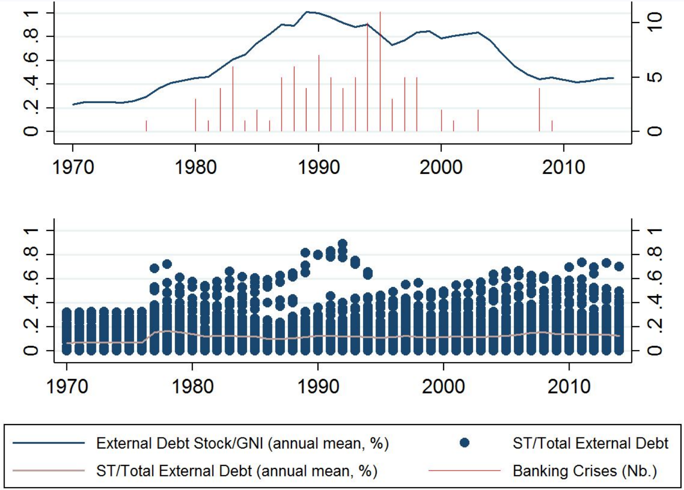
Fire Sales and Debt Maturity

Samuel Ligonnière

LEM University of Lille & ENS Paris-Saclay

CIRANO Seminar, 2018



Sample of 122 countries (emerging and developing countries)

External Debt Stock & Debt Maturity $\longleftrightarrow$ Frequency of Banking Crises

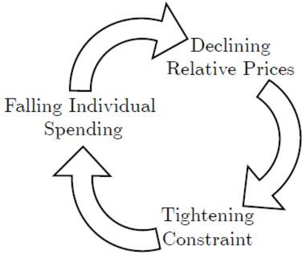
Motivations

- New theoretical foundations of financial crises based on Fisher (1933), but quite silent on debt maturity structure.
- For a given level of debt, debt maturity structure probably matters.

Background: Fire Sales

Fisher (1933)

- Collateral constraint based on the value of their assets = agent's access to credit.
- If not able to repay their debt → sell their assets. But if many agents do the same, it may result in a feedback loop between binding collateral constraints and a drop of asset prices.



From Korinek and Mendoza (2014)

Question

How does debt maturity affect the likelihood and the cost of financial crises?

Contributions

1. For a given level of debt, specific debt maturity structure could trigger financial crises.
   - Overborrowing case: agents borrow "too much" and purchase "not enough" assets in boom times. $\rightarrow$ debt level still matters!
   - Debt maturity portfolio $\rightarrow$ both liquidity and solvency concerns
   - Different market-determined term premium: DE $\neq$ social planner allocation
2. Design of optimal policies to counteract these inefficiencies:
   - Optimal policies on financing and investment decisions.
   - Ex-ante (*i.e. macroprudential*) and ex-post policy intervention.

Outline

Introduction

Empirical Analysis

Model

Conclusion

Early-warning indicators of financial crises

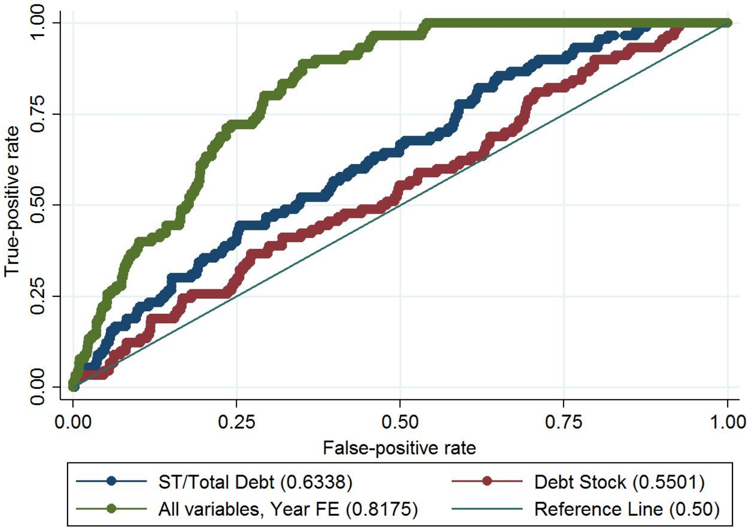
$$logit(p_{it}) \quad = \quad \alpha_i + \sum_{s=1}^{5} \beta_{it-s} \frac{ST}{ST+LT}_{it-s} + \sum_{s=1}^{5} \delta'_{it-s} X_{it-s} + \epsilon_{it}$$

- 5 years: formal lag selection processes (AIC, BIC)
- Advanced economies $\neq$ developing world: 121 countries, 1970-2012.
- Dep variable: systemic banking crises, dummy, Laeven and Valencia (2012).
- External Debt: stock, flows, debt service, debt maturity from International Debt Statistics.
- Global financial forces: FED rate, VIX, oil price.

Dependent variable: Systemic Banking Crisis. Logit Estimates.

	Benchmark (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\frac{ST}{ST+LT}$		2.921*			3.653**	4.063**	5.059**	5.144***	6.246**
Sum of lags		(1.571)			(1.680)	(1.952)	(2.090)	(2.175)	(2.336)
$\frac{Debt\ Stock}{GNI}$			0.331*		0.0203		-0.184		-0.404
Sum of lags			(0.183)		(0.241)		(0.287)		(0.314)
$\frac{Debt\ Service}{GNI}$				7.697**	8.873*		9.743*		7.487
Sum of lags				(3.795)	(4.700)		(5.402)		(5.753)
FED rate						0.0608	0.0713		
Sum of lags						(0.0508)	(0.0561)		
VIX						−0.0906**	−0.100***		
Sum of lags						(0.0365)	(0.0374)		
Oil Price						−1.738**	−2.084***		
Sum of lags						(0.750)	(0.804)		
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No	No	No	Yes	Yes
Obs.	2351	2351	2351	2351	2351	2351	2351	2351	2351
Countries	68	68	68	68	68	68	68	68	68
Pseudolikelihood	-372.5	-290.8	-295.4	-295.1	-283.6	-260.6	-254.5	-226.5	-222.3
R^2		0.029	0.0141	0.0149	0.0532	0.130	0.151	0.244	0.258
AUROC	0.615	0.634	0.550	0.557	0.633	0.750	0.736	0.824	0.817
Standard error	0.0295	0.0278	0.0300	0.0291	0.0280	0.0222	0.0221	0.0164	0.0160

Quantification



AUROC: details

Counterfactual probability of crises without the debt maturity structure

	Nb.	Predicted	Counterfactual	|Difference|
True-Positive Signal	90	0.102	0.087	0.033
False-Positive Signal	2261	0.026	0.027	0.009

Country	Year	Predicted	Counterfactual	Difference
		True-Positive Signal		
Guyana	1993	0.622	0.475	0.147
Nicaragua	1990	0.609	0.666	-0.057
Ukraine	2008	0.450	0.201	0.249
Kazakhstan	2008	0.405	0.418	-0.013
Russia	2008	0.395	0.208	0.187
Niger	1983	0.390	0.081	0.309
Paraguay	1995	0.317	0.136	0.181
Mongolia	2008	0.215	0.119	0.096
Turkey	1982	0.179	0.045	0.134
Vietnam	1997	0.169	0.148	0.021

Counterfactual probability of crises without the debt maturity structure

	Nb.	Predicted	Counterfactual	|Difference|
True-Positive Signal	90	0.102	0.087	0.033
False-Positive Signal	2261	0.026	0.027	0.009

Country	Year	Predicted	Counterfactual	Difference
		False-Positive Signal		
Swaziland	1998	0.663	0.130	0.533
Yemen	1995	0.537	0.401	0.136
Mongolia	1997	0.416	0.314	0.102
Nigeria	1982	0.397	0.038	0.359
Russia	1997	0.323	0.284	0.039
Macedonia, FYR	1998	0.287	0.340	-0.053
Ukraine	1997	0.277	0.273	0.004
Zambia	1998	0.266	0.366	-0.10
Congo, Rep	1994	0.231	0.165	0.066
Macedonia, FYR	2008	0.227	0.252	-0.025

False-positive alarm: (i) misleading timing, (ii) currency and/or sovereign debt crises

Robustness and Falsification Tests

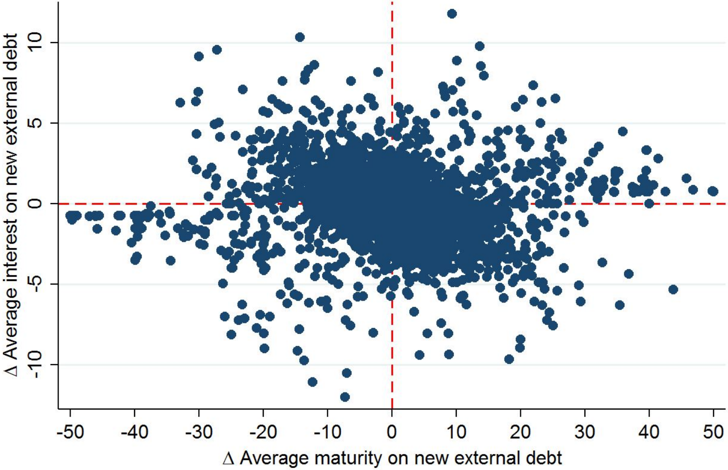
Robustness

- Other control variables: International Reserves, IMF credit, multilateral credit, GDP growth ▸ Control Variables
- *Maturity mismatch* $\neq$ *currency mismatch* ▸ Currency Mismatch

Inspecting the mechanism: the Spread Channel

- Endogeneity issues: $\neq$ mechanism if a country is unwilling or unable to choose more long-term debt.
- Explicit treatment by controlling for term premium.

