Sovereign Local Currency Debt and Original Sin Redux*

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Abstract

I study how government debt financing influences firms' access to credit, in turn shaping the response of the economy to fluctuations in global financial conditions. Governments' debt financing in their local currencies allows them to avoid currency mismatch, which is expected to insulate them from global financial fluctuation. However, this insulation is only partial, a phenomenon referred to as the "original sin redux". Based on 11 emerging economies that borrow abroad in their local currencies, I document that the extent to which shocks in the global financial market lead to higher default risks on local currency government bonds depends on a country's level of financial development and debt level. I also find that banks in a country with low financial development relative to its debt level disrupt private credit more significantly when foreign capital exits from the local currency bond market. This makes the local economy more exposed to external factors despite a seemingly lowered exposure of government debt, as government debt crowds out credit for firms. To better understand the patterns I document, I build a sovereign default model incorporating financial intermediaries and endogenous foreign investors' investment in local currency government bonds. The model replicates key patterns observed in the data, related to the relationship between an economy's capacity to maintain private credit during capital outflows, credit risk, and external vulnerability.

Keywords: Emerging market, currency mismatch, capital flows, exchange rate

JEL codes: F31, F34, F41, G15, G20

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1. Introduction

A substantial body of literature has extensively documented that currency mismatch leaves emerging economies vulnerable to global financial conditions. The currency mismatch usually arises in emerging economies due to their inability to borrow abroad in their local currency (LC), termed as “original sin" byEichengreen, Hausmann, and Panizza (2005). This original sin has been pointed out as a critical factor contributing to the difficulties emerging economies face in managing their debt levels, leading to a higher degree of debt intolerance. [1]

However, since the mid-2000s, the share of emerging government debt issued in foreign currencies (FC) has fallen, and the original sin has gradually dissipated (Du, Pflueger, and Schreger 2020, Ottonello and D. J. Perez 2019). Contrary to the expectation that this development reduces the exposure of emerging economics to global financial shocks, borrowing in domestic currency has not insulated EMEs from the vicissitudes of the global financial conditions, as suggested and termed as “original sin redux" by Hofmann, Shim, and Shin (2020).

Specifically, the original sin redux arises from the following negative feedback loop through foreign investors’ currency mismatch, as presented by Carstens and Shin (2019), Hofmann, Shim, and Shin (2020). During global financial market turmoil, emerging currencies tend to depreciate against the dollar, leading foreign investors to sell local currency bonds as they assess gains and losses from their unhedged exposure to local currency in terms of dollars. This results in an increase in local currency bond yields. Even with external debt denominated in local currency, currency mismatch is now borne by foreign investors with unhedged exposure even though it is no longer borne

[1] Debt intolerance indicates the relationship between a country’s credit rating (credit risk) and its external debt. It is reported that credit risk tends to increase more rapidly with respect to debt in emerging markets than in advanced countries as if the former have less debt management capacity. See Eichengreen, Hausmann, and Panizza (2007), Reinhart, Rogoff, and Savastano (2003)

by emerging economies' governments issuing debt in local currency.[2]

In this paper, I study the phenomenon of original sin redux and its cross-country differences. Specifically, based on 11 emerging economies that borrow abroad in their local currencies, I document the cross-country differences in the extent to which shocks in the global financial market lead to higher default risks on local currency government bonds and provide a theoretical explanation behind these cross-country differences.[3] To do so, I construct the data by decomposing the local currency sovereign spread into two parts: currency risk spread and default risk, following Du and Schreger (2016).[4] The former arises from currency mismatch exposed by unhedged foreign investors, while the latter arises from the positive probability of default by emerging governments.

Using the constructed data series on LC yields, I illustrate the behavior of EMEs' local currency bond markets during recent financial market turbulence amid the Covid-19 pandemic, aiming to document the presence of original sin redux. During this period, EMEs experienced an approximately 8 % currency depreciation against the dollar, significant capital outflows resulting in a 3.7 percentage point decrease in foreign holdings of LC bond, a 1.54 percentage point increase in local currency yields, and a 1.28 percentage point increase in credit spreads on average. I also find higher reliance on foreign capital leads to more vulnerability during the periods, consistent with Carstens and Shin (2019), Hofmann, Shim, and Shin (2020) who connects unhedged foreign investors to interactions between currency fluctuations and EMEs LC bond market.

I next document the following patterns: in a country with low financial development relative to its debt level, private credits tend to be more adversely affected by foreign capital outflows from the LC bond market. For expositional purposes, I refer

[2]According to the BIS survey result presented in Cantú, Chui, et al. (2020), about half of the central banks do not have information on whether foreign investors have hedged their LC government bond FX exposures or not. Central banks with the information report that only a small portion of foreign investors' FX exposures are hedged.

[3]Sample countries include Brazil, Colombia, Hungary, Indonesia, Malaysia, Mexico, the Philippines, Poland, South Africa, Thailand, and Turkey.

[4]Credit spreads, default risks, and credit risks are used interchangeably in the paper

to this sensitivity of private credits to foreign capital outflows as the credit channel vulnerability, specifically measured as a regression coefficient of the change in private credit on the change in foreign holdings of LC government bonds. A higher coefficient indicates that banks exhibit a more significant reduction in the supply of private credit when foreign capital exits from the LC bond market. Moreover, I also find that a country with low financial development relative to its debt level experiences higher default risk, which is further exacerbated during global financial turmoil, indicating higher external vulnerability.

By linking these two empirical findings, we can conclude that when the level of financial development of a country is low compared to its debt level, the country becomes more vulnerable to external shocks, even if the government debt exposure seems lower due to borrowing in the local currency. This is because the government debt takes up the credit that could have been provided to firms, which adversely affects the economy and leads to a higher default risk. [5] The high level of government debt crowds out the level of financial development, making the economy more vulnerable to external shocks.

To better understand the 11-country patterns I document, I build a three-period small open economy based on a standard sovereign default model incorporating a banking sector along the lines of Gertler and Kiyotaki (2010). I extend a standard sovereign default model with the financial intermediation sector along two key dimensions to capture interactions between foreign capital movements in the LC bond market depending on the global financial states and their economic impacts on EMEs. First, the foreign investor's investments in the government LC bond are endogenously determined. Second, losses from the government's default are different on whether domestic or foreign investors hold the bond.

[5] This pattern has been widely documented in the literature. See Gennaioli, Martin, and Rossi (2014), D. Perez (2015), Sosa-Padilla (2018), Farhi and Tirole (2018).

In the model, both foreign investors and domestic financial intermediaries hold local currency government bonds in equilibrium. Given the negative shock in the global financial market, the emerging local currency depreciates, which induces foreign investors to reduce local currency bond holdings due to expected losses from their unhedged exposure to local currency. As a result, domestic financial intermediaries increase their government bond holdings, which leads to a reduction in private credit due to collateral constraints, which limit financial intermediaries' access to household savings. This disruption adversely affects the economy, ultimately increasing the government default risk.

The level of financial development, captured by the degree of collateral constraint, relative to the debt level plays a significant role in determining the intensity of interaction between capital outflow from the local currency government bond market and private credit disruption. This intensity, in turn, determines the extent to which shocks in the global financial market lead to higher default risks on local currency government bonds. This mechanism generated by the model helps explain the key cross-sectional patterns observed in the data, particularly with regard to the relationship between an economy's ability to maintain private credit during capital outflows, credit risk, and external vulnerability.

Related literature This paper builds on the literature based on the standard sovereign default models such as Arellano (2008), Aguiar and Gopinath (2006), incorporating a banking sector along the line with Gertler and Kiyotaki (2010). Particularly, the paper contributes to three strands of the literature on open macro emerging economies.

The paper is related to literature that links sovereign risk, the banking sector's fragility, and economic activity. In the sovereign debt literature, several papers study the linkage between sovereign defaults and banking crises characterized by large private credit contraction. Gennaioli, Martin, and Rossi (2014), D. Perez (2015),

Sosa-Padilla (2018), and Farhi and Tirole (2018) propose a model in which banks holding the government bond are impeded from providing credits to firms conditional on a government default. They show that such a mechanism can generate substantial output costs of a sovereign default. Different from the above papers, I focus more on periods characterized by rising sovereign LC spreads and significant capital outflows but no actual default, mainly driven by shifts of global financial conditions. In that sense, my work is also closer to Arellano, Bai, and Bocola (2017) that show the increase in sovereign credit spreads tightens leverage constraint deteriorating financial intermediaries' balance sheets and constrains credit supply to firms and output. My paper shares the emphasis on financial intermediation with these papers. But my work departs from their works by explicitly modeling foreign investors' behaviors, motivated by the significance of foreign investors' impact on EMEs LC bond markets as pointed out by Ho (2019), Carrera, Aguirre, Raffin, et al. (2020).

My research is complementary to theirs: I consider currency risks borne by foreign investors holding the LC bonds and study interactions between foreign investors' decisions and their impacts on EMEs through domestic banks. Foreign capital outflow from the LC bond markets, triggered by the shifts of global financial conditions, has a recessionary effect on EMEs because domestic banks need to hold more government bonds in such periods. And this leads to disruption of private credit and an increase in default risks. The foreign investors' behavior and its impact on EMEs is the novel key mechanism in this paper.

My paper also complements the literature that studies EMEs issuing sovereign debts internationally in LC. Methodologically, I follow Du and Schreger (2016) to measure the default risk on LC sovereign debt separately from currency risk. Recent work paying more attention to benefits from LC debts, such as Du, Pflueger, and Schreger (2020), Ottonello and D. J. Perez (2019), mainly studies the government's currency composition problem. These papers study the implication of monetary credibility in currency

composition dynamics with focusing on the hedging benefit of LC debt. Meanwhile, policy papers including Ho (2019), Carstens and Shin (2019), Hofmann, Shim, and Shin (2020) study the phenomena that borrowing in the LC has not eliminated the external vulnerability EMEs suffered with their debt mainly denominated in FC. My work studies the determinants of the differential degree of the external vulnerability with foreign holdings of LC bonds as in Du, Pflueger, and Schreger (2020). Risk-averse foreign investors in Du, Pflueger, and Schreger (2020) require a higher risk premium for holding bonds whose dollar returns are more procyclical. In my model, foreign investors reduce the LC bonds' investment when the expected return in dollar terms is low, leading to foreign capital outflows from the LC bond market. Foreign investors solely hold the LC government bond in Du, Pflueger, and Schreger (2020). Domestic banks also hold the bond in my paper, which generates the interaction between foreign capital movements in the LC bond markets and domestic banks' private credit supply.

Finally, the paper also contributes to the literature that studies the impacts of the global financial cycle on emerging economies (Rey 2015, Bruno and Shin 2015). I show that the degree of global financial states' impact on developing countries is associated with the financial development and its debt service ratio. Financial development relative to the debt level determines the domestic banking sector's capability to continue providing private credit when a global financial condition is tightened. In this regard, my work is in line with literature that empirically studies interactions between global financial cycles and domestic credit market (Di Giovanni, Kalemli-Ozcan, Ulu, and Baskaya 2017), and also related with literature that works on the determinant of the external vulnerability (Iacoviello and Navarro 2019, Gonzalez-Aguado 2018). I take the effects of global financial states' changes in reduced form: decline in productivity and currency depreciation with higher uncertainty in FX market. I study how domestic banks' private credit supply responds to foreign capital movement triggered by a shift in global financial states and associate the responses to the degree of external

vulnerability. The paper is also close to literature that establishes a significant fraction of sovereign spreads volatility is accounted for by the global risk premium volatility (Bianchi, Hatchondo, and Martinez 2018, Longstaff, Pan, Pedersen, and Singleton 2011).

Layout The rest of the paper is organized as follows. Section 2 presents empirical evidence regarding the effects of global financial shocks on LC debt market. I lay out the setup of of the model in section 3, and perform a quantitative evaluation of the model to see how the model explains the empirical facts in section 4. Section 5 concludes.

