Macro-Financial Implications of the Surging Global Demand and Supply of International Reserves*

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Abstract

Since the 1990s, the foreign reserves of emerging economies (*demand* for reserve assets) and the public debt of advanced economies (*supply* of reserve assets) have risen sharply. We study their implications using a two-region model in which private and public debt have a productive use. Higher reserves or public debt in one region affect financial and macroeconomic volatility in both regions by altering the leverage of borrowers and the composition of producers' financial portfolios. Quantitative counterfactuals show that the observed surge in reserves sharply increased financial and macroeconomic instability in *both* regions, while the surge in public debt had the opposite effect. When considering reserves and public debt jointly, volatility declined.

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1 Introduction

The foreign exchange (FX) reserves of emerging market economies (EMEs) increased significantly during the last three decades, as shown in the first panel of Figure 1. The sharp increase is especially notable after the 1990s Sudden Stops: FX reserves increased from 10 percent of GDP in 1997 to 30 percent in 2009.[1] Foreign reserves also increased in advanced economies but at a much slower pace.

Foreign reserves are mainly held in the form of short-term public debt issued by advanced economies (AEs), particularly U.S., Europe and Japan. The second panel of Figure 1 shows that the public debt of AEs rose sharply following the 2008 global financial crisis. It rose from about 60 percent of GDP in 2007 to about 95 percent in 2012.

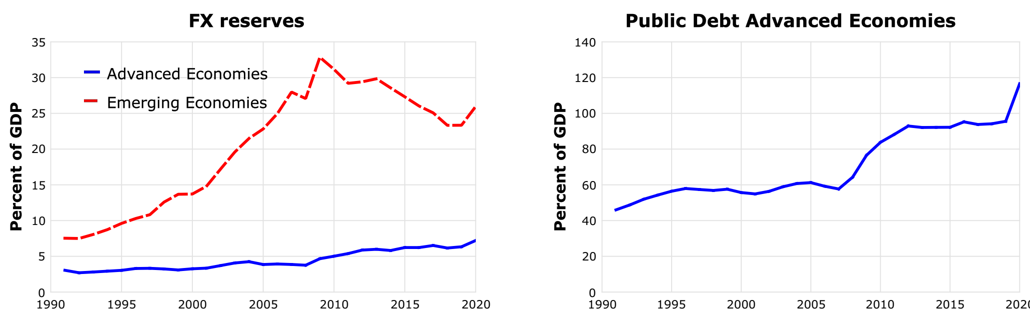

Figure 1: Foreign Exchange Reserves of Advanced and Emerging economies and Public Debt of Advanced economies.

Note: Data for FX reserves is from External Wealth of Nations database (Lane and Milesi-Ferretti (2018)). Advanced economies: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States. Emerging economies: Algeria, Argentina, Brazil, Bulgaria, Chile, China, Czech Republic, Colombia, Estonia, Hong Kong, Hungary, India, Indonesia, Israel, South Korea, Latvia, Lithuania, Malaysia, Mexico, Pakistan, Peru, Philippines, Poland, Romania, Russia, Saudi Arabia, Singapore, South Africa, Thailand, Turkey, Ukraine, Venezuela. Data on public debt is from IMF Global Debt Database. We use the series Central Government Debt which is available for thirteen countries: Canada, Finland, France, Germany, Italy, Japan, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States. The Global Debt Database provides two series: 'Central Government Debt' and 'General Government Debt'. We use the former. Data for all years 1991-2020 are available only for thirteen of the advanced economies (listed above). Hence, our measure of debt-to-GDP ratio for advanced economies results from the aggregation of these thirteen countries.

From a global perspective, these changes are important because the growth of EMEs' reserves raised the demand for risk-free financial assets (contributing to a lower world interest rate), while more issuance of public debt by AEs increased their supply (contributing to a higher interest rate). The goal of this paper is to understand how these changes affected world credit markets (the world interest rate and credit positions in EMEs and AEs) and impacted global financial and macroeconomic volatility.

To this end, we develop a quantitative model that features two regions representing, respectively, AEs and EMEs. In each region, there are borrowers (issuers of financial liabilities) and lenders (buyers of those liabilities). Two characteristics of borrowing and

[1] It is well-known that China played an important role in this increase, but other EMEs did too. As a share of global GDP, EME's (China's) reserves grew from roughly 1.2% (0.2%) in 1991 to 11.25% (4.8%) in 2010.

lending are central to our analysis. The first is that lenders in the private sector hold liabilities because for them they are financial assets that facilitate production and, therefore, they provide a convenience yield. The second is that the liabilities issued by the private sector are defaultable.

A financial crisis occurs when private borrowers default and do not repay their debt in full. This happens in states in which the debt exceeds the liquidation value of real assets owned by borrowers, with this liquidation value exhibiting self-fulfilling fluctuations driven by "sunspot" shocks. A default generates haircuts that redistribute wealth from creditors to debtors. This redistribution causes adverse real macroeconomic effects by wiping out some of the financial wealth held by producers. The magnitude of these effects depends on the financial structure of the economy: When leverage is high, a financial crisis generates a larger redistribution of wealth and hence a larger drop in output.

Changes in foreign reserves by EMEs or in the public debt of AEs affect the magnitude of financial crises and global macroeconomic volatility. An increase in EMEs' reserves leads, in general equilibrium, to riskier financial holdings by lending producers. Due to riskier portfolios, a financial crisis generates a larger redistribution of wealth from lenders to borrowers with greater macroeconomic consequences.

The portfolio holdings of lending producers become riskier for two reasons. First, the purchase of safe assets for foreign reserves crowds out private holdings of AEs public bonds by lending producers. At equilibrium, their portfolios contain a smaller share of risk-free public bonds and a larger share of risky private bonds. Second, the increase in EMEs' reserves reduces the world interest rate, prompting borrowing producers to lever up. Higher leverage then implies that creditors face larger haircuts in the event of a financial crisis. In short, lending producers' portfolios become riskier because they hold fewer safe public bonds, and private bonds become riskier.

An increase in the supply of public debt issued by AEs has the opposite effect, leading to safer financial holdings for lending producers. Their portfolios contain a larger share of public bonds (since the global supply of safe assets expands), while private bonds become less risky (as the interest rises and leverage falls). Safer portfolios, in turn, result in smaller redistribution from lenders to borrowers during a financial crisis, reducing its macroeconomic impact.

In order to use the model to quantify the impact of reserves accumulation and public debt issuance on the financial and real sectors globally, we need to set the values of three key parameters in each of the two regions: Total factor productivity; a parameter that affects the private demand for financial instruments (determining the extent to which they are needed in production); and a parameter that affects the private supply of financial assets (determining the liquidation value of borrowers' capital in a default, and thus their capacity to issue debt). We also need to set the initial values of foreign reserves in both AEs and EMEs and public debt in AEs.

We calibrate the six parameters together with the three initial values of foreign reserves and public debt so that the model matches nine data observations from the year 1991. We then conduct counterfactual simulations over the period 1991-2020 comparing a scenario in which (detrended) reserves and debt are kept constant at their 1991 values with scenarios in which they take the actual (increasing) values observed in the data. The results show that the observed surge in reserves caused a sharp increase in macroeconomic and financial volatility while the increase in public debt reduced it. The impact of higher public debt, however, dominates the impact of higher reserves, so that the combined effects reduced global volatility. Importantly, these experiments only aim to isolate the contributions of the growth in reserves and/or public debt to financial and macro volatility, keeping all other model parameters (and all other potential determinants of interest rates, portfolio compositions and volatility) unchanged.

We also explore the possibility that FX reserves may be used to provide liquidity and stabilize the economy in the event of a financial crisis. In particular, since the adverse real effects of a financial crisis in our model are due to the destruction of entrepreneurial wealth (i.e., the defaulted debt), we assume that FX reserves are used to bail out a fraction of the financial losses of entrepreneurs. This arrangement helps little to reduce the volatility of advanced economies, because they do not hold large stocks of FX reserves relatively to their size, and hence they support small bailouts. In contrast, aggregate volatility drops markedly for emerging economies that accumulate reserves, providing a potential justification for their desire to accumulate reserves.

Quantifying the welfare implications of the surges in reserves and public debt, we find that households and entrepreneurs fare very differently. In both regions, the combined effect of higher reserves and higher public debt results in sizable welfare gains for households and losses for entrepreneurs. These welfare effects are driven by fiscal implications as changes in the world real interest rate, reserves and debt affect taxation of households, and by changes in the profits and financial income of entrepreneurs as their financial wealth changes.

Related literature. Our work is related to three strands of literature: (i) financial and macroeconomic implications of FX reserves; (ii) financial crises or Sudden Stops; (iii) scarcity of financial assets.

There is an extensive literature on the financial and macroeconomic implications of FX reserves. One branch focuses on foreign exchange interventions and their effects on exchange rates and financial stability (see the survey by Popper (2022)). Interestingly, Kim et al. (2020) find that firm-level leverage in EMEs increases in the aftermath of these interventions.

Several studies focus on the implications of reserves for sovereign borrowing, vulnerability to financial crises, and design of macroprudential policy (e.g., Alfaro and Kanczuk (2009), Durdu et al. (2009), Devereux and Wu (2022), Bianchi et al. (2018), Bianchi and Lorenzoni (2022), Bianchi and Sosa Padilla (2024), Kondo and Hur (2016)). These studies analyze the role of reserves in the context of small open economies, and thus treat the world interest rate as exogenous. Our analysis deviates from the small open economy setup by highlighting a mechanism that operates through global general equilibrium changes.

This literature also includes two interesting studies that, like this paper, examine adverse global spillovers of reserve accumulation. Das et al. (2023) study a model with currency mismatch in the private sector to show that central banks may over-accumulate reserves because they ignore general equilibrium effects on the dollar interest rate. Steiner (2014) proposes a model where crisis probabilities are exogenously linked to the accumulation and issuance of reserve assets. It shows that the accumulation of reserves strengthens macroeconomic stability in reserve-accumulating countries, but weakens it in reserve-issuing countries.

Our analysis differs from these studies in three key respects. First, the transmission mechanisms differ. In Das et. al., the effects of changes in the world interest rate operate through currency mismatch while in our model they operate via private leverage and portfolio holdings. In contrast with Steiner, both the world interest rate and the probability of crises are endogenous in our model. Furthermore, the EMEs' accumulation of reserves generates not only a negative global spillover that increases financial and macroeconomic volatility in AEs, but also increases volatility in EMEs themselves. Second, we quantify general-equilibrium effects on global volatility rather than on the optimality of reserves accumulation. Third, in addition to studying the surge in *demand* for reserves by EMEs, we study the growing *supply* of reserves created with the issuance of public debt by AEs. We emphasize that the *supply* of reserves is also important for understanding the importance of the market for risk-free assets on macroeconomic volatility. In particular, we show that the negative cross-country spillovers caused by an increase in demand for reserves by emerging economies can be offset by the response of the supply: if higher accumulation of reserves lowers the equilibrium interest rate, AEs may have an incentive to issue more public debt. Although our paper does not study the *optimal* accumulation of reserves and issuance of public debt, it shows that the recent trends exert pressure for higher, not lower interest rates.

Various contributions in the Sudden Stops literature examine the role of financial globalization, credit booms and high leverage as causing factors of financial crises. Examples include Calvo and Mendoza (1996), Caballero and Krishnamurthy (2001), Gertler et al. (2007), Edwards (2004), Mendoza and Quadrini (2010), Mendoza and Smith (2014), Fornaro (2018). See also Bianchi and Mendoza (2020) for a survey of the literature. Crises in our model also follow from periods of fast credit and leverage growth. Our paper is also related to the broader macro literature that links macro volatility to financial frictions, as in the work of Arellano et al. (2019).

Studies in the corporate finance literature document and provide explanations for the raising demand of financial assets. An example is the literature on the growing cash holdings of nonfinancial businesses (e.g., Riddick and Whited (2009), Busso et al. (2016) and Bebczuk and Cavallo (2016)). These studies highlight the heterogeneity in firms' financial structures within a country, distinguishing between net borrowers (firms holding negative net financial assets) and net lenders (firms holding positive net financial assets). This heterogeneity is a core feature of our model and is central to the mechanism driving the effects of a financial crisis on the real economy. Specifically, the real effects of a crisis intensify with the scale of positive and negative gross financial positions within a country, and these positions are influenced by the demand and supply of reserve assets.

The remainder of the paper is organized as follows: Section 2 describes the model and characterizes the equilibrium. Section 3 calibrates the model and conducts counterfactual simulations to quantify the general equilibrium effects of FX reserves and public debt on some macro indicators. Section 4 analyzes the implications of changes in FX reserves and public debt for macro and financial volatility. Section 5 studies an extension of the model in which reserves are used to cover part of the entrepreneurs' losses in the eventuality of a crisis. Section 6 discusses the welfare implications of FX reserves accumulation and issuance of public debt. Section 7 concludes.

2 Model Structure

Consider a world economy with two regions indexed by $j \in \{1, 2\}$. Region 1 represents advanced economies and Region 2 emerging economies. In each region, there are three sectors: (i) a business sector with two types of firms; (ii) a household sector that consumes goods and supplies labor; and (iii) a public sector that provides lump-sum transfers to households, holds financial assets in the form of FX reserves and, in Region 1, issues liabilities (public debt).

We model two types of firms as a means to generate private borrowing and lending within a region (in addition to cross-regional borrowing and lending). We distinguish the private demand for financial assets by firms with positive financial positions (net lenders) from the private supply by firms with negative financial positions (net borrowers). This modeling structure aligns with the empirical evidence of growing corporate cash emphasized earlier in the literature review and, importantly, allows us to generate well defined *gross* foreign asset positions: each region holds both foreign assets and foreign liabilities. It is through *gross* foreign asset positions that our model generates real spillovers across regions. *Net* positions—often referred to as imbalances—are not important for our results. The introduction of the public sector allows us to study how the issuance of public debt and accumulation of FX reserves affect the economies of the two regions.[2]

Regions are heterogeneous in three key dimensions: (i) economic *size*, captured by differences in aggregate productivity, z_j; (ii) a financial parameter that affects directly

[2]Several contributions in the literature propose mechanisms through which financial crises could spread from one country/region to another country/region. Examples include Arellano et al. (2017) and Perri and Quadrini (2018). Our paper differs in that we focus on how the spillover is affected by the global demand and supply of safe assets, and in that our spillover channel relies on gross foreign holdings rather than net holdings.

the *demand* for financial assets, ϕ_j; and (iii) a financial parameter that affects directly the *supply* of financial assets, κ_j. Differences in size could be generated by other factors besides productivity (e.g., population, real exchange rates, etc.). For the questions addressed in this paper, however, they are isomorphic to productivity differences.

Regions also differ in their stocks of foreign reserves, $FX_{j,t}$, and public debt issued by the government of advanced economies, $D_{p,t}$. For simplicity, we assume that emerging economies do not issue public debt, reflecting the fact that their debt is not used for accumulating reserves and is more akin to a defaultable asset, like the private liabilities we model. Foreign reserves $FX_{j,t}$ and public debt $D_{p,t}$, are time-varying but not stochastic. Thus, their evolution over time is fully anticipated. The only source of uncertainty in the model comes from "sunspot" shocks described later.

2.1 Household sector

In each region, there is a unit mass of households that maximize the following expected lifetime utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(c_{j,t} - \mu_j \frac{h_{j,t}^{1+\frac{1}{\nu}}}{1+\frac{1}{\nu}} \right),$$

where $c_{j,t}$ is consumption, $h_{j,t}$ is the supply of labor, ν is the elasticity of labor supply, and μ_j is a parameter that scales labor disutility. The assumption that utility is linear in consumption simplifies the characterization of the equilibrium. It allows us to derive analytic results without affecting, in important ways, the properties of the model that are central for the questions addressed in this paper. The scale parameter μ_j allows the model to support similar employment rates in the two regions even if there are larger regional differences in productivity.

The households' budget constraint is

$$c_{j,t} = w_{j,t} h_{j,t} + \text{div}_{j,t} + T_{j,t}.$$

Consumption is paid for with wage income, $w_{j,t} h_{j,t}$, where $w_{j,t}$ is the wage rate, dividends distributed by firms owned by households, $\text{div}_{j,t}$, and government transfers, $T_{j,t}$, or taxes when $T_{j,t} < 0$. Households take as given the wage rate, dividends and transfers.

The only relevant decision made by households is the supply of labor, which is determined by this first-order condition equating the marginal disutility of labor to the wage rate:

$$\mu_j h_{j,t}^{\frac{1}{\nu}} = w_{j,t}. \tag{1}$$

Notice the separability of utility in $c_{j,t}$ neutralizes the wealth effect on labor supply by making the marginal rate of substitution between labor and consumption (i.e., the left-hand-side of eq. (1)) independent of the latter. Once the labor supply is determined, consumption immediately follows from the budget constraint.

2.2 Business sector

There are two types of firms: producers of intermediate goods (owned by households) and producers of final goods (owned and operated by entrepreneurs). An important difference between them is that capital—which is pledgeable as collateral—is used only by intermediate-goods firms. Final-goods producers lack collateral assets. At equilibrium, then, the first type of firms are net borrowers and the second are net lenders (i.e., they have a positive position in financial assets). In this way, we generate borrowing and lending within the business sector.[3] We describe first the producers of intermediate goods.

2.2.1 Intermediate goods producers

Intermediate-goods firms produce inputs $x_{j,t}$ using labor, $l_{j,t}$, and capital, $k_{j,t}$, with the following Cobb-Douglas technology:

$$x_{j,t} = l_{j,t}^{\gamma} k_{j,t}^{1-\gamma}.$$

These firms choose debt and labor demand by solving a dynamic problem that maximizes the present discounted value of dividends paid to households (see Online Appendix C). Capital stocks ($k_{j,t}$) change with investment flows. However, to keep the model tractable, we assume that capital and investment evolve exogenously. The optimal labor demand decision is equivalent to a static choice separate from the borrowing decision. Given $k_{j,t}$, we can think of firms choosing $l_{j,t}$ to maximize profits $p_{j,t}x_{j,t} - w_{j,t}l_{j,t}$, where $p_{j,t}$ is the price of intermediate goods sold to final producers in competitive markets (in units of final goods). The optimal demand for labor is then determined by the first-order condition that equates the marginal revenue product of labor to the wage rate,

$$\gamma p_{j,t} l_{j,t}^{\gamma-1} k_{j,t}^{1-\gamma} = w_{j,t}.$$

Borrowing and default. Since intermediate goods firms are owned by households, they discount future dividends at the households' discount factor, β. Hence, if the risk-free interest rate is lower than the rate of time preference (given by $1/\beta - 1$), intermediate goods firms have an incentive to borrow.[4] As we will see, this condition is usually satisfied

[3] Differences in financial structure could reflect the tangibility of capital. Firms that are intensive in intangible capital do not have enough collateral assets to borrow and, as a result, accumulate financial assets or cash. Falato et al. (2022) show the importance of this mechanism for explaining the rising cash holdings of US corporations during the last four decades. These firms are captured in the model by the final-goods producers. However, the fact that in the model intermediate-goods producers are net borrowers and final-goods producers are net lenders should not be interpreted literally when mapping the model to the data. What really matters is that there is production complementarity between the two groups of firms, so that, when firms in one group cut production due to financial conditions, the other firms also cut their production due to lower demand.

[4] Borrowing at date t increases div_t and, if the interest rate is lower than the rate of time preference, the reduction in div_{t+1} if the debt is repaid is worth less in present value (discounted at β) than the increase in

at equilibrium because the debt issued by intermediate firms provides production services (convenience yield) to final producers. Thus, final-goods firms are willing to hold the debt even if its interest rate is lower than the rate of time preference.

At the end of period $t-1$, intermediate goods firms borrow $d_{j,t}/R_{j,t-1}$, where $R_{j,t-1}$ is the gross interest rate and $d_{j,t}$ is the debt (promised repayment) due at time t. At the beginning of period t, when the debt is due, they could default. Under default, creditors have the right to liquidate the capital $k_{j,t}$. However, the liquidation value of capital could be insufficient to fully repay the debt $d_{j,t}$.

Denote by $\ell_{j,t}$ the liquidation price of capital at the beginning of period t. If the debt exceeds the liquidation value, that is, $d_{j,t} > \ell_t k_{j,t}$, the debt is renegotiated. Under the assumption that borrowers have all the bargaining power, the renegotiated debt is

$$\tilde{d}(d_{j,t}, \ell_{j,t} k_{j,t}) = \min \Big\{ d_{j,t} \ , \ \ell_{j,t} k_{j,t} \Big\}. \tag{2}$$

After renegotiation, the market for capital returns to normal at the end of the period (i.e., there is no market exclusion). Note also that liquidation never happens at equilibrium, it only acts as a threat to renegotiate the debt because neither party gains from liquidation, and so they settle for a lower repayment (for the amount $\ell_t k_{j,t}$) with the capital remaining in place.

A key assumption we make is that there are states of nature in which the market for liquidated capital freezes and the liquidation price at the beginning of the period drops below its normal price of 1. Specifically, with probability $1-\lambda$ the liquidation price remains at its normal price $\ell_{j,t} = 1$. With probability λ, however, it drops to $\ell_{j,t} = \kappa_j$, where $\kappa_j < 1$. As we explain below, κ_j is a key parameter for determining the private supply of financial assets.

Online appendix D describes the mechanism that generates a freeze in the market for liquidated capital as a result of self-fulfilling expectations about the liquidation price. This depends on the borrowers' leverage. In particular, when $d_{j,t} > \kappa_j k_{j,t}$, there are two equilibria. One in which the market does not freeze and the liquidation price is 1, and one in which the market freezes and the liquidation price drops to $\kappa_j < 1$. The selection between the two equilibria is determined by the draw of a sunspot shock $\varepsilon_j \in \{0, 1\}$, and λ then corresponds to the exogenous probability that the draw of the sunspot shock is the one associated with the market freeze.

Readers interested in the micro-foundation of the market freeze can treat the Online Appendix D as an integral part of the current section. Otherwise, the Appendix can be skipped. What is essential for the analysis that follows is that the liquidation price of capital $\ell_{j,t}$ takes the value of 1 with probability $1-\lambda$ and $\kappa_j < 1$ with probability λ. The sunspot variables ε_1 and ε_2 are the only exogenous stochastic variables (shocks) in the model.[5]

div_t, resulting in a higher present value of dividends.

[5]Benhabib et al. (2024) develop an interesting model of self-fulfilling default cycles. The mechanism

We also assume that newly issued debt $d_{j,t+1}$ incurs this convex cost

$$\varphi\left(d_{j,t+1}, \kappa_j k_{j,t+1}\right) = \eta \left[\frac{\max\{\, 0 \;,\; d_{j,t+1} - \kappa_j k_{j,t+1} \,\}}{d_{j,t+1}}\right]^2 d_{j,t+1}. \tag{3}$$

Figure 2 provides a graphical illustration of this cost. As long as the debt repayment promised for the next period, $d_{j,t+1}$, does not exceed the minimum liquidation value, $\kappa_j k_{j,t+1}$, the cost is zero. Beyond that point, the cost rises at an increasing rate.

This debt issuