation* model and I highlight that the mix of these debts chosen by a decentralized agent follows a suboptimal path, which amplifies both liquidity risk (i.e. the rise in term premium) and solvency risk (i.e. the rise in risk premium), and then triggers fire sales. It makes harder the art of policymaking and calls for both ex-ante and ex-post policies. Nevertheless, the optimal corrective policies can be globally designed using three statistics, namely the share of consumption good in total income, the liquidity concern and the solvency one.

This framework can be extended by including global financial forces, that is called the global financial cycle by Rey (2015). Clearly, the spillover effects from the US monetary policy are large, because it drives global liquidity and this adds up to the high level of comovement in asset prices, credit, and risk aversion around the world. The global financial cycle can be seen in two phases: (i) boom with low US interest rates and high global liquidity and (ii) bust with high US interest rates and low global liquidity. These regime shifts are introduced into a *Fisherian deflation* model by Bianchi et al. (2016). The current framework that includes debt maturity structure can be enhanced to include these regime shifts. This affects the mix of short and long-term bonds chosen by the agent, which in turn could 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, both the likelihood and the amplitude of the financial crisis increase.

References

Aguiar, M., Amador, M., Hopenhayn, H., and Werning, I. (2016). Take the Short Route: Equilibrium Default and Debt Maturity. NBER Working Papers 22847.

Alfaro, L. and Kanczuk, F. (2009). Debt Maturity: Is Long-Term Debt Optimal? *Review of international Economics*, 17(5):890–905.

Arellano, C. and Ramanarayanan, A. (2012). Default and the Maturity Structure in Sovereign Bonds. *Journal of Political Economy*, 120(2):187–232.

Arteta, C. O. (2005). Exchange Rate Regimes and Financial Dollarization: Does Flexibility Reduce Currency Mismatches in Bank Intermediation? *Topics in Macroeconomics*, 5(1).

Avdjiev, S., Binder, S., and Sousa, R. (2017a). External Debt Composition and Domestic Credit Cycles. BIS Working Papers 627, Bank for International Settlements.

Avdjiev, S., Gambacorta, L., Goldberg, L. S., and Schiaffi, S. (2017b). The Shifting Drivers of International Capital Flows. NBER Working Papers 23565.

Bénétrix, A. S., Lane, P. R., and Shambaugh, J. C. (2015). International Currency Exposures, Valuation Effects and the Global Financial Crisis. *Journal of International Economics*, 96:98–109.

Benigno, G., Chen, H., Otrok, C., Rebucci, A., and Young, E. R. (2013). Financial Crises and Macro-Prudential Policies. *Journal of International Economics*, 89(2):453–470.

Benigno, G., Chen, H., Otrok, C., Rebucci, A., and Young, E. R. (2016). Optimal Capital Controls and Real Exchange Rate Policies: A Pecuniary Externality Perspective. *Journal of Monetary Economics*, 84:147–165.

Bian, J., He, Z., Shue, K., and Zhou, H. (2018). Leverage-Induced Fire Sales and Stock Market Crashes. NBER Working Papers 25040.

Bianchi, J. (2011). Overborrowing and Systemic Externalities in the Business Cycle. *American Economic Review*, 101(7):3400–3426.

Bianchi, J. (2016). Efficient Bailouts? *American Economic Review*, 106(12):3607–59.

Bianchi, J., Hatchondo, J. C., and Martinez, L. (2018). International Reserves and Rollover Risk. *American Economic Review*, 108(9):2629–70.

Bianchi, J. and Mendoza, E. G. (2018). Optimal Time-Consistent Macroprudential Policy. *Journal of Political Economy*, 126(2):588–634.

Bianchi, J., Mendoza, Enrique, G., and Liu, C. (2016). Fundamentals News, Global Liquidity and Macroprudential Policy. *Journal of International Economics*, 99(1):2–15.

Bordo, M. D., Meissner, C. M., and Stuckler, D. (2010). Foreign Currency Debt, Financial Crises and Economic Growth: A Long-Run View. *Journal of international Money and Finance*, 29(4):642–665.

Broner, F. A., Lorenzoni, G., and Schmukler, S. L. (2013). Why Do Emerging Economies Borrow Short Term? *Journal of the European Economic Association*, 11(1):67–100.