2. Effects of global financial shocks on LC debt market

This section presents empirical evidence regarding the effects of global financial shocks on emerging LC debt market based on cross-country comparison. Subsection 2.1 describes the construction of variables of interest that are used for analysis and the sources of the data, and subsection 2.2 presents empirical evidence that will be mainly studied with the model in the following section.

2.1. Data

There are 11 EMEs in the sample, running from 2007 to June 2020.[6] [7] In this section, I present the detailed construction process of key variables and all the variables of interest with the sources are presented in Table A1 in the appendix.

LC bond yield spread I construct the series of currency risks and credit spreads following Du and Schreger (2016). The nominal spread on LC bond can be decomposed

[6] Brazil, Colombia, Hungary, Indonesia, Malaysia, Mexico, Philippines, Poland, South Africa, Thailand, Turkey

[7] EMEs' nominal LC yield spreads are constructed from 2007 to June 2020 while the variables used for regression are constructed quarterly up to Q1 2020 due to data availability.

into a default risk free rate and a default risk (credit risk). The currency risk added to U.S. risk free rate (r_t^*) is defined as a risk-free rate on LC bond, and the spread of LC bond over the risk-free rate on LC bond is defined as a credit risk. Then the nominal LC bond yield (y_t^{LC}) is as follows:

$$y_t^{LC} = \underbrace{r_t^* + \rho_t}_{\text{Default risk free rate}} + CS_t.$$

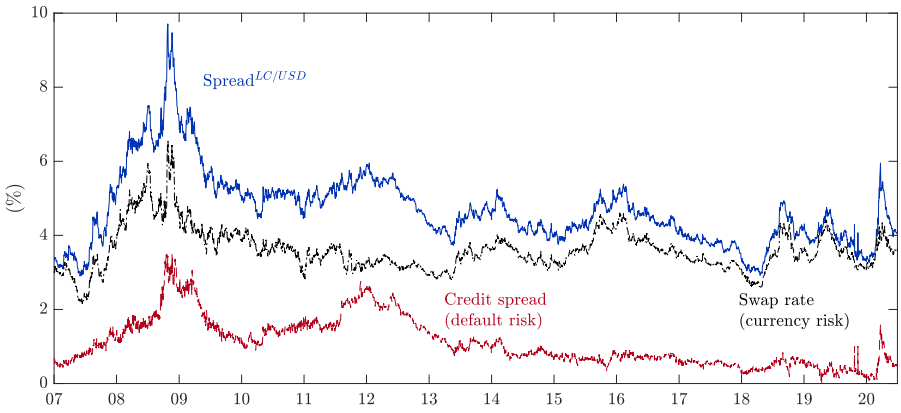
With assuming of a frictionless financial market, LC default risk free rate is compensation for changes in value paid to investor induced by exchange rate fluctuations, which capture currency risk, added to investors' borrowing cost, the U.S. Treasury bond yield. Then in the absence of financial market frictions, the LC spread over the LC risk free rate is positive only if there is default risks on the debt. risk. Specifically, I construct the currency risk by swapping the dollar cash flows from a default-free U.S. Treasury bond into the LC using a cross-currency swap (CCS). Specifically, I define an implied long-term forward premium between emerging economies' currencies and the US dollars (ρ_t) using the fixed-for-floating CCS and the US dollar interest rate swap, as currency risk. And the spread of LC bond over the default risk free rate is defined as a credit risk.

On average, the credit spread is 1.1% and around 77% of the nominal spread is composed of currency risk and the remaining 23% is composed of credit spread.[8] The average LC yields, currency risks, and credit risks of the sample countries are depicted in Figure 1. The summary statistics for the series of the sample countries are reported in Table A2.

Foreign holdings of LC sovereign debt securities Foreign holdings of LC sovereign

[8] Du and Schreger (2016) reported that 75% of the nominal spread is composed of currency risk and 25% is composed of credit spread based on 13 EMEs (sample countries with South Korea, Peru) from 2005∼2013.

FIGURE 1. EME's average nominal LC yield spread, swap rate and credit spread



Note: Average of 11 EMEs (Brazil, Colombia, Hungary, Indonesia, Malaysia Mexico, Philippines, Poland,South Africa, Thailand, Turkey)

Sources: Bloomberg, St. Louis Fed, Author's calculation

debt securities are calculated LC government debt held by foreign investors as the percentage of total outstanding LC government debt. The data is sourced from Arslanalp and Tsuda (2014) and Institute of International Finance (IIF). Arslanalp and Tsuda (2014) constructed 24 emerging economies' government debt held by foreign investors in local and hard currency from 2004 to 2019 on a quarterly basis. IIF quarterly releases related data of 17 emerging economies. Most of data comes from IIF. Philippines' data is sourced from Arslanalp and Tsuda (2014) and South Africa's data from 2007 to 2010 is also sourced from Arslanalp and Tsuda (2014) due to the availability of data released from IIF.

Over the sample periods, all the sample countries excluding Hungary experiences increase in foreign participants in LC sovereign debt market.[9] Participation of foreign investors decreased temporarily during the periods of the financial crisis in 2008. LC sovereign debt held by foreigner significantly increased from 2009 to 2014 as foreign

[9]In the first panel of Figure A1 in appendix, the average foreign holding of LC government debt and change over the sample periods are reported. In the second panel, the series of 11 sample countries foreign holdings are plotted.

investors chased for yields amid continuing monetary easing of advanced countries. Then foreign participants gradually decreased with Fed's tapering and the following concerns over emerging economies' currency risks.

Banks' exposure to government and private sector Banking sectors' holdings of government debt is measured as banks' net claims on the domestic governments (central and local government and public non-financial sector) as a share of the banking sector's total assets, following Gennaioli, Martin, and Rossi (2014), Kumhof and Tanner (2005). Claims on private sectors are measured as claims on non financial private sectors. Data is sourced from IFS. Claims by banking sectors (other depository corporations) are considered here because of data limitation.[10]

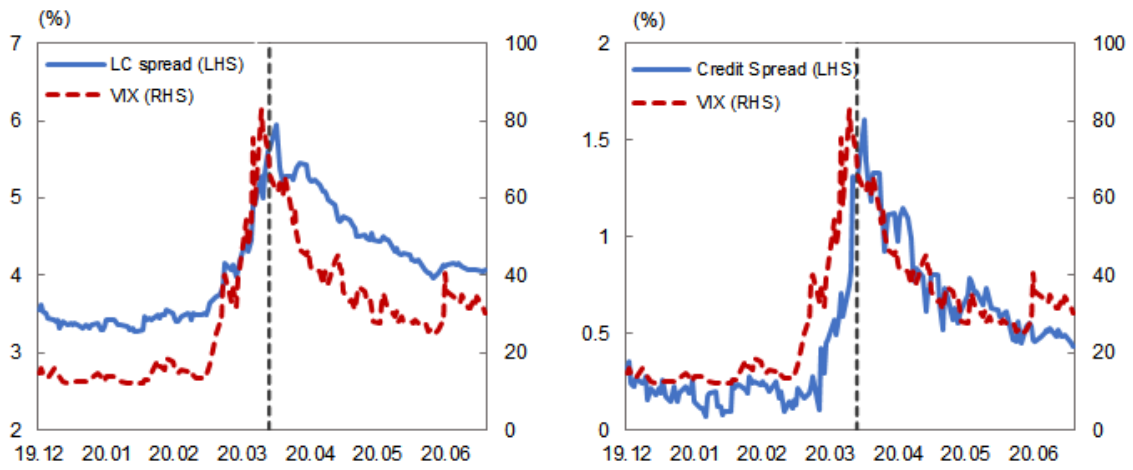
Financial development indicator I used the ratio of liquid liabilities to GDP as an indicator for financial development, which is sourced from the World Bank. This has been one of the main indicator used for financial development in the literature including King and Levine (1993), Rousseau and Wachtel (2011). The liquid liabilities are known as broad money, which includes currency and deposits in the central bank, deposits at financial intermediaries.

2.2. The effects of global shocks on LC sovereign bond market

This section describes the cross-country difference in impacts of global shocks on LC sovereign debt market. I investigate factors that determines the degree of global shocks pass-throughs. Firstly I document that higher reliance on foreign capital leads to more vulnerability using movements of LC yields and credit spread during recent financial market turbulence amid the Covid-19 pandemic, as presented in Carstens and

[10]The role of non-bank financial companies in financial market is sizable and increasing, however, only the banking sectors are considered for analysis because the data collection for non-bank financial companies is at early stage and limited

FIGURE 2. EME's average nominal LC yield spread (5-yr) amid the Covid-19 pandemic



(A) LC Yield Spread **(B)** Credit Spread

Notes: (1) Average of sample 11 EMEs.
(2) Black dashes line indicates the period when the Fed announced the unlimited bond purchases (March 23, 2020).

Sources: Bloomberg, St. Louis Fed, Author's calculation

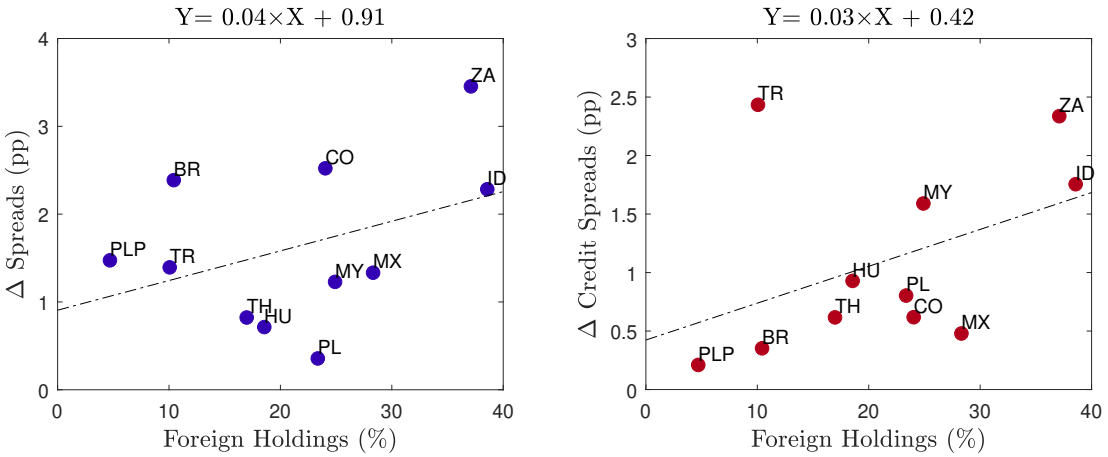
Shin (2019) and Hofmann, Shim, and Shin (2020). Secondly, I link the level of financial development to the vulnerability to global shocks and find a country with low financial market depth shows a higher vulnerability to the shocks.

2.2.1. Original sin redux during the COVID-19 pandemic

The financial shock triggered by the Covid-19 pandemic provides a vivid illustration of original sin redux, as documented in Hofmann, Shim, and Shin (2020): global financial shock, EMEs currency depreciation, capital outflow, LC yield spike. [11] During the Covid-19 pandemic, all of sample EMEs LC bond markets experienced massive bond portfolio

[11] They lay out the key mechanisms of such original sin redux phenomena focusing on interactions of currency fluctuations and financial market outcomes in EMEs. EMEs currencies tend to decline significantly with tightened global financial conditions. The currency decline leads capital outflows from EMEs LC bond market as foreign investors evaluate gains and losses in terms of dollars (or other advanced currency), and increase in the LC bond yield. Thus, reliance on foreign capital leads to a greater vulnerability to global financial shocks.

FIGURE 3. Changes in LC Yield Spreads (5-yr) & the Level of Foreign Holdings



(A) Changes in LC spread over US spread **(B)** Change in Credit spread

Notes: (1) Foreign holdings/Total outstanding of LC sovereign bond (%, as of end of 2019).
(2) Change in spreads between the last week of February and the third week of March 2020, before the Fed's announcement of the unlimited bond purchases (March 23, 2020).

Sources: Arslanalp and Tsuda (2014), IIF, Bloomberg

outflows, sharp exchange rate depreciation, and surges in bond yields. By late March 2020, EME currencies had depreciated by around 8% against the dollar on average compared to their levels before the outbreak of Covid-19 pandemic. The share of foreign holdings by the end of March 2020 was 18.4% on average, decreased by 2.2%p compared to the end of 2020, and decreased by 3.7%p compared to the end of March 2019. See Figure 2 that shows the EME's average nominal LC yield spreads over the U.S. treasury yields, credit spreads and VIX index during the periods of financial turbulence amid Covid-19 pandemic.

To see the details, as the Covid-19 pandemic has sparked widespread, EME's LC spreads and credit spreads reacted sensitively to global risks. After the Fed announced the unlimited bond purchases, indicated with black dashed line, global financial shocks decreased and EMEs' LC yield and credit spread decreased as well.

I also find that government's larger reliance on foreign finance leads to a more sensitivity of sovereign LC bond market to global financial shocks, presented in Figure

3. EMEs with higher shares of foreign ownership in their LC bond markets experienced significantly larger increase in their LC bond spreads and credit spreads during the periods of financial turbulence amid the Covid-19 pandemic. This is consistent with Hofmann, Shim, and Shin (2020) that documents a larger reliance on foreign capital leads to a greater vulnerability to global financial shocks with an emphasis on interactions between currency fluctuations and EMEs LC bond market.

2.2.2. Financial development and vulnerability to global shocks

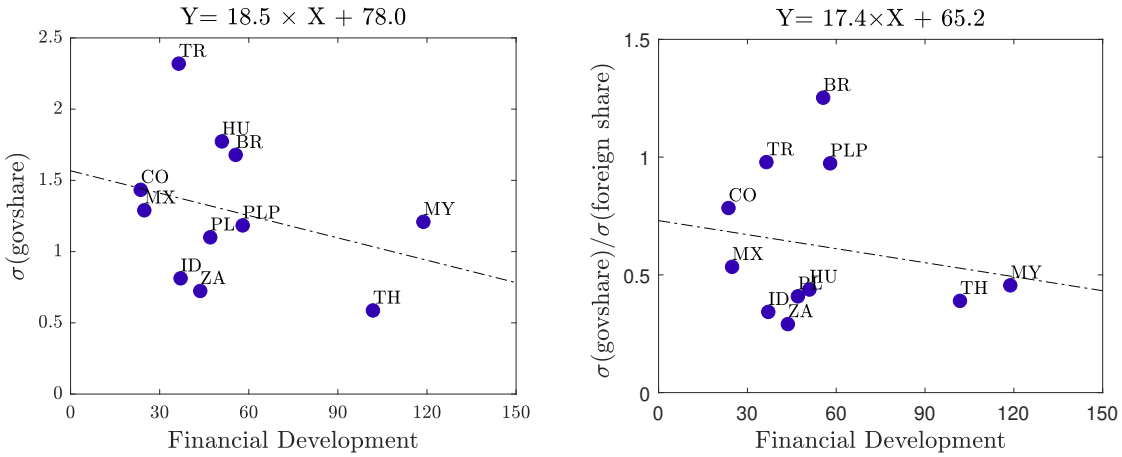
Financial development and banks' balance sheet (B/S) composition volatility In the data there is a negative relationship between the level of financial development of a country and the domestic banks balance sheet (B/S) composition volatility as depicted in the left panel of Figure 4. The negative relationship indicates that banks in a less financially developed country is more likely to adjust their B/S composition in a greater scale. Scaled by the volatility of foreign holdings of LC bonds, we also see the negative relationship. Considering the negative relationship between foreign holdings and banks claims on government[12], banks in a less financial developed country tend to increase their claims on government (decrease private credit) in a greater degree when foreign capitals outflow from the LC bond market.

Credit channel vulnerability I measure the vulnerability of credit channel and investigate the relationship between the level of financial development and the vulnerability. The result shows that the private credit tends to be more adversely affected by foreign capital outflows from the LC bond market (higher credit channel vulnerability) in a less financially developed country. Such an economy shows a higher credit risk and also a higher vulnerability to global financial shocks.

Specifically, I measure the credit channel vulnerability regressing the change in

[12] Refer to the Table A3 in Appendix.

FIGURE 4. Financial Development[1] & Banks' B/S composition Volatility



(A) σ(govshare) **(B)** σ(govshare)/σ(foreign share)

Notes: (1) Liquid liabilities to GDP (%, average between 1997∼ 2017).
(2) St.dev of domestic banks' net claims on government as a share of total claim.
(3) St.dev of foreign holding as a share of total outstanding LC government bond.
(4) St.dev is calculated based on hp-filtered series.

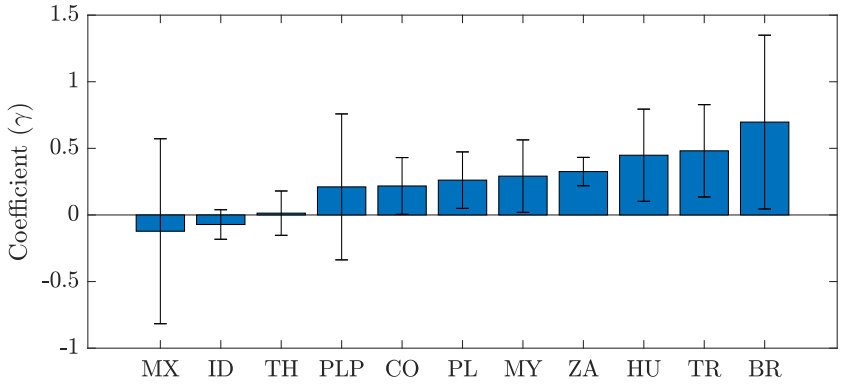
Sources: Arslanalp and Tsuda (2014), IIF, IFS, World Bank

private credit on the change in foreign holdings of LC debt for each country as follows:

$$\Delta\text{Private Credit}_t = \gamma\Delta\text{Foreign Holding}_t + \beta_l X_{t-1} + \beta_g \text{Global}_t + \epsilon_t \quad (1)$$

where $\Delta\text{Foreignholding}_t$ is changes in the foreign holdings of LC bond, $X_{i,t}$ is a vector of control variables including change in nominal exchange rate, change in volatility of exchange rate, debt to GDP ratio, claims on the government as the share of total claim, inflation rate, real GDP growth rate, and Global_t is a vector of global control variables, including the VIX index, the BBB-Treasury spread, the 10-Year Treasury yield, the TED spread, and the US Federal Funds Rate considered following Du, Pflueger, and Schreger (2020). For dependant variable $\Delta\text{Private Credit}_t$, I use the growth of banks claims on private sector net of total claim growth inspired by Gennaioli, Martin, and Rossi (2018). The private credit growth net of total claims growth gives information on the change of the banking sector's B/S composition. A lower private credit growth net of total claims

FIGURE 5. Coefficient γ in equation (1)



Note: (1) γ is the regression coefficient of the growth of banks claim on private sector net of the growth of banks' total claim (%p) on changes in foreign holdings of LC government bond (%p)
(2) The line through the bar indicates 95% confidence interval of each coefficient.

growth indicates the expansion of the balance sheet is mainly driven by the increase in claims on the government.

The coefficient of interest is γ, which indicates that a one percent point increase in foreign holdings is related to γ percent point higher increase in private credit than total credit. Higher γ represents that banks exhibit a larger decrease in private credit supply when foreign capitals exit from the LC bond market. I define higher γ as a higher credit channel vulnerability. The coefficient is positive and significant for all sample countries except for Mexico, Indonesia, Thailand, Philippines.

I examine the relationship between the credit channel vulnerability and the level of financial development. I consider one other factor to gauge the relationship, debt to GDP ratio. Credit channel vulnerability measures how much domestic banks disrupt private credit when they need to hold more government bond, and the debt level compared to the level of financial development needs to be considered. In Table 1, I divide the sample countries by the level of debt and financial development. The debt level tends to be higher in a country with more developed financial market, and this tendency makes the

TABLE 1. Sample Countries Profile by the Level of Debt[1] and Financial Development

	Low debt	High debt
Low financial development	Colombia, Indonesia, Mexico, Turkey	South Africa
High financial development	Thailand	Brazil, Hungary, Malaysia

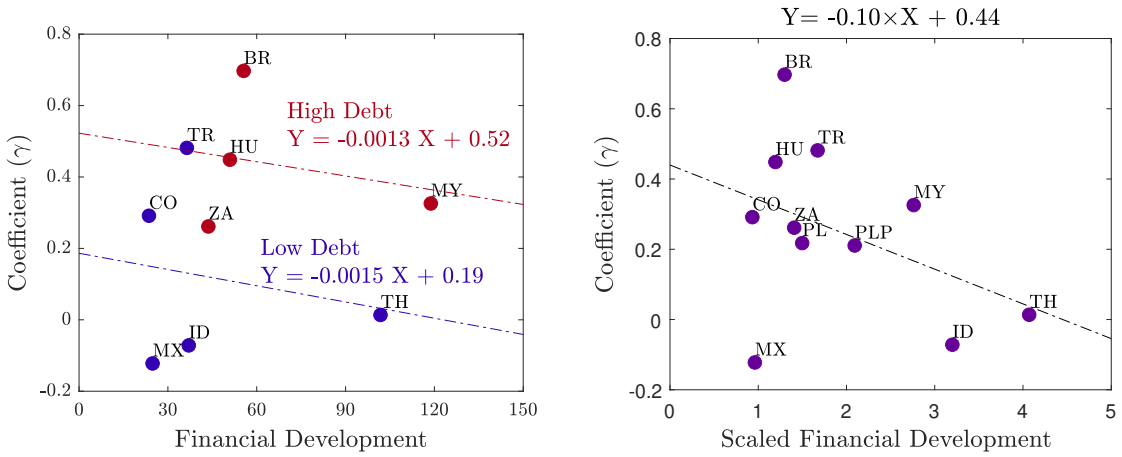
Notes: (1) Debt to GDP
(2) "Low" and "high" is determined by the median level.

relationship based on the level of financial development be misinterpreted. For example, Thailand has a developed financial market while the government debt level is relatively low, and Thailand's credit channel vulnerability is low. This is hard to be interpreted as a result of financial development because there is also effects of low debt level. Figure 6A shows the relationship of "high debt group" and "low debt group" between the level of financial development and credit vulnerability. In both groups, I find that a level of financial development is negatively related to credit vulnerability. Thus I use the level of financial development scaled by the debt to GDP ratio to gauge the relationship. I find a negative relationship between the scaled level of financial development and the credit channel vulnerability, which is depicted in the Figure 6B. The average credit channel vulnerability of countries with high ralative financial development is 0.19 while that of countries with low ralative financial development is 0.32.

Banks in a country with more developed financial market does not increase claims on the government that much compared to their total claims with respect to global financial shocks and following foreign capitals movement.[13] This is associated with the banks ability to continue supplying private credit during periods of sudden stops and lower sensitivity to global financial conditions. On the other hand, banks in a less financially

[13]Lower credit channel vulnerability means that banks do not disrupt private credit supply during the periods of capital outflows from LC bond market when the banks need to hold more government bond. This makes the economy more resilient to external shocks with lower increase in credit risks during periods of high global financial shocks.

FIGURE 6. Financial Development & Credit Channel Vulnerability



(A) **(B)**

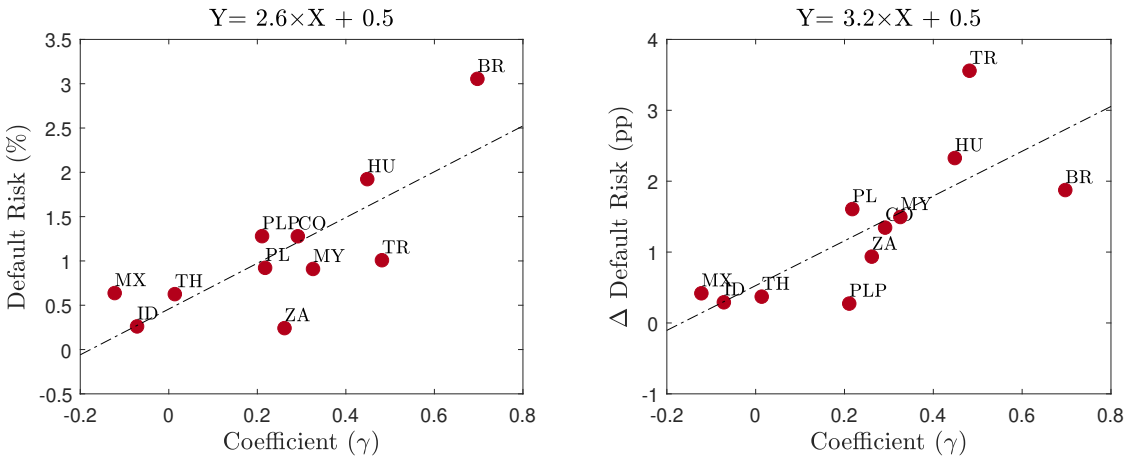
Notes: (1) Coefficient γ in equation (1) for each country.
(2) "Low" and "high" is determined by the median level.
(3) Relative financial development is the level of financial development scaled by the debt to GDP ratio.

developed country adjust their B/S with allocating a larger share to the government when capital outflows from the LC debt market, which leads to significant decline in private credit and increase in default risks. See details in the Figure 7A presenting that the economy with higher credit channel vulnerability tends to have higher default risk, and the Figure 7B presenting such an economy is likely to be more vulnerable to global shocks as the default risk reacts more sensitively to changes in global financial conditions.

3. Model

In this section, I build a three-period small open economy model to study the empirical features presented in the previous section. The model incorporates a banking sector along the lines of Gertler and Kiyotaki (2010) into a sovereign default model where the government bond is to be purchased by both domestic and foreign investors. I

FIGURE 7. Credit Channel Vulnerability & Default Risks



(A) **(B)**

Notes: (1) Coefficient γ in equation (1) for each country.
(2) Difference between average default risk in low global financial risk periods and that in high global financial risk periods. Periods of high global financial risk is the period when the VIX index is above the average + 1.5 times of the st.dev.

extend the model along two key dimensions. First the foreign investors' investments in the government bond is endogenously determined instead being determined by the government's decision as in Erce and Mallucci (2018), Gonzalez-Aguado (2018). Second I allow losses (haircuts) from the government's default to be different by whether the bond is held by domestic or foreign investors. The extension enables to capture interactions between foreign investor's investment decision depending on the state of global financial risk and its impacts on EMEs economy.

There is a small open economy that lasts for three periods $t = 0, 1, 2$. The economy is populated by a representative household whose members randomly switch between being workers and bankers, firms, foreign investors, and a government. Households sell labor to firms and lend to banks as a form of deposit. Firms produce consumption goods with capital borrowed from banks and labor. Bankers take deposits from households and lend to firms and the government, but do not have access to international markets. The government issues one-period local currency bond to finance its expenditures.

Foreign investors invest in LC government bonds.

3.1. Exogenous states

In the model, the exogenous state is given by $\Lambda_t = (z_t, S_t, x_t)$, where z_t is total factor productivity, S_t is the nominal exchange rate and x_t is an indicator whether global financial risk is high at time t or not.

The productivity process is as follows:

$$\log(z_t) = \mu_z + \rho_z \log(z_{t-1}) + \varepsilon_{z,t} - \phi_z x_t, \tag{2}$$

where $|\rho_z| < 1$ and $\varepsilon_{z,t} \sim N\left(0, \sigma_z^2\right)$. Note that the economy's productivity is assumed to decline by ϕ_z in high global financial risk periods.

The nominal exchange rate changes dollar returns of foreign investors holding LC bond and the investor's level of investment, which is as follows :

$$\log(S_t) = \mu_s + \rho_S \log(S_{t-1}) + \varepsilon_{S,t} + \phi_S x_t, \tag{3}$$

where $|\rho_S| < 1$, $\varepsilon_{S,t} \mid x_t = 0 \sim N\left(0, \sigma_{s0}^2\right)$, $\varepsilon_{S,t} \mid x_t = 1 \sim N\left(0, \sigma_{s1}^2\right)$, and $\sigma_{s1} = \sigma_{s0}(1+\eta)$. It is assumed that the nominal exchange rate depreciates ($\phi_s > 0$) and the variance of shocks to the exchange rate increases ($\eta > 0$) in high risk aversion periods.

The process of states of global financial risk follows a two-state Markov process, where $x_t = 0$ indicates a normal time and $x_t = 1$ a period of high global financial risk. Transition probabilities are π_{01}, π_{10}, where π_{01} is the probability from state state 0 to 1. In high global financial risks periods, the emerging economy is assumed to experience decline in productivity and currency depreciation with higher volatility.

3.2. Government

The government finances an exogenous level of public spending $\overline{g}$ in period 0 with LC government bond, which is non-defaultable.[14] In period 1 and 2, the government finances its expenditure G_1, G_2. The instrument that the government can access in period 1 includes proportional taxes on labor income constant across states τ and debt that the government can default. The government only can access to labor income taxes in period 2. The government bond is held both by foreign investors and domestic banks.

3.3. Private sector

Households There is a representative household composed of a measure 1 of workers and a measure 1 of bankers. Workers starts with endowment $\overline{n}_0^h$ in period 0 and choose how much to deposit (a_1) at price q_0^a and consume (c_1) out of endowment. In period 1, a measure λ of workers become new bankers and workers transfer $\overline{N}$ to newly born bankers. The λ of bankers cease to operate transferring the net worth to household. In period 1 workers decide on the level of deposit and labor supply, and they consume after tax labor income ($(1-\tau)w_1 l_1$), net worth transferred from exiting bankers, and deposit paid by banks net of savings for period 2. In period 2 they consumes after tax labor income based on their labor supply decision, net-worth transferred from domestic banks (N_2) and saving deposited in period 1. Lifetime utility of workers in household is as follows:

$$\max_{\left[c_{t=0,1,2}, l_{t=1,2}, a_{t=1,2}\right]} c_0 + \mathbb{E}_0 \left[\sum_{t=1}^{t=2} \beta^t \left(c_t - \frac{l_t^{1+\frac{1}{\zeta}}}{1+\frac{1}{\zeta}} \right) \right] \tag{4}$$

[14]The argument behind non-defaultable debt in period 0 is that the main focus is on how the default risk of bond issued in period 1 increases depending on the state of global financial risk.

$$\begin{aligned} \text{s.t.} \quad & c_0 + q_0^a a_1 = \overline{n}_0^h \\ & c_1 + q_1^a a_2 = (1-\tau)\, w_1 l_1 + a_1 + \lambda(N_1 - \overline{N}) \\ & c_2 = (1-\tau)\, w_2 l_2 + a_2 + N_2. \end{aligned} \tag{5}$$

Preferences over consumption are assumed to be linear as in Arellano, Bai, and Bocola (2017) and Chari, Dovis, and Kehoe (2020) and decreasing and convex over labor, with $\zeta > 0$ being the Frisch elasticity of labor supply. The linearity of preference over consumption ensures $q_t^a = \beta$ because the household would not be willing to to supply deposit to the bank unless the price of deposit is at least as large as the rate at which they discount the future. Labor supply satisfies the following conditions:

$$(1-\tau) w_t = l_t^{\frac{1}{\zeta}} \tag{6}$$

Firms A representative firm produce consumption goods in period 1, 2. The firm rents capital from banks at rate $R_{k,t}$, and hires workers at wage w_t. In period 1 and2, the firm maximizes the following objective function:

$$\max_{k_t, l_t} z_t k_t^{\alpha} l_t^{1-\alpha} - r_{k,t} k_t - w_t l_t \tag{7}$$

The first order conditions are:

$$r_{k,t} = z_t \alpha k_t^{\alpha-1} l_t^{1-\alpha} \tag{8}$$

$$w_t = z_t (1-\alpha) k_t^{\alpha} l_t^{-\alpha}. \tag{9}$$

Domestic banks At the beginning, a unit mass of risk neutral bankers endowed with N_0 start the business. In period 1, the bankers cease to operate with a probability λ and transfer the net worth to households, and go back to households as workers.

In period 0, the banks choose the level of investment in capital k_1, which depreciates at rate δ and default-free LC government bond b_1. Capital investment brings a return $R_{k,1}$ period 1, and the government bond bring 1 unit of consumption in period 1 with paying price q_0 in period 0. Then the banks net worth in period 1 is as follows:

$$N_1 = \underbrace{(r_{k,1} + (1 - \delta))}_{R_{k,1}} k_1 + b_1 - a_1. \tag{10}$$

In period 1, the banks choose capital investment and defaultable government bonds. Capital investment gives a return of $R_{k,2}$ in period 2. With investment in the government bond with a price q_1 in period 1, they receive 1 unit of consumption goods next period if the government repays ($D_{t+1} = 0$), and receive $\psi_d < 1$ unit of consumption goods if the government defaults ($D_{t+1} = 1$). The banks net worth in period 2 is as follows:

$$N_2 = \underbrace{(r_{k,2} + (1 - \delta))}_{R_{k,2}} k_2 + b_2(1 - D_2) + b_2\psi_d D_2 - a_2. \tag{11}$$

In period 0 and 1, the banks also decide on how much to borrow from the households as a form of deposit a_{t+1} at price q_t^a, which will be used as the resource for the investment along with the banks' net worth N_t. The budget constraint for banks is then,

$$k_{t+1} + q_t b_{t+1} \leq N_t + q_t^a a_{t+1}, \text{ for } t = 0, 1. \tag{12}$$

Banks are also constrained on how much they can borrow using deposits. In particular, they face the following collateral constraint:

$$a_{t+1} \leq \chi N_t \text{ for } t = 0, 1. \tag{13}$$

The constraint indicates that the amount the banks can borrow from households cannot exceed a certain fraction $\chi \in (0, 1)$ of the banks net worth.