Inspecting the mechanism: the Spread Channel



Note: Four outliers with an average maturity higher than 100 years (India 2010, Zimbabwe 1982, 1986 and 1987) are dropped for better readibility.

Assumption: no composition effect.

Inspecting the mechanism: the Spread Channel

	Upper left		Upper right		Lower right		Lower left	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\frac{ST}{ST+LT}$	7.688**	7.377*	-1.523	1.873	3.016	3.423	3.102	0.352
Sum of lags	(3.670)	(3.784)	(7.038)	(10.30)	(2.574)	(2.684)	(5.971)	(7.535)
$\frac{Debt\_Stock}{GNI}$		0.569		-0.505		0.849		1.412
Sum of lags		(0.582)		(1.501)		(0.638)		(1.142)
Obs.	290	290	67	67	344	344	97	97
Countries	26	26	10	10	30	30	13	13
Pseudolikelihood	-60.48	-56.99	-14	-12.07	-75.61	-72.26	-22.97	-21.34
R^2	0.0608	0.115	0.237	0.342	0.0520	0.0939	0.0895	0.154
AUROC	0.624	0.647	0.747	0.793	0.655	0.693	0.617	0.647
Standard error	0.0527	0.0548	0.0904	0.0671	0.0455	0.0420	0.0925	0.0800

The mechanism holds iff *unanticipated* rise of term premium.
Debt maturity structure triggers financial crisis through *unwanted* excessive reliance on ST debt.

Model

Recent *Fisherian deflation* models

- Overborrowing, under-investment in assets in boom times. Fire sales in bust times.
- Pecuniary externality: decentralized equilibrium $\neq$ social planner $\rightarrow$ policy intervention.

My contribution

- Extension of *Fisherian deflation* models: ST and LT debt at the same time.
- For a given level of debt, suboptimal path of debt maturity structure.

Setup

- Small open economy model $\rightarrow$ world interest rate
- Discrete time framework with $t = 0, 1, 2$
- 2 agents: borrowers (B) and savers (S)
  - consume good, capital good at price q: invest or sell?
  - trade various bonds, both ST and LT bonds.
- Occasionally binding collateral constraints $\rightarrow$ financial market imperfections
- Term premium and capital price: market-determined

Following Korinek and Sandri (2018), with *one-period* debt, Small open economy model, $t = 0, 1, 2$, borrowers and savers:

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

subject to

$$\begin{aligned}
c_0^i + q_0(k_1^i - k_0^i) + \frac{b_{01}^i}{R_{01}} &= e_0^i + b_0^i \\
c_1^i + q_1(k_2^i - k_1^i) + \frac{b_{12}^i}{R_{12}} &= e_1^i + b_{01}^i + F_1^i(k_1^i) \\
c_2^i &= e_2^i + b_{12}^i + F_2^i(k_2^i) \\
\frac{b_{01}^B}{R_{01}} &> -\kappa q_0 k_1^B \\
\frac{b_{12}^B}{R_{12}} &> -\Phi q_1 k_2^B
\end{aligned}$$

Setup

With short- and long-term debt,

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

subject to

$$\begin{aligned} c_0^i + q_0(k_1^i - k_0^i) + \frac{b_{01}^i}{R_{01}} + \frac{b_{02}^i}{R_{02}} &= e_0^i + b_0^i \\ c_1^i + q_1(k_2^i - k_1^i) + \frac{b_{12}^i}{R_{12}} &= e_1^i + b_{01}^i + F_1^i(k_1^i) \\ c_2^i &= e_2^i + b_{02}^i + b_{12}^i + F_2^i(k_2^i) \\ \frac{b_{01}^B}{R_{01}} &> -\kappa q_0 k_1^B \\ \frac{b_{01}^B}{R_{01}} + \frac{b_{02}^B}{R_{02}} > -\Phi q_0 k_1^B \quad \frac{b_{02}^B}{R_{02}} + \frac{b_{12}^B}{R_{12}} &> -\Phi q_1 k_2^B \end{aligned}$$

Decentralized Equilibrium

Set of allocations $\left(c_0^i, c_1^i, c_2^i, k_1^i, k_2^i, b_{01}^i, b_{02}^i, b_{12}^i\right)$ 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.

Impact of uncertainty: financial net worth and capital holdings

$$\begin{aligned} n_0^i &= e_0^i + b_0^i + k_0^i \\ n_1^i &= e_1^i + b_{01}^i + b_{02}^i + F_1^i(k_1^i) \end{aligned}$$

Decentralized Equilibrium

FOC - Backward induction

Date 2 equilibrium $\rightarrow$ consumes the good, settles their bond positions.

Decentralized Equilibrium

Date 1 equilibrium:

$$
\begin{aligned}
V^i(n_1^i, k_1^i) &= max\ u(c_1^i) + \beta u(c_2^i) \\
\text{subject to} & \\
c_1^i + q_1(k_2^i - k_1^i) + \frac{b_{12}^i}{R_{12}} &= e_1^i + b_{01}^i + F_1^i(k_1^i) \\
c_2^i &= e_2^i + b_{02}^i + b_{12}^i + F_2^i(k_2^i) \\
\frac{b_{02}^B}{R_{02}} + \frac{b_{12}^B}{R_{12}} &> -\Phi q_1 k_2^B
\end{aligned}
$$

where λ_1^i, λ_2^i and μ_2^i respectively denote the Lagrangian multipliers on the budget constraints and and on the collateral stock constraint. (By construction, $\mu_2^S = 0$)

Decentralized Equilibrium

Date 1 equilibrium:

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

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

- Standard Euler equation weighting the marginal benefit of higher consumption today against the marginal cost of lower consumption tomorrow.
- If the collateral constraint is slack, standard Euler equation for assets: marginal product of capital discounted by the MRS.
- If instead $\mu_2^B > 0$, the effect on capital prices is quite ambiguous.

Decentralized Equilibrium

Date 0 equilibrium:

$$max U^i(c_0^i) + \beta \mathbb{E}_0 V^i(n_1^i, k_1^i)$$

subject to

$$\begin{aligned} c_0^i + q_0(k_1^i - k_0^i) + \frac{b_{01}^i}{R_{01}} + \frac{b_{02}^i}{R_{02}} &= e_0^i + b_0^i \\ \frac{b_{01}^B}{R_{01}} &> -\kappa q_0 k_1^B \\ \frac{b_{01}^B}{R_{01}} + \frac{b_{02}^B}{R_{02}} &> -\Phi q_0 k_1^B \end{aligned}$$

where λ_0^i,η_1^i and μ_1^i respectively denote the Lagrangian multipliers on the budget constraint, on the flows collateral constraint and on the stock collateral constraint and on the flows collateral constraint.

Decentralized Equilibrium

Date 0 equilibrium:

$$\begin{aligned}
\lambda_0^i &= \beta R_{01}\mathbb{E}_0(\lambda_1^i) + \mu_1^i + \eta_1^i \quad \text{with} \quad \lambda_0^i = U_0'^i \\
\lambda_0^i &= \beta R_{02}\mathbb{E}_0(\lambda_1^i) + \mu_1^i \\
q_0 &= \frac{\beta \mathbb{E}_0 \left[\lambda_1^i (F_1'^i(k_1^i) + q_1)\right]}{\lambda_0^i - \Phi \mu_1^i - \kappa \eta_1^i}
\end{aligned}$$

No-arbitrage condition:

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

Social Planner

ξ_t^{SP} as Lagrange multiplier on the implementability constraint (i.e. to internalize the pecuniary externality)

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

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

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

DE $\neq$ SP $\rightarrow$ Taxes on debt

Social Planner

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

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

DE $\neq$ SP $\rightarrow$ Subsidies on capital

Implementation via Taxes

Policy intervention:

- Taxes on short-term bonds τ_0^{ST} and τ_1^{ST}
- Tax on long-term bonds τ_0^{LT}
- Subsidies on capital good τ_0^k and τ_1^k ($\tau < 0$)

New budget constraints with lump-sum transfers T^t:

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

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

Implementation via Taxes

$$\tau_0^{ST} = \tau_0^{LT} =$$

$$1-\beta\left[R_{01}+\underbrace{\frac{\eta_1^B}{\beta\mathbb{E}_0(\lambda_1^{SP})}}_{Risk\ \ prem.}\right]\mathbb{E}_0\left[\frac{\beta U_1^{\prime B}-(\overbrace{\xi_1^{SP}}^{Date\ \ 1}\overbrace{-\xi_0^{SP})q_1 U_1^{\prime\prime B}+\xi_0^{SP}\beta U_1^{\prime\prime B}F_1^{\prime B}(k_1^B)}^{Ex-ante:\ pecuniary\ \ externality}}{U_0^{\prime B}\underbrace{-\xi_0^{SP}q_0 U_0^{\prime\prime B}}_{Ex-post}}\right]-\underbrace{\frac{\mu_1^B}{\lambda_0^{SP}}}_{Stock}$$

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

Implementation via Taxes

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

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

Conclusion

1. Debt maturity structure as a key early-warning indicator of financial crises for the developing world.
2. Suboptimal path of debt $\rightarrow$ could be too much oriented to short-term debt, but also too much oriented to long-term debt.