Bussiere, M., Fratzscher, M., and Koeniger, W. (2006). Uncertainty and Debt-Maturity in Emerging Markets. *The B.E. Journal of Macroeconomics*, 6(1):1–28.

Campbell, J. Y., Giglio, S., and Pathak, P. (2011). Forced Sales and House Prices. *Journal of International Economics*, 101(5):2108–31.

Catão, L. A. and Milesi-Ferretti, G. M. (2014). External Liabilities and Crises. *Journal of International Economics*, 94(1):18–32.

Cerutti, E., Claessens, S., and Puy, M. D. (2015). Push Factors and Capital Flows to Emerging markets: Why knowing your lender matters more than fundamentals. IMF Working Papers 15-127, International Monetary Fund.

Cerutti, E., Claessens, S., and Rose, A. K. (2017). How Important is the Global Financial Cycle? Evidence from Capital Flows. BIS Working Papers 661, Bank for International Settlements.

Cesa-Bianchi, A., Eguren Martin, F., and Thwaites, G. (2019). Foreign booms, domestic busts: The global dimension of banking crises. *Journal of Financial Intermediation*, 37:58 – 74.

Chang, R. and Velasco, A. (2000). Banks, debt maturity and financial crises. *Journal of international Economics*, 51(1):169–194.

Cole, H. L. and Kehoe, T. J. (1996). A self-fulfilling model of mexico's 1994–1995 debt crisis. *Journal of international Economics*, 41(3-4):309–330.

Cole, H. L. and Kehoe, T. J. (2000). Self-fulfilling debt crises. *The Review of Economic Studies*, 67(1):91–116.

Debortoli, D., Nunes, R., and Yared, P. (2017). Optimal Time-Consistent Government Debt Maturity. *The Quarterly Journal of Economics*, 132(1):55–102.

Drehmann, M. and Juselius, M. (2014). Evaluating Early Warning Indicators of Banking Crises: Satisfying Policy Requirements. *International Journal of Forecasting*, 30(3):759–780.

Drehmann, M., Juselius, M., and Korinek, A. (2017). Accounting for Debt Service: The Painful Legacy of Credit Booms. BIS Working Papers 645, Bank for International Settlements.

Fernández, R. and Martin, A. (2015). The Long and the Short of It: Sovereign Debt Crises and Debt Maturity. Barcelona GSE Working Papers 818, Barcelona Graduate School of Economics.

Fisher, I. (1933). The Debt-Deflation Theory of Great Depressions. *Econometrica: Journal of the Econometric Society*, pages 337–357.

Gourinchas, P.-O. and Obstfeld, M. (2012). Stories of the Twentieth Century for the Twenty-First. *American Economic Journal: Macroeconomics*, 4(1):226–265.

Jeanne, O. (2009). Debt Maturity and the International Financial Architecture. *American Economic Review*, 99(5):2135–48.

Jeanne, O. and Korinek, A. (2013). Macroprudential Regulation versus Mopping Up After the Crash. NBER Working Papers 18675.

Jeanne, O. and Korinek, A. (2018). Managing Credit Booms and Busts: A Pigouvian Taxation Approach. *Journal of Monetary Economics*, Forthcoming.

Jordà, O., Schularick, M., and Taylor, A. M. (2015). Leveraged Bubbles. *Journal of Monetary Economics*, 76(S):S1–S20.

Jordà, Ò., Schularick, M., and Taylor, A. M. (2016). Sovereigns versus Banks: Credit, Crises, and Consequences. *Journal of European Economic Association*, 14(1):45–79.

Kalantzis, Y. (2015). Financial Fragility in Small Open Economies: Firm Balance Sheets and the Sectoral Structure. *The Review of Economic Studies*, 82(3):1194–1222.

Korinek, A. and Dávila, E. (2018). Pecuniary Externalities in Economies with Financial Frictions. *Review of Economic Studies*, 85(1):352–395.

Korinek, A. and Mendoza, E. G. (2014). From Sudden Stops to Fisherian Deflation: Quantitative Theory and Policy. *Annual Review of Economics*, 6(1):299–332.

Korinek, A. and Sandri, D. (2016). Capital Controls or Macroprudential Regulation? *Journal of International Economics*, 99(1):27–42.

Kuruc, E., Tissot, B., and Turner, P. (2016). Looking at Aggregate Currency Mismatches and Beyond. BIS Conference Paper, Bank for International Settlements.

Laeven, L. and Valencia, F. (2018). Systemic banking crises revisited.

Ligonnière, S. (2018). Trilemma, dilemma and global players. *Journal of International Money and Finance*, 85:20–39.

Mendoza, E. G. and Terrones, M. E. (2012). An Anatomy of Credit Booms and their Demise. NBER Working Papers 18379.

Mendoza, Enrique, G. (2017). Macroprudential Policy: Promise and Challenges. NBER Working Papers 22868.

Niepelt, D. (2014). Debt Maturity without Commitment. *Journal of Monetary Economics*, 68:S37–S54.

Qian, X. and Steiner, A. (2017). International Reserves and the Maturity of External Debt. *Journal of International Money and Finance*, 73(B):399–418.

Rancière, R., Tornell, A., and Vamvakidis, A. (2010). Currency Mismatch, Systemic Risk and Growth in Emerging Europe. *Economic Policy*, 25:597–658.

Reinhart, C. M., Reinhart, V., and Trebesch, C. (2016). Global cycles: Capital flows, commodities, and sovereign defaults, 1815-2015. *American Economic Review*, 106(5):574–80.

Reinhart, C. M. and Rogoff, K. (2009). *This Time is Different: Eight Centuries of Financial Folly*. Princeton University Press.

Rey, H. (2015). Dilemma not Trilemma: The global Financial Cycle and Monetary Policy Independence. NBER Working Papers 21162.

Schmitt-Grohé, S. and Uribe, M. (2016). Multiple Equilibria in Open Economy Models with Collateral Constraints: Overborrowing Revisited. NBER Working Papers 22264.

Schmitt-Grohé, S. and Uribe, M. (2017). Is Optimal Capital-Control Policy Counteryclical in Open-Economy Models with Collateral Constraints. *IMF Economic Review*, 65(3):498–527.

Schularick, M. and Taylor, A. M. (2012). Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises, 1870-2008. *American Economic Review*, 102(2):1029–61.

Tobal, M. (2018). Currency Mismatch in the Banking Sector in Latin America and the Caribbean. *International Journal of Central Banking*, 14(1):317–364.

Zhou, J. (2018). Financial Crises, Debt Maturity, and Capital Controls. Unpublished.

Appendix 1: Stylized Facts

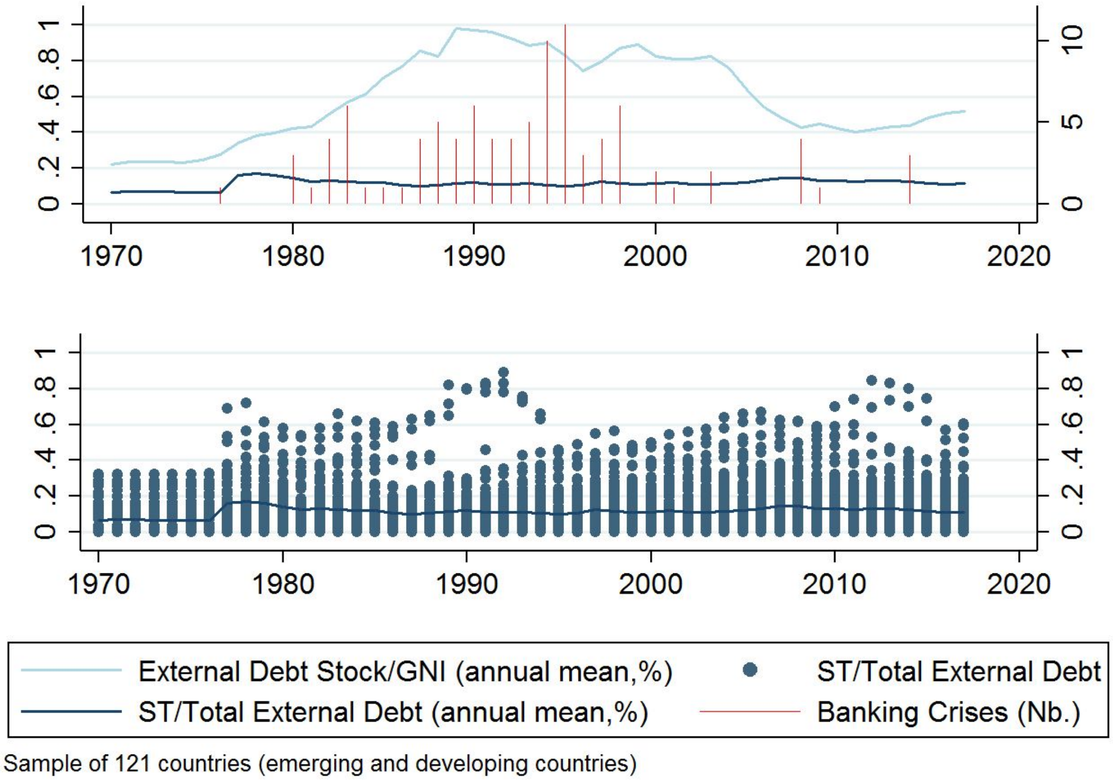

Figure A.1: Debt Stock, Debt Maturity Structure and Number of Systemic Banking Crises

Appendix 2: List of Countries and Data Sources

Table A.1: List of countries

	Time Coverage		Time Coverage		Time Coverage
Afghanistan	2013-2017	Gambia, The	1983-2017	Nigeria	1982-2017
Albania	1996-2017	Georgia	2002-2017	Pakistan	1981-2017
Algeria	1982-2017	Ghana	1980-2017	Papua New Guinea	1981-2017
Angola	1994-2017	Grenada	1982-2017	Paraguay	1980-2017
Argentina	1975-2016	Guatemala	1982-2017	Peru	1982-2017
Armenia	1998-2017	Guinea	1991-2017	Philippines	1982-2017
Azerbaijan	2000-2017	Guinea-Bissau	1987-2017	Romania	1994-2017
Bangladesh	1981-2017	Guyana	1982-2017	Russia	1999-2017
Belarus	1998-2017	Haiti	1976-2017	Rwanda	1981-2017
Belize	1989-2017	Honduras	1979-2017	Sao Tome	1982-2017
Benin	1979-2017	India	1980-2017	Samoa	1982-2017
Bhutan	2011-2017	Indonesia	1986-2017	Senegal	1979-2017
Bolivia	1981-2017	Iran	1985-2017	Serbia	2012-2017
Bosnia	2004-2017	Ivory Coast	1980-2017	Sierra Leone	1982-2017
Botswana	1980-2017	Jamaica	1981-2017	Solomon Islands	1983-2017
Brazil	1970-2012	Jordan	1977-2017	South Africa	1999-2017
Bulgaria	1986-2017	Kazakhstan	2000-2017	Sri Lanka	1980-2017
Burkina Faso	1979-2017	Kenya	1980-2017	St. Lucia	1986-2017
Burundi	1990-2017	Kyrgyz Rep.	1998-2017	St. Vincent	1983-2017
Cambodia	1990-2017	Lao PDR	1989-2017	Sudan	1982-2017
Cameroon	1982-2017	Lebanon	1994-2017	Swaziland	1995-2017
Cape Verde	1986-2017	Lesotho	1980-2017	Syria	2000-2002
Central African Rep.	1982-1995	Liberia	1984-2017	Tajikistan	2007-2017
Chad	1982-1995	Macedonia, FYR	2001-2017	Tanzania	1993-2017
China	1987-2017	Madagascar	1979-2017	Thailand	1980-2017
Colombia	1975-2017	Malawi	1982-2017	Timor-Leste	2011-2017
Comoros	1985-2017	Maldives	1983-2017	Togo	1979-2017
Congo, Dem. Rep.	2010-2017	Mali	1980-2017	Tonga	1990-2017
Congo, Rep.	1983-2017	Mauritania	1980-2017	Tunisia	1981-2017
Costa Rica	1982-2017	Mauritius	1981-2017	Turkey	1975-2017
Djibouti	1996-2017	Mexico	1984-2017	Uganda	1985-2017
Dominica	1986-2017	Moldova	2000-2017	Ukraine	1999-2017
Dominican Rep.	1975-2017	Mongolia	1997-2017	Vanuatu	1987-2017
Ecuador	1981-2017	Montenegro	2012-2017	Venezuela	1975-2015
Egypt	1975-2017	Morocco	1980-2017	Vietnam	1994-2017
El Salvador	1981-2017	Mozambique	1989-2017	Yemen	1995-2017
Eritrea	1999-2001	Myanmar	2005-2017	Zambia	1983-2017
Ethiopia	1986-2017	Nepal	1981-2017	Zimbabwe	1982-2017
Fiji	1984-2017	Nicaragua	1994-2017		
Gabon	1983-2013	Niger	1979-2017		

Note: this table corresponds to the sample of 118 countries with 3402 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. Could be decomposed into short (ST) and long-term (LT).	World Bank
$\frac{Debt\ Service}{GNI}$	Ratio of external debt service (payment of principal and interests) to gross national income. Could be decomposed into short (ST) and long-term (LT).	World Bank
Average Interest	Average interest on new external debt commitments, %.	World Bank
Average Maturity	Average maturity on new external debt commitments, %.	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
	Other Control Variables	
log(GDP)	GDP, current US dollars.	World Bank
$\frac{Reserves}{Debt\ Stock}$	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.	World Bank
$\frac{Private\ Credit}{GDP}$	Domestic credit to private sector as a share of GDP. It refers to financial resources provided to the private sector by financial corporations.	World Bank
$\frac{IMF\ credit}{GNI}$	Specific ratio with the credit provided by the IMF Treasurer's Department.	World Bank

Appendix 3: Additional Tests

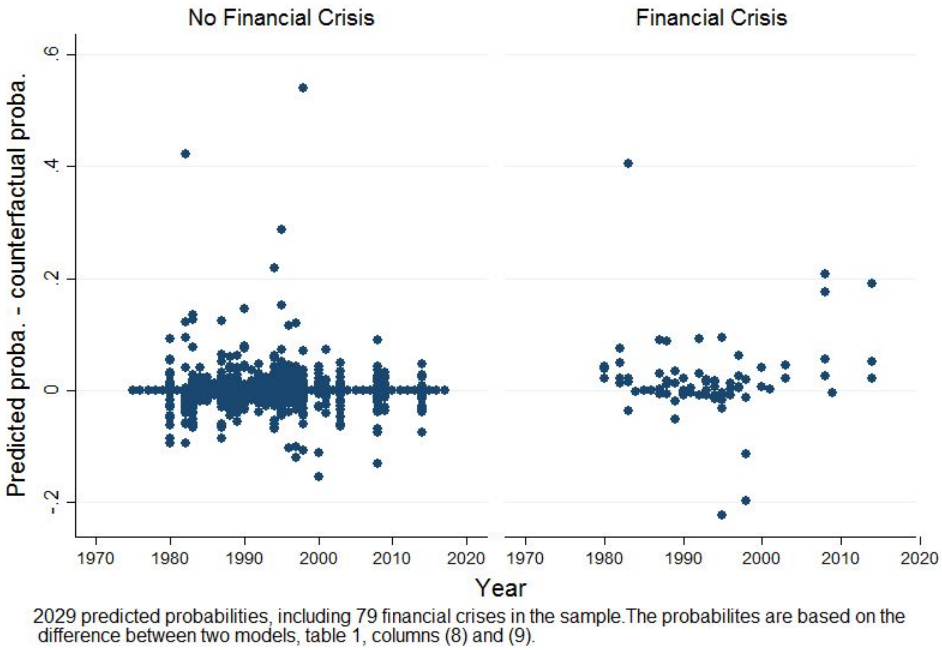

Figure A.2: Difference between predicted and counterfactual probabilities

Table A.3: Full set of results with individual lags - Table 1

	Dependent variable: Systemic Banking Crisis. Logit Estimates.								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
L.$\frac{ST}{ST+LT}$	6.766**				6.586**	6.963**	7.242**	7.349**	
	(2.897)				(2.891)	(2.952)	(2.972)	(3.023)	
L2.$\frac{ST}{ST+LT}$	-8.464**				-8.428**	-7.915*	-9.055**	-7.966*	
	(4.092)				(4.056)	(4.207)	(4.192)	(4.262)	
L3.$\frac{ST}{ST+LT}$	2.322				2.875	1.452	2.415	1.523	
	(4.055)				(4.068)	(4.196)	(4.098)	(4.225)	
L4.$\frac{ST}{ST+LT}$	-3.290				-3.667	-3.162	-3.014	-2.759	
	(3.648)				(3.694)	(3.691)	(3.646)	(3.706)	
L5.$\frac{ST}{ST+LT}$	6.551***				6.829***	6.862***	6.398***	7.370***	
	(2.469)				(2.518)	(2.486)	(2.464)	(2.538)	
L.$\frac{Debt\ Stock}{GNI}$		-0.0395			-0.0104			-0.104	-0.0958
		(0.723)			(0.734)			(0.787)	(0.758)
L2.$\frac{Debt\ Stock}{GNI}$		-0.362			-0.381			-0.985	-0.816
		(0.974)			(0.992)			(1.054)	(1.006)
L3.$\frac{Debt\ Stock}{GNI}$		-0.554			-0.599			-0.354	-0.344
		(0.892)			(0.923)			(0.868)	(0.864)
L4.$\frac{Debt\ Stock}{GNI}$		0.119			0.177			0.142	0.0658
		(0.562)			(0.567)			(0.641)	(0.612)
L5.$\frac{Debt\ Stock}{GNI}$		0.0771			0.0740			-0.0162	0.0269
		(0.420)			(0.440)			(0.470)	(0.442)
L.$\frac{Debt\ Service}{GNI}$			-0.623			1.683		2.841	0.496
			(5.347)			(5.467)		(6.457)	(6.185)
L2.$\frac{Debt\ Service}{GNI}$			4.983			3.919		9.415	9.654
			(5.913)			(6.013)		(7.236)	(7.076)
L3.$\frac{Debt\ Service}{GNI}$			-5.875			-5.741		-10.59	-9.977
			(6.274)			(6.310)		(8.251)	(8.273)
L4.$\frac{Debt\ Service}{GNI}$			0.678			0.658		8.035	6.479
			(3.882)			(3.777)		(6.389)	(6.429)
L5.$\frac{Debt\ Service}{GNI}$			1.764			3.346		4.552	2.986
			(3.904)			(3.815)		(5.750)	(5.638)
L.$\frac{Net\ Debt\ Flows}{Net\ Exports}$				0.000971			0.000870	0.00163	0.00101
				(0.0149)			(0.0157)	(0.0155)	(0.0149)
L2.$\frac{Net\ Debt\ Flows}{Net\ Exports}$				0.00547			0.00372	0.00274	0.00324
				(0.0162)			(0.0160)	(0.0153)	(0.0153)
L3.$\frac{Net\ Debt\ Flows}{Net\ Exports}$				0.0291			0.0298	0.0336*	0.0320*
				(0.0181)			(0.0188)	(0.0196)	(0.0187)
L4.$\frac{Net\ Debt\ Flows}{Net\ Exports}$				-0.00286			-0.00490	-0.00471	-0.00273
				(0.0167)			(0.0159)	(0.0150)	(0.0161)
L5.$\frac{Net\ Debt\ Flows}{Net\ Exports}$				-0.00280			-0.00785	-0.00736	-0.00331
				(0.0142)			(0.0136)	(0.0132)	(0.0133)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	2029	2029	2029	2029	2029	2029	2029	2029	2029
Countries	62	62	62	62	62	62	62	62	62

Standard errors in parentheses. Following formal lag selection procedures, I consider 5 lags of all variables.

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

Table A.4: External debt level and structure - OLS estimates

	Dependent variable: Systemic Banking Crisis. OLS Estimates.								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\frac{ST}{ST+LT}$	0.0649*				0.0692*	0.0652*	0.0654*	0.0714*	
Sum of lags	(0.0367)				(0.0371)	(0.0369)	(0.0366)	(0.0371)	
$\frac{Debt\ Stock}{GNI}$		-0.00699			-0.00822			-0.0130	-0.0114
Sum of lags		(0.00613)			(0.00615)			(0.00794)	(0.00790)
$\frac{Debt\ Service}{GNI}$			0.0335			0.0268		0.109	0.101
Sum of lags			(0.0726)			(0.0741)		(0.0990)	(0.0976)
$\frac{Net\ Debt\ Flows}{Net\ Exports}$				0.000192			0.000228	0.000169	0.000139
Sum of lags				(0.00110)			(0.00110)	(0.00110)	(0.00110)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	3402	3402	3402	3402	3402	3402	3402	3402	3402
Countries	118	118	118	118	118	118	118	118	118
R^2	0.060	0.057	0.057	0.057	0.061	0.060	0.061	0.062	0.059
AUROC	0.891	0.887	0.885	0.887	0.893	0.892	0.895	0.899	0.892
Standard error	0.0127	0.0125	0.0125	0.0126	0.0125	0.0126	0.0125	0.0122	0.0123

Robust standard errors in parentheses. Following formal lag selection procedures, I consider 5 lags of all variables.

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

Table A.5: Other control variables - Sensitivity analysis

	Dependent variable: Systemic Banking Crisis. Logit Estimates.							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\frac{ST}{ST+LT}$	3.227	7.949***	2.604	3.984*	5.813*	4.476*	4.310*	5.727*
Sum of lags	(2.423)	(2.739)	(2.547)	(2.373)	(3.031)	(2.376)	(2.387)	(3.259)
Log(GDP)	0.965				1.284*			1.508*
Sum of lags	(0.609)				(0.782)			(0.812)
$\frac{Reserves}{Debt\ Stock}$		−4.176***			−4.634***			−4.400***
Sum of lags		(1.410)			(1.566)			(1.666)
$\frac{Private\ credit}{GDP}$			0.0356**		0.0320*			0.0346*
Sum of lags			(0.0158)		(0.0189)			(0.0201)
$\frac{IMF\ credit}{GNI}$				-4.835	-2.769			-0.201
Sum of lags				(5.855)	(7.352)			(7.823)
Average Maturity (new debt)						−0.0565**		−0.0870***
Sum of lags						(0.0271)		(0.0329)
Average Interest (new debt)							-0.113	-0.136
Sum of lags							(0.146)	(0.174)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	1969	1969	1969	1969	1969	1969	1969	1969
Countries	57	57	57	57	57	57	57	57
Pseudolikelihood	-179.2	-171.6	-176.8	-181.1	-161.3	-179.8	-181	-155.3
R^2	0.303	0.332	0.312	0.296	0.373	0.300	0.296	0.396
AUROC	0.794	0.849	0.837	0.849	0.804	0.849	0.837	0.803
Standard error	0.0190	0.0158	0.0164	0.0161	0.0185	0.0158	0.0174	0.0184

Standard errors in parentheses. Following formal lag selection procedures, I consider 5 lags of all variables.

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

Table A.6: Other dependent variable - Sensitivity analysis

	Dependent variable: Various types of crisis. Logit Estimates.					
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	SystBankLV	CurrencyLV	SoverDebtLV	BankRR	SystemicBankRR	StockCrash
$\frac{ST}{ST+LT}$	4.090*	1.635	0.528	2.908**	2.696*	0.952
Sum of lags	(2.098)	(1.225)	(2.249)	(1.335)	(1.430)	(1.557)
$\frac{Debt\ Stock}{GNI}$	-0.264	-0.393^{*}	-0.754	0.914***	1.017***	0.448
Sum of lags	(0.243)	(0.236)	(0.517)	(0.294)	(0.325)	(0.557)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	2627	3172	1737	1373	1235	677
Countries	68	85	43	37	32	20
Pseudolikelihood	-229.5	-439.4	-139.2	-448.5	-382.4	-263.4
R^2	0.265	0.151	0.279	0.200	0.196	0.257
AUROC	0.832	0.769	0.874	0.768	0.774	0.799
Standard error	0.0169	0.0241	0.0245	0.0177	0.0182	0.0209

"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 5 lags of all variables.
*, ** and *** denote respectively significance at the 10, 5 and 1% levels.