The value of bankers can be defined using one state variable, net worth. The value in period 1, $V_1^B(N_1)$ is as follows:

$$V_1^B(N_1) = \max_{[a_2,k_2,b_2]} \beta \mathbb{E}_1 [N_2] \tag{14}$$

which is subject to the law of motion for net worth (11), the collateral constraint (13), and the budget constraint (12). Given that the budget constraint, we can substitute $a_2 = \frac{k_2+q_1b_2-N_1}{q_1^a}$ into the collateral constraint:

$$k_2 + q_1 b_2 \leq (q_1^a \chi + 1) N_1. \tag{15}$$

The first order conditions are as follows:

$$\begin{aligned} b_2 &: q_1(1+\mu_1) = \beta \mathbb{E}_1((1-D_2) + D_2\psi_d) \\ k_2 &: (1+\mu_1) = \beta \mathbb{E}_1(R_{k,2}) \end{aligned} \tag{16}$$

where μ_1 is the Lagrangian multiplier of the collateral constraint in period 1. Notice that the expected interest rate the firm needs to pay is higher than $\frac{1}{\beta}$ with the collateral constraint being bind. Combining two equations in (16) brings the following condition:

$$\mathbb{E}_1(R_{k,2}) = \frac{\mathbb{E}_1((1-D_2) + D_2\psi_d)}{q_1}, \tag{17}$$

Substituting the law of motion for net worth (11) and the budget constraint (12) into the banks' value function (14),

$$V_1^B(N_1) = \beta \left(\mathbb{E}_1 \left[R_{k,2} \right] (q_1^a a_2 + N_1 - q_1 b_2) + \mathbb{E}_1 \left[((1-D_2) + D_2\psi_d \right] b_2 - a_2 \right), \tag{18}$$

and using the banks' optimization condition (17), we can derive the value function as follows:

$$V_1^B(N_1) = \beta(\mathbb{E}_1\left[R_{k,2}\right](q_1^a a_2 + N_1) - a_2) - \beta \underbrace{(\mathbb{E}_1\left[R_{k,2}\right] q_1 - \mathbb{E}_1\left[((1-D_2) + D_2\psi_d\right])}_{=0} b_2. \quad (19)$$

Given that the collateral constraint binds such as $a_2 = \chi N_1$ and $q_1^a = \beta$

$$V_1^B(N_1) = (\beta\mathbb{E}_1\left[R_{k,2}\right] + \beta\chi(\mathbb{E}_1\left[R_{k,2}\right]\beta - 1))N_1. \quad (20)$$

The value in period 0, $V_0^B(N_0)$ is as follows:

$$V_0^B(N_0) = \max_{[a_1,k_1,b_1]} \beta\mathbb{E}_0\left[\lambda N_1 + (1-\lambda)V_1^B(N_1)\right] \quad (21)$$

which is subject to the law of motion for net worth (10), the budget constraint (12), the collateral constraint (13) and the value function in period 1 (20).

The first order conditions are as follows:

$$\begin{aligned} b_1 &: q_0(1+\mu_0) = \beta\mathbb{E}_0[W(\Lambda_1)] \\ k_1 &: (1+\mu_0) = \beta\mathbb{E}_0[W(\Lambda_1)R_{k,1}] \end{aligned} \quad (22)$$

where μ_0 is the Lagrangian multiplier of the collateral constraint in period 0, and $W(\Lambda_1)$ is the marginal value of an additional unit of net worth as follows,

$$W(\Lambda_1) = \lambda + (1-\lambda)(\beta\mathbb{E}_1\left[R_{k,2}\right] + \beta\chi(\mathbb{E}_1\left[R_{k,2}\right]\beta - 1)). \quad (23)$$

Note that $W(\Lambda_1) = 1$ when the collateral constraint in period 1 does not bind. Combining two equations in (22), we have a following condition:

$$\frac{\mathbb{E}_0[W(\Lambda_1)]}{q_0} = \mathbb{E}_0[W(\Lambda_1)R_{k,1}] \quad (24)$$

The banks optimality conditions in (17), (24) indicates that banks have to be indifferent between investing in the government bonds and and in capital for the banks to be willing to hold the government debt.

Foreign investor I assume there exists a unit mass of foreign investors labeled by $i \in [0, 1]$, which can invest in the emerging government's LC bonds in period 0 and 1. Foreign investors have access to an international risk free asset. I follow Alvarez, Atkeson, and Kehoe (2009), Fanelli and Straub (2020) in assuming that foreign investors face heterogeneous participation costs. In particular, each investor i is obligated to pay a participation cost of i per dollar invested.

Denote by $\tilde{R}_{i,t}$ the return on the LC bond in dollar terms when investor i purchases the bond in period t:

$$1 + \tilde{R}_{i,t} \equiv \frac{\frac{1}{(1+r^*)} \left(\left[(1 - D_{t+1}) + D_{t+1}\psi \right] / S_{t+1} \right)}{\left[q_t(1+i) \right] / S_t} \tag{25}$$

where D_t is the government's decision to default, $D_t = 1$ if it defaults and $D_t = 0$ if it repays; $\psi \in (0, 1)$ is the fraction foreign investors can receive as a compensation for holding defaulted debt, which is assumed $\psi \leq \psi_D$; q_t is the bond price; r^* is risk free rate. When the foreign investor i buys the government bond in period t, the investor needs to pay $\frac{q_t(1+i)}{S_t}$ dollars in period t. The denominator of the term in right side of equation (25) indicates the cost paid by the investor in period t, which is denominated in dollar terms. The investor are going to be paid 1 unit of domestic consumption goods when the government repays ($D_{t+1} = 0$), and be paid ψ unit of domestic consumption goods when the government defaults ($D_{t+1} = 1$) in period t+1. $\frac{[(1-D_{t+1})+D_{t+1}\psi]}{S_{t+1}}$ denotes the dollar return paid to foreign investors in period t+1. The numerator indicates the discounted return which is converted into dollar terms. The return on the bond free from default issued in period 0 is the return with $D_{t+1} = 0$.

And denote the log return as $\tilde{r}_i \equiv \ln(1+\tilde{R}_i)$, which is as follows:

$$\tilde{r}_{i,t} = \underbrace{\ln((1-D_{t+1})+D_{t+1}\psi)+\ln(S_t)-\ln(S_{t+1})-\ln(q_t)-r^*}_{\tilde{r}_t} - i \tag{26}$$

The log return of investor i can be expressed as the return which does not depend on the type of investor $\tilde{r}_t$ net of i. Then the expected log return on an investor i's investment $E_t(\tilde{r}_{i,t})$ equals to $E_t(\tilde{r}_t) - i$ and the variance $\mathrm{Var}_t(\tilde{r}_{i,t})$ equals to $\mathrm{Var}_t(\tilde{r}_t)$.

An investor i maximises the following quadratic objective function by choosing $b^*_{i,t}$,

$$(E_t(\tilde{r}_t) - i)\, b^*_{i,t} - \frac{\Gamma}{2}\mathrm{Var}_t(\tilde{r}_t) b^{*2}_{i,t} \tag{27}$$

where $\Gamma > 0$ is preference parameter that measures the level of risk aversion. $E_t(\cdot)$ and $\mathrm{Var}_t(\cdot)$ indicates the expectation and variance taken with respect to the information set at date t. The investor i's bond holding then satisfies:

$$b^*_{i,t} = \frac{(E_t(\tilde{r}_t) - i)}{\Gamma\,\mathrm{Var}_t(\tilde{r}_t)} \tag{28}$$

Let's denote $\hat{i}_t \in [0,1]$ the marginal foreign investors who participate in the bond market in period t:

$$\hat{i}_t = E_t(\tilde{r}_t). \tag{29}$$

Thus, investing is optimal for all investors $i \in [0, \hat{i}_t]$. Foreign holdings of the government bonds b^*_t is determined by integrating equation (28):

$$\int_{i=0}^{i=\hat{i}_t} b^*_{i,t} di = \frac{1}{\Gamma\,\mathrm{Var}_t(\tilde{r}_t)} \int_{i=0}^{i=\hat{i}_t} (E_t(\tilde{r}_t) - i)\ di \tag{30}$$

Using the condition for the marginal foreign investor (29) and the following equilibrium

condition:

$$\int_{i=0}^{i=\hat{i}_t} b_{i,t}^* di = b_t^*,$$

we can derive foreign holdings b_t^* as follows:

$$b_t^* = \frac{E_t(\tilde{r}_t)^2}{2\gamma \operatorname{Var}_t(\tilde{r}_t)} \tag{31}$$

The foreign investment is determined by the expected log return and the variance of the return. I present how the foreign investment is determined in period 1, particularly when the government issues the defaultable bond. The expected log return equals to the sum of the expected return when the government defaults and the expected return when the government repays by the law of total expectation:

$$E_t(\tilde{r}_t) = E_t(\tilde{r}_t \mid D_{t+1} = 1)\overbrace{Pr(D_{t+1} = 1)}^{\Delta_{t+1}} + E_t(\tilde{r}_t \mid D_{t+1} = 0)\overbrace{Pr(D_{t+1} = 0)}^{1-\Delta_{t+1}}. \tag{32}$$

Using the process of the nominal exchange rate in equation (3) and the definition of $\tilde{r}_t$ in equation (26), we can have following equations for the conditional expectation:

$$\begin{aligned} E_t(\tilde{r}_t \mid D_{t+1} = 0) &= (1-\rho_s)\ln S_t - \phi_s E_t(x_{t+1}) - \ln(q_t) - r^* \\ E_t(\tilde{r}_t \mid D_{t+1} = 1) &= \underbrace{\ln(\psi)}_{<0} + (1-\rho_s)\ln S_t - \phi_s E_t(x_{t+1}) - \ln(q_t) - r^* \end{aligned}$$

With denoting $Pr(D_{t+1} = 1)$ by Δ_{t+1} and substituting the banks' optimality condition (17), we can decompose the expected log return into default risk, currency risk, and compensation for these risks:

$$E_t(\tilde{r}_t) = \underbrace{\ln(\psi)\Delta_{t+1} - \ln(\Delta_{t+1}\psi_D + (1-\Delta_{t+1}))}_{\text{Default risk}} + \underbrace{(1-\rho_s)\ln S_t - \phi_s E_t(x_{t+1})}_{\text{Currency risk}} + \underbrace{\mathbb{E}_t(R_{k,t+1} - 1) - r^*}_{\text{Compensation for risk}} \tag{33}$$

The first two terms in (33) indicate default risk, which is decreasing in the default

probability, Δ_{t+1}. The next two term measure currency risk, associated with the expected currency deprecation. Note that currency risk increases if it is more probable that a state of high global financial risk is realized. The last two terms are the compensation for these risks.

The variance of the log return is as follows based on the total law of variance:

$$\begin{aligned} \mathrm{Var}_t(\tilde{r}_t) = \quad & \sigma_s^2(1+\eta E_t(x_{t+1})) + \phi_s^2 E_t(x_{t+1})(1-E_t(x_{t+1})) \\ & + \underbrace{\left[E_t(\tilde{r}_i \mid D_{t+1}=1) - E_t(\tilde{r}_i \mid D_{t+1}=0)\right]^2}_{(\ln(\psi))^2} \Delta_{t+1}(1-\Delta_{t+1}) \end{aligned} \tag{34}$$

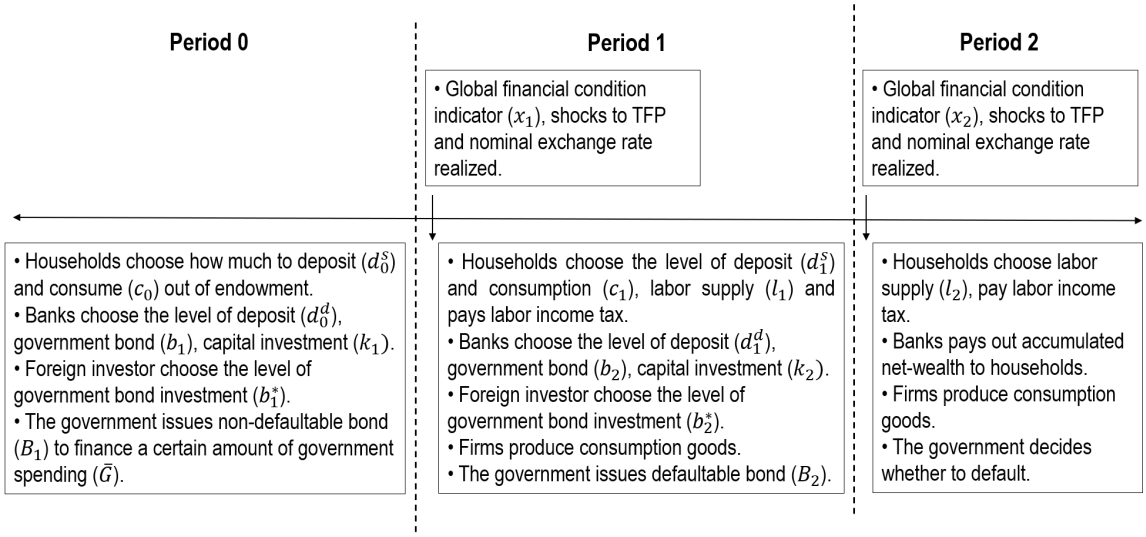
The variance of the return is decomposed into two parts, one related to the nominal exchange rate and the other related to the default risk.

All else equal, foreign LC bond holdings increase when (1) a default probability Δ_{t+1} is low, (2) compensation rate for holding defaulted debt ψ is high, (3) it is more likely that a global financial state is realized as normal, low $E_t(x_{t+1})$, (4) the expected return of domestic banks' capital investment $E_t(R_{k,t+1})$ is high. With a higher default probability, the expected log return decreases with the condition that $\psi \leq \psi_D < 1$, and the variance increases unless the default risk is too high. Higher ψ is associated with a higher expected return and a smaller variance, which leads the investors to increase investment. A higher probability that the global financial risk is high decreases the expected return because the local currency is likely to be more depreciated. The variance of log return increases with a higher risk in local currency market. Domestic banks' higher expected return on capital investment enlarges a deviation from UIRP and increases foreign investor's expected return on the bond.

3.4. Competitive equilibrium

Definition 1. A competitive equilibrium given government policies is allocations $\{c_t\}_{t=1,2,3}$ $\left\{a_t, l_t, k_t, b_t, b_t^*\right\}_{t=1,2}$ and prices $\{r_t, w_t\}_{t=1,2}$ $\left\{q_t^a\right\}_{t=0,1}$ such that given

FIGURE 8. Model Timeline



sovereign bond prices $\{q_t\}_{t=0,1}$ government policies $\{D_2, B_1, B_2, G_1, G_2\}$ exogenous state $\{\Lambda_t\}_{t=0,1,2}$ and initial values $\overline{n}_0^h$, N_0, the following holds:

(a) $\{c_t\}_{t=1,2,3}$ $\{a_t, l_t\}_{t=1,2}$ solve the household's problem in (4) $\sim$ (5).

(b) $\{l_t, k_t\}_{t=1,2}$ solve the firm's problem in (7).

(c) $\{b_t^*\}_{t=1,2}$ satisfies equation (31).

(d) $\{a_t, k_t, b_t\}_{t=1,2}$ solve the financial intermediaries' problem in (10) $\sim$ (14), (21) .

(e) Capital, labor and deposit markets clear, and the government bond market clears:
$b_t + b_t^* = B_t$

(f) Resource constraint holds: $c_t + G_t + k_{t+1} - (1-\delta)k_t = q_t b_{t+1}^* - b_t^*(1 - D_t) + z_t F(n_t, k_t)$

3.5. Government's problem

The timeline of the model is depicted in Figure 8. The following section describes government's problem in each period. $\{b, b^*, k\}$ is a set of endogenous state variables.

The government chooses the bond issuance B and the share of bond held by bank and foreign investors is endogenously determined. I redefine the endogenous state variable as $\{B, f, k\}$, where f is the foreign holdings of LC debt, $\frac{b^*}{B}$.

3.5.1. Government's problem in period 2

Let $V_2(B_2, f_2, k_2, \Lambda_2)$ be the value with the option to default in period 2 such that

$$V_2(B_2, f_2, k_2, \Lambda_2) = \max_{D=\{0,1\}} \{(1-D)V_2^R(B_2, f_2, k_2, \Lambda_2) + D[V_2^D(B_2, f_2, k_2, \Lambda_2) - \nu]\} \quad (35)$$

where V_2^R is the value from repaying debt, and V_2^D is the value from defaulting.

$$V_2^R(B_2, f_2, k_2, \Lambda_2) = U(G_2)$$
$$V_2^D(B_2, f_2, k_2, \Lambda_2) = U(G_2)$$

If the government chooses to default, the government pays only a fraction of the debt. Specifically, the government pays ψ_d fraction of the debt to domestic banks and pays ψ fraction to foreign investors with $\psi \leq \psi_d < 1$. With the government's default, productivity is reduced, and the government suffers the utility cost ν.

It is convenient to write the government's default default decision as a cutoff rule based on the default cost ν. Given that default costs ν are i.i.d., the default decision $D(B_2, f_2, k_2, \lambda_2)$ can be characterized by a cutoff cost $\nu^*(B_2, f_2, k_2, \lambda_2)$ where the value of repaying equals to the value of defaulting on debt such that,

$$\nu^*(B_2, f_2, k_2, \Lambda_2) = V_2^D(B_2, f_2, k_2, \Lambda_2) - V_2^R(B_2, f_2, k_2, \Lambda_2) \quad (36)$$

Then $D(B_2, f_2, k_2, \lambda_2) = 1$, whenever $\nu \leq \nu^*(B_2, f_2, k_2, \Lambda_2)$ and $D(B_2, f_2, k_2, \lambda_2) = 0$ otherwise. Let Φ be the cumulative distribution of ν, then default probability given $(B_2, f_2, k_2, \Lambda_2)$ is equal to $\Phi(\nu^*(B_2, f_2, k_2, \Lambda_2))$.

3.5.2. Government's problem in period 1 and 0

$V_1(B_1, f_1, k_1, \Lambda_1)$ is the value in period 1 such that

$$V_1(B_1, f_1, k_1, \Lambda_1) = \max_{B_2} U(G_1) + \beta_g \mathbb{E}_1 \left[V_2(B_2, f_2, k_2, \Lambda_2) \right] \tag{37}$$

$$\begin{aligned} s.t. \quad & G_1 = q_1 B_2 - B_1 + \tau w_1 n_1 \\ & G_2 = \tau w_2 n_2 - (1-D)B_2 - D(B_2 f_2 \psi + B_2(1-f_2)\psi_d) + W_2 \end{aligned} \tag{38}$$

where, W_2 is the government's endowment in period 2.

V_0 is the value in period 0 such that

$$\begin{aligned} V_0 \quad &= U(\overline{g}) + \beta_g \mathbb{E}_0 \left[V_1(B_1, f_1, k_1, \Lambda_1) \right] \\ \text{s.t.} \quad & \overline{g} = q_0 B_1 \end{aligned}$$

4. Quantitative Analysis

This section performs a quantitative evaluation of our model to study how global states affect EMEs LC bond market, and how the effects vary depending on the level of financial development. I first discuss the calibration strategy in subsection 4.1, and illustrate model mechanisms in the following subsection. In subsection 4.3, I perform a quantitative exercise with the model to see how the level of financial development explains the vulnerability of global shocks as discussed in the previous section.

4.1. Functional form and parameterization

I start with some functional forms. The preferences of the government are given by the standard utility function $U(G) = \frac{G^{1-\sigma}-1}{1-\sigma}$, where σ is the risk aversion parameter. I assume that the government's default incurs two types of cost, productivity decline and

a disutility cost, ν. Productivity shocks z_t are assumed to follow an AR(1) process as in equation (2). Following Chatterjee and Eyigungor (2012), I assume that productivity suffers a convex penalty $\max\left\{0, \lambda_0 z + \lambda_1 z^2\right\}$ with $\lambda_0 \leq 0 \leq \lambda_1$ with government's default as follows,

$$z(D) = \begin{cases} z & \text{if } D = 0 \\ z - \max\left\{0, \lambda_0 z + \lambda_1 z^2\right\} & \text{otherwise.} \end{cases} \tag{39}$$

The disutility cost ν is assumed to follow a logistic distribution with location λ_d and scale σ_D as in Arellano, Bai, and Mihalache (2020).

I first choose a subset of parameters values that can be directly pinned down from the data or that have standard values from the literature. I estimated the process of TFP and nominal exchange rate for each sample country, and use the average value for the parameters. The transition probabilities are calculated using the VIX index with defining high global financial risk periods ($x_t = 1$) as the periods with the VIX index above the average plus 1.5 times of its st.deviation. The set of parameters, assigned directly, includes risk aversion parameter set to a standard value, $\sigma = 2$, capital share to $\alpha = 0.33$. I choose capital depreciation rate (δ) to be 0.1, the Frisch elasticity (ζ) to be 0.33, risk free rate (r^*) to be 0.5% following Arellano, Bai, and Mihalache (2020). Tax rate is set to be 28% as in Wu (2020). The discount rate of households are set to be 0.96 and the discount rate of the government is set to be 0.92. The productivity decline in high global financial risk periods, ϕ_z, is set to be 0.03, and the increase in nominal exchange rate and increase in st.dev of shocks to the nominal exchange rate are set to be 0.1 respectively. The parameters of the default cost function λ_0 and λ_1 are set to be -0.17 and 0.21. Compensation rate of holding defaulted debt for domestic banks is set to be 0.1 while that for foreign investors is set to be 0.05. The scale parameter for disutility cost of default is set to be 0.01.

The second set of parameters $\{\chi, \Gamma, \lambda_d, \overline{g}\}$ is chosen to match four key moments of sample EMEs data. The moments are (1) the average LC debt to GDP ratio, 29.0 % (2) the average foreign holdings, 20.8% (3) the average default risk, 1.1%, (4) the average increase in default risk with change in states of global financial risk 1.3%p. The model lasts for three periods, and the economy starts with the exogenous variables held at the mean level. In period 1, economic agents decides optimizing the objective function given the exogenous states realized in the beginning of the period and state variables decides in period 0, bank's net worth, capital stock, government debt level, and foreign holdings. I compute the moments in period 1, and use these moments to choose the parameters. Banks' leverage constraint parameter χ is set to be 0.352 and foreign investors' risk preference parameter Γ is to be 5.85. Distuility cost of default is set to be 1.247 and exogenous government spending is set 0.205. Table 2 summarizes all values for the parameters. Table 3 reports the target moments in the model and the data. Overall the model reproduces the targeted main features of the data.

4.2. Model mechanisms

I examine the model mechanisms based on the government's decision in period 1.

Incentives to issue debt The government's decision on the debt issuance B_2 in period 1 mainly depends on the effect of bond issuance on banks and resultant tax revenue. The first order condition with respect to the debt issuance is as follows:

$$\overbrace{\left[q_1 + \frac{\partial q_1}{\partial B_2} B_2\right]}^{\text{revenue effect}} U'(G_1) + \beta_g \mathbb{E}_1[U'(G_2) \overbrace{\left(\frac{\partial TR_2}{\partial B_2}\right)}^{\text{crowding-out}}]$$
$$= \beta_g \underbrace{\mathbb{E}_1\left[U'(G_2) \mid D = 0\right]}_{\text{mg. cost in repayment states}} + \beta_g \underbrace{\mathbb{E}_1\left[U'(G_2)\left(\psi_d - (\psi_d - \psi)\left(f_2 + B_2 \frac{\partial f_2}{\partial B_2}\right)\right) \mid D = 1\right]}_{\text{mg. cost in default states}} \tag{40}$$

TABLE 2. Parameter Values

Parameters	Description	Value
Parameters from the data		
ρ_z	Autocorrelation of TFP	0.93
σ_z	Std. dev of TFP shocks	0.025
ρ_s	Autocorrelation of nominal exchange rate	0.95
σ_s	Std. dev of nominal exchange rate shocks	0.06
π_{01}, π_{10}	Transition probability	0.045, 0.78
Parameters assigned		
σ	Risk aversion	2.0
α	Capital share	0.33
δ	Capital depreciation rate	0.1
ζ	Frisch elasticity	0.33
β	Private discount rate	0.96
β_g	Government discount rate	0.92
r^*	Risk free rate	0.005
τ	Tax rate on labor income	0.28
W_2	Government endowment in t=2	0.42
ϕ_z	Productivity decline	0.03
ϕ_s	Nominal exchange rate increase	0.1
η	increase in std.dev of nominal exchange rate shocks	0.1
λ_0	Productivity in default	-0.17
λ_1	Productivity in default	0.21
ψ_D	Compensation rate for domestic banks	0.1
ψ	Compensation rate for foreign investors	0.05
σ_D	Enforcement shock	0.01
Parameters from moment matching		
χ	Leverage constraint	0.352
Γ	Preference parameter of foreign investors	5.85
λ_d	Disutility cost of default	1.247
$\overline{g}$	exogenous government spending	0.205

where TR_2 is tax revenue in period 2 such that $TR_2 = \tau w_2 n_2$. The government condition for issuing additional bond equates the revenue from the additional unit of debt net of its crowding-out effect to the cost of repaying in in the next period as in equation (40). Issuing an additional unit of bond increases total revenues by q_1 net of effects from bond

TABLE 3. Model Fit

	Data	Model
mean (LC debt/y, %)	29.0	29.1
mean (foreign holding, %)	20.8	20.8
mean (default risk, %)	1.1	3.1
mean (increase in default risk, %p)	1.3	1.3

price declines with increasing debt, which is denoted as revenue effect in the equation. The government also takes into account that issuing additional debt constrains banks' investment for capital unless banks collateral constraint does not bind, as less capital investment is associated with lower tax revenue. Given that the collateral constraint binds, the amount of banks investment in capital and the government bond is bounded by the level of net worth as in equation (15). The more the banks hold more government bond the less the next period's capital stock invested. With the collateral constraint binding, the government's issuance of additional debt has an impact on the banks' investment in capital as follows:

$$-\frac{\partial k_2}{\partial B_2} = \frac{\partial(q_1 B_2(1-f_2))}{\partial B_2} = q_1(1-f_2)\left[1+\frac{B_2}{q_1}\frac{\partial q_1}{\partial B_2}+\frac{B_2}{(1-f_2)}\frac{\partial(1-f_2)}{\partial B_2}\right] \tag{41}$$

I focus the channel through which the government's debt issuance crowds out capital investment via foreign holdings, which is captured by the elasticity of domestic banks' bond holding with respect to the government's debt issuance, $(\frac{B_2}{(1-f_2)}\frac{\partial(1-f_2)}{\partial B_2})$. The government's debt issuance has an impact on capital investment through foreign investors in three ways. First it increases the banks' government bond holding and decreases capital investment overall. Second it increase the banks' expected return of capital investment $E_1(R_{k,2})$ with constraining banks' capital investment, which induces more foreign capital. This allows the domestic banks to invest more capital. Third higher debt decreases the probability of repayment, which leads foreign investors

reduce investing in the government debt and banks to hold more government bond and to reduce capital investment. Taken together, the crowding-out effect depends on the elasticity of banks bond holding with respect to the government's debt issuance. A higher elasticity leads the banks to hold more government bonds with the government's additional issuance of debt, and this crowds out more capital investment and reduces tax revenue to a greater extent. If the government repays the debt, it costs one unit of the government expenditure. If it defaults, the cost varies by how much of debt is held by banks and foreign investors because compensation rate for holding defaulted debt is different by whether the debt is held by banks or foreign investors.

Incentives to default The default decision is characterized by a cutoff cost $v^* = V_2^D - V_2^R$ in equation (36). The value of repayment V_2^R and default V_2^D is as follows:

$$\begin{aligned} V_2^R\left(B_2, f_2, k_2, \Lambda_2\right) &= U\left(TR_2^R - B_2\right) \\ V_2^D\left(B_2, f_2, k_2, \Lambda_2\right) &= U\left(TR_2^D - B_2\psi_d + B_2 f_2(\psi_d - \psi)\right) \end{aligned} \tag{42}$$

where TR_2^R is tax revenue when the government repays and $TR_2^D$is tax revenue when the government defaults[15]. The default probability increases in v^*, and thus, there are four variables that affect the default probability: the level of debt B_2, capital k_2, foreign holdings, f_2, and productivity z_2. Note that the nominal exchange rate does not affect the government value. It changes foreign investors realized return for holding LC bonds, but has no impact on the government value and default decision. A higher level of debts and a lower level of capital increases the default probability, as it decrease the government's tolerance to debt with raising debt burden and lowering tax revenue. Given that $\psi_d > \psi$, higher foreign holdings makes the government be more likely to default. With a larger share of debt being held by foreign investors, the government's

[15]With the government's default, the productivity declines as in equation (39), and therefore the outputs and tax revenues in default and repayment states are not same even with the same level of capital

cost of compensating defaulted debt holders become smaller, which increases the government's incentive to default. The government tends to default when productivity is low because the default cost related to productivity is marginal when the productivity is low as assumed in equation (39).

Default risk conditional on global states I now turn to the investigation of how the change of global states affects the default probability. Denote a state of high global financial risks by "high state" and a state of low global financial risks by "low state". With a realization of a high state in period 1, it is more likely that the next period state is also high given that $\pi_{01} < \pi_{11}$. Then, foreign holdings decrease with a higher probability of high state realization. The government needs to resort more to banks when issuing the same level of bonds in high states than in low states. This has three effects on a default probability. First foreign holding of the debt is lower in high states and this decreases the government's incentive to default, leading to lower default risks. Second the government's debt issuance constrain banks capital investment more in high states, which is associated with a higher default probability. Lastly, this decreases the government's incentive to issue debt because the crowding-out effect is more significant in high states, which is associated with a lower default probability. With a high state realization, foreign holdings decrease, capital investment decreases, and the government's debt issuance falls when other state variables are equal. Lower foreign holdings and lower debt issuance reduce default probability, while lower capital investment increases default probability. The consequent effects on default risk from shifts in states of global financial risk depend on what effects are dominant.

Policy rules Figure 9 presents policy rules as a function of government debt B_2 in a high global financial risk state and a low state, relative to the mean level of productivity and the nominal exchange rate. The figures in the first row display how default probability

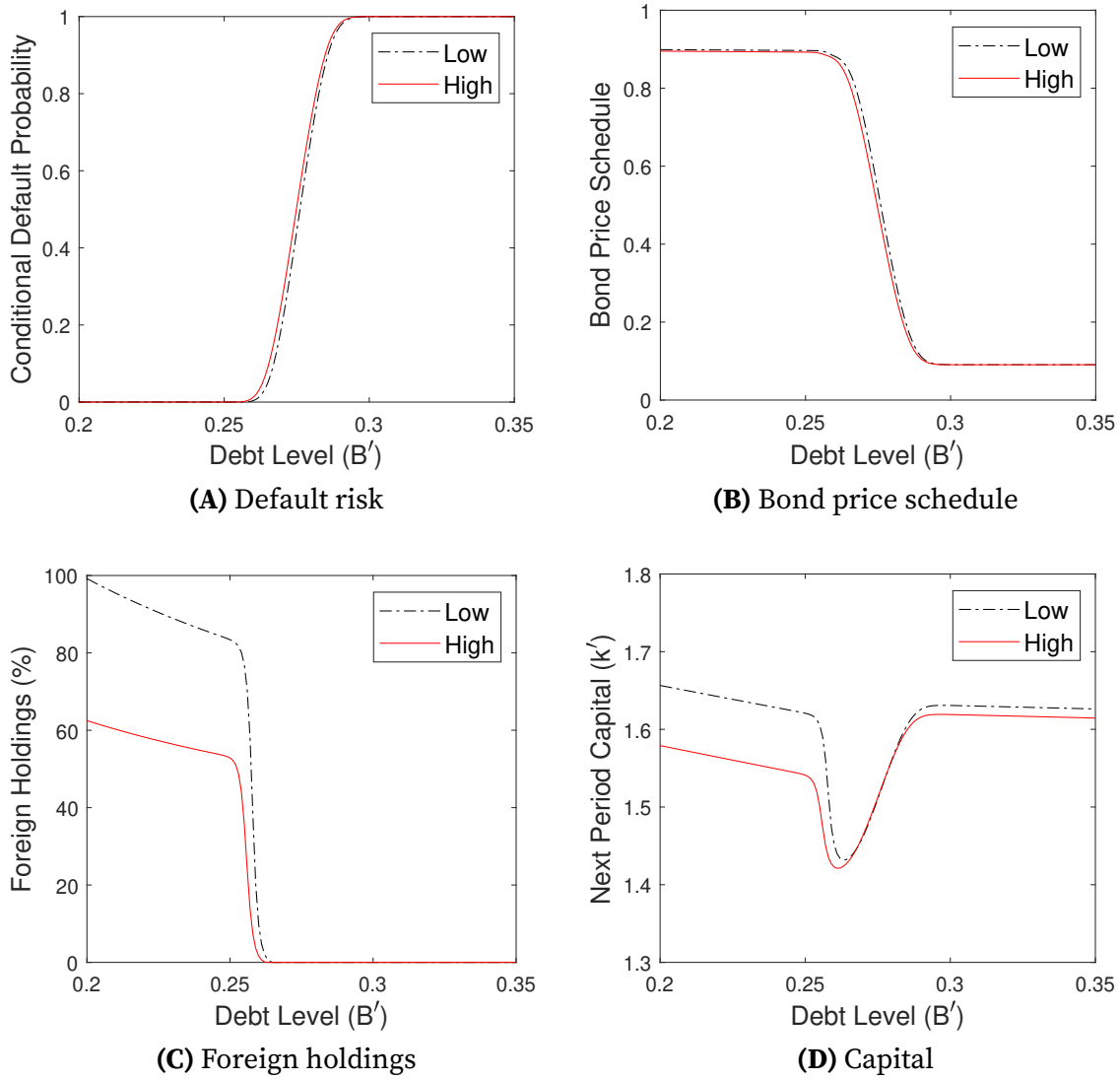
and bond price varies with bond issuance. The left figure in the second row plots how foreign holdings changes with bond issuance and the right figure plots how capital investment change with bond issuance. Foreign holdings decrease with the government bond issuance. Capital investment falls with bond issuance when the debt level is not too high, as the government bond issuance constrain banks from investing in capital. There are no capital inflows to the government bond market, with the debt level being above a certain level due to high default probability. With such a high level of debt, the government's revenue decreases with additional debt issuance because the decrease of revenue from price drop with issuing more debt outweighs the increase of revenue from issuing more debts. To see the policy rules by the states of global financial risks, foreign holdings decrease, and capital investment drops in high states as discussed in the previous part. The default probability is higher and bond price is lower in high states than in low states given the same level of debt issuance. This is mainly because the effect of fall in capital investment outweighs the effect of decrease in foreign holdings.

4.3. Financial development and vulnerability to global shocks

In this section I perform a quantitative exercise with the model and see how the model generates the empirical features presented in the previous section. The empirical features includes higher banks' B/S composition volatility, higher vulnerability of credit channel and LC bond market with less financial development.

In the model the level of financial development of a country is controlled by the parameter χ in banks collateral constraint (13). The higher χ is associated with the lower friction in financial sector and allows banks to extend investment in capital and the government bonds more, which I associate with a higher financial development. I perform the following quantitative exercise to see the implication of the model with regard to the relationship between the level of financial development and the

FIGURE 9. Policy Rules



(A) Default risk

(B) Bond price schedule

(C) Foreign holdings

(D) Capital

Note: The figures plot the conditional default probability, bond price schedule, foreign holdings, and next period capital as the government's bond issuance B_2 varies given the TFP and the nominal exchange rate held at their mean level with the state of global financial risk being "high" and "low".

vulnerability of LC bond market to global financial risks. I vary the value for parameter χ to differ the level of financial development. I compare the ralative financial development, credit channel vulnerability, default risk and external vulnerability of the economy with different level of financial development. I only change the value of

TABLE 4. Selected Moments: Data, Benchmark and Alternative Economies

	Data	Benchmark	Low	High
χ	-	0.352	0.342	0.37
mean (financial development[1], %)	54.3	50.4	48.9	53.4
mean (ralative financial development[2])	1.92	1.73	1.68	1.85
σ (govshare)	1.28	1.83	1.91	1.67
σ (govshare) / σ (foreign share)	0.623	0.161	0.163	0.157
$\gamma(\Delta$private credit, Δforeignholding)	0.214	0.182	0.184	0.177
mean (default risk, %)	1.1	3.1	3.2	2.0
mean (increase in default risk, %p)	1.3	1.3	1.8	0.4

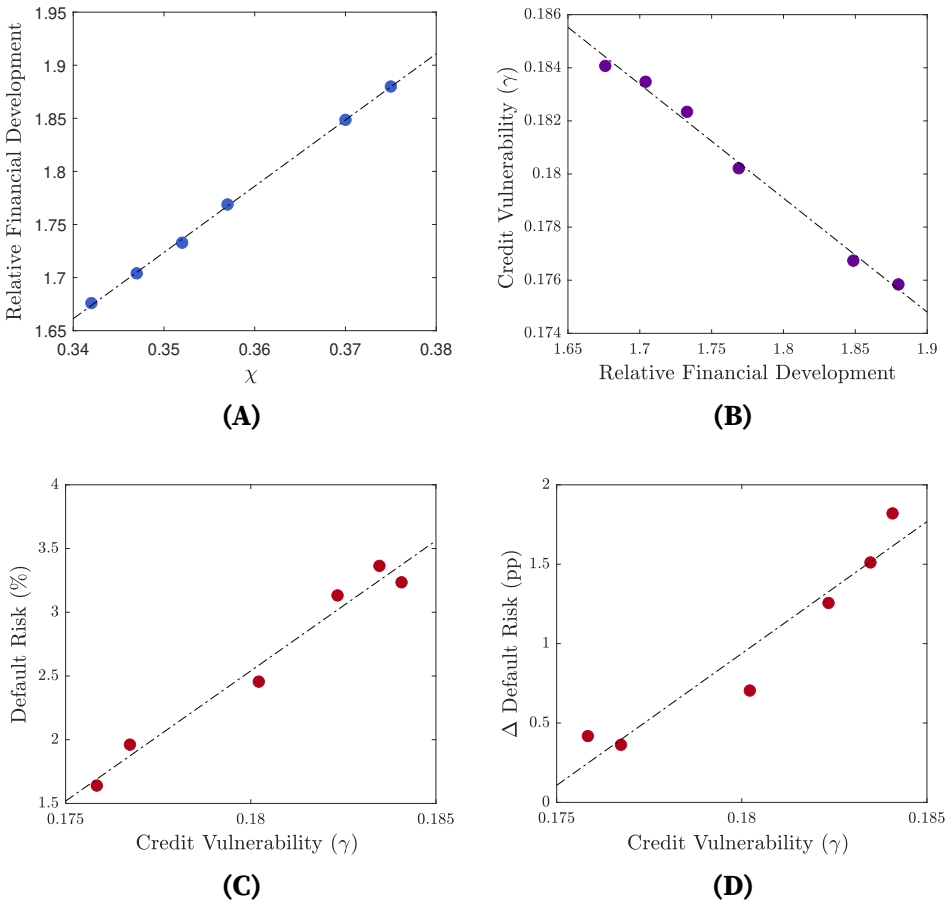
Notes: (1) Deposit to GDP (%)
(2) Financial development scaled by debt to GDP ratio

the parameter χ for this exercise, and I keep the other parameter fixed at their level as in Table 2.

Table 4 presents selected moments of data, the benchmark model, models with lower and higher value for χ. The model captures the difference in banks' B/S composition volatility with the level of financial development. Banks in a less financially developed economy tends to adjust their B/S in a greater scaled. With regressing the growth rate of capital net of total claim growth on the change in foreign holdings, I calculated the coefficient γ that measures the credit channel vulnerability as in 2.2.2. The model generates the empirical pattern that a country with low ralative financial development shows a higher credit channel vulnerability. In other words, the economy with lower χ reduces capital investment to a greater extent when foreign capital outflows from the LC bond market and banks need to hold more government debt. The mean default risk in the economy with lower χ is higher and the LC bond market's vulnerability to global financial risks also higher with larger increase in default probability with shifts in global financial conditions.

In Figure 10, I show the level of scaled of financial development, credit vulnerability,

FIGURE 10. Selected Moments with Different Parameter Value for χ



Note: The figures plot ralative financial development: financial development (deposit to GDP ratio) scaled by the debt to GDP ratio, credit vulnerability (γ): coefficient of change in private credit on the change in foreign holdings, average default risk, and average increase in default risk to global back shock

and external vulnerability with varying the value for χ. The feature generated by the model is consistent with what is found in data: a less financially developed economy shows higher credit vulnerability, and also higher vulnerability to global financial conditions.

5. Conclusion

This paper investigates the key factors determining the cross-country difference in impacts of global shocks on the LC sovereign debt market. I mainly study the phenomenon where EMEs are vulnerable to global financial conditions even with their significant share of debt being denominated in LC, which was termed as "original sin redux" by Carstens and Shin (2019). I fill gaps in the literature by linking financial development, credit channel vulnerability, and vulnerability to global financial conditions.

I illustrate LC yields and credit spread movement during recent financial market turbulence amid the Covid-19 pandemic to show that borrowing in LC has not insulated EMEs from changes in global financial conditions. I document that higher reliance on foreign capital leads to more vulnerability during the periods, as presented in Carstens and Shin (2019) and Hofmann, Shim, and Shin (2020). I link the level of financial development to the vulnerability to global shocks and find a country with low financial development shows a higher vulnerability to the shocks. I empirically show that the private credit tends to be more adversely affected by foreign capital outflows from the LC bond market (higher credit channel vulnerability) in a less financially developed country. Such an economy shows a higher credit risk and also a higher vulnerability to global financial shocks.

I develop a model consistent with all these empirical features. I extend a standard sovereign default model incorporated with the financial intermediation sector by allowing foreign investor's decisions to be endogenously determined and losses to be different by whether domestic or foreign investors hold the bond. I capture interactions between foreign investor's investment decisions depending on the state of global financial risk and its impacts on EMEs with these extensions. I perform a quantitative exercise with varying a parameter governing friction in the financial

sector to see how the credit vulnerability and vulnerability to global financial risks vary by financial development level. The model generates the main features in data that a less financially developed economy shows higher credit vulnerability and also higher vulnerability to global financial conditions.

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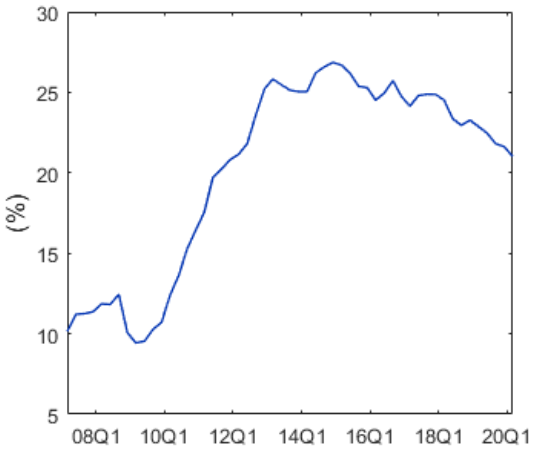
Appendix

FIGURE A1. Foreign Holding of LC Sovereign Debt Securities (07Q1∼20Q1)

	Average	Change (07Q1∼20Q1)
Brazil	12.13	10.29
Colombia	11.58	9.38
Hungary	26.30	-2.64
Indonesia	30.84	16.34
Malaysia	24.04	15.37
Mexico	26.50	18.48
Philippines	5.00	4.64
Poland	28.69	6.87
South Africa	5.85	5.61
Thailand	11.64	10.35
Turkey	15.95	1.53
(Mean[2])	20.17	10.01

(A) By country



(B) Average of sample countries

Notes: (1) Table reports the average LC debt held by foreign investors as % of total outstanding.
(2) The equal weighted mean of the 11 country means.

Sources: Arslanalp and Tsuda (2014), IIF

Table A1. Data description and source

	Description	Sources
Nominal LC yield spread	Unhedged 5-year zero-coupon LC government yield over US treasury yield.	Bloomberg
Swap rate	5-year implicit forward premium of LC (Calculated by spot rate from fixed LC for US Libor, cross currency swap, less spot rate from fixed US for Libor interest swap)	Bloomberg
Credit spread	Swapped 5-yr zero-coupon LC sovereign yield over US treasury yield. (Nominal LC yield spread less swap rate)	Author's calculation (Du & Schreger)
Foreign holdings of LC sovereign bond (level)	Outstanding central government debt securities denominated in local currency held by foreign investors.	Arslanalp and Tsuda
Foreign holdings of LC sovereign bond (share)	Share of Foreign holdings of LC sovereign bond as a percentage of total outstanding LC government bonds.	Arslanalp and Tsuda IIF
Exchange rate	Local currency units relative to US dollar	Bloomberg
Exchange rate volatility	Estimated exchange rate volatility with Garch (1,1)	Author's estimation
Real GDP growth rate	Percentage change in real GDP corresponding to the quarter of the previous year.	IFS
$\frac{\text{Government Debt}}{GDP}$	Debt owed by country's general government sector as a percentage of nominal GDP	National Institutes of each country
Banks' claims on government	Sum of net claims on (central government, local government, public nonfinancial) / Total claims	IFS
Bank's claims on private sector	Banks' claims on the non financial private sector.	IFS
Vix	30 day implied volatility of the S&P,	FRED (St.Louis Fed)
Ted Spread	the spread between 3-month dollar Libor and the 3-Month Treasury Bill	FRED (St.Louis Fed)
Fed Funds Rate	the effective overnight Federal Funds Rate	FRED (St.Louis Fed)
BBB-Treasury Spread	the option-adjusted spread of the Bank of America Merrill Lynch US Corporate BBB Index over US Treasuries	FRED (St.Louis Fed)
10-Year Treasury Spread	10-yr Treasury constant maturity rate	FRED (St.Louis Fed)

Table A2. Sovereign LC Bond (5-Yr) Yield Spread Decomposition (Jan.2007-June.2020)

(%)

	Yield Spread	Swap rate (Currency risk)	Credit spread
Brazil[2]	9.64	6.59	3.05
Colombia[3]	5.19	3.93	1.29
Hungary	3.20	1.28	1.92
Indonesia	5.82	5.56	0.26
Malaysia	1.58	0.67	0.91
Mexico	4.50	3.86	0.64
Philippines	3.14	1.86	1.28
Poland	1.88	0.96	0.92
South Africa	5.85	5.61	0.24
Thailand	0.85	0.23	0.63
Turkey	10.13	9.13	1.01
(Mean[4])	4.71	3.61	1.10

Notes: (1) This table reports the average daily nominal yield spread (LC over US treasury bond), cross currency swap rate (currency risk) and credit spreads.
(2) Data starts from Apr.2007 due to data availability.
(3) Data ends at Nov.2019 due to data availability.
(4) The equal weighted mean of the 11 country means.

Sources: Bloomberg, Author's calculation

TABLE A3. Foreign Holdings of LC Bonds and Banks B/S Compositions

	Corr(Δforeign holding[1], ΔPrivate[2])	Corr(Δforeign holding[1], ΔGovernment[3])
Brazil	0.73	-0.77
Colombia	0.14	-0.40
Hungary	0.41	-0.40
Indonesia	0.11	-0.41
Malaysia	0.68	0.29
Mexico	-0.20	-0.17
Philippines	-0.26	0.01
Poland	0.24	-0.39
South Africa	0.19	-0.04
Thailand	-0.02	0.14
Turkey	0.62	-0.69
(Mean[4])	0.24	-0.26

Notes: (1) %p change in the share of LC debt held by foreign investors (yoy)
(2) Growth of banks private claim net of growth of total claim
(3) Annual growth of banks' claims on the government.
(4) The equal weighted mean of the 11 countries correlations.

Sources: Arslanalp and Tsuda (2014), IIF, IFS