AUROC: *area under the curve* Receiver Operating Characteristics

- Various thresholds.
- Informative signals $\rightarrow$ higher probability of true positive without the cost of a many false positives.

F as binary outcome, $\hat{\beta}$X as continuous signal, c as threshold

$$
\begin{aligned}
TP(c) &= P(\hat{\beta}X > c | F = 1) \\
FP(c) &= P(\hat{\beta}X > c | F = 0)
\end{aligned}
$$

Back

	Dependent variable: Systemic Banking Crisis. Logit Estimates.					
	(1)	(2)	(3)	(4)	(5)	(6)
$\frac{ST}{ST+LT}$	6.972***	4.093*	4.764*	2.668	3.036	5.487*
Sum of lags	(2.647)	(2.413)	(2.471)	(2.537)	(2.518)	(3.018)
$\frac{Reserves}{Debt\ Stock}$	−2.782**					−3.190**
Sum of lags	(1.275)					(1.460)
$\frac{IMF\ credit}{GNI}$		-5.479				-1.706
Sum of lags		(6.221)				(7.457)
$\frac{Multilateral\ credit}{GNI}$			−3.692*			-1.979
Sum of lags			2.023			2.334
$\frac{Private\ credit}{GDP}$				0.0331***		0.0276
Sum of lags				(0.0165)		(0.0197)
Log(GDP)					1.223*	1.274
Sum of lags					(0.629)	(0.824)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	1880	1880	1880	1880	1880	1880
Countries	58	58	58	58	58	58
Pseudolikelihood	-175.5	-181.3	-179.7	-177.4	-178.3	-163.1
R^2	0.301	0.278	0.284	0.293	0.290	0.350
AUROC	0.837	0.842	0.834	0.821	0.778	0.791
Standard error	0.0170	0.0170	0.0171	0.0178	0.0204	0.0200

Back

Currency mismatch measures

1. Debt stock (or debt service)/ exports
2. FXAGG Aggregate foreign currency exposure from Benetrix et al. (2015):
   "*A value of -1 corresponds to a country has zero foreign currency foreign assets and only foreign currency foreign liabilities, whereas +1 corresponds to a country that has only foreign currency foreign assets and only domestic currency foreign liabilities.*"
3. Rancière et al. (2010):

$$\frac{Foreign\ currency\ liabilities - For.\ currency\ assets + For.\ currency\ assets\ unhedged}{Total\ bank\ assets}$$

	Dependent variable: Systemic Banking Crisis. Logit Estimates.							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\frac{ST}{ST+LT}$	3.456*	4.214**	5.498**	5.576**	3.252	6.880	10.93	18.73**
Sum of lags	(1.774)	(1.837)	(2.416)	(2.446)	(3.900)	(4.252)	(6.837)	(9.552)
$\frac{Debt\ Stock}{Exports}$	0.0761		-0.0460					
Sum of lags	(0.0565)		(0.0756)					
$\frac{Debt\ Service}{Exports}$		3.392***		0.810				
Sum of lags		(1.264)		(1.674)				
FXAGG					−3.126*	−8.332***	7.778	3.481
Sum of lags					(1.760)	(2.922)	(5.060)	(7.074)
$\frac{Debt\ Stock}{GNI}$						−5.504**		-2.669
Sum of lags						(2.435)		(3.238)
$\frac{Debt\ Service}{GNI}$						15.84		35.84
Sum of lags						(17.54)		(35.68)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	No	No	Yes	Yes
Obs.	1759	1759	1759	1759	319	319	319	319
Countries	62	62	62	62	19	19	19	19
Pseudolikelihood	-233.6	-232.8	-188.6	-190.5	-51.81	-45.67	-26.63	-20.49
R^2	0.0457	0.0487	0.229	0.222	0.0673	0.178	0.521	0.631
AUROC	0.670	0.644	0.805	0.804	0.604	0.649	0.869	0.892
Standard error	0.0290	0.0306	0.0198	0.0197	0.0600	0.0614	0.0295	0.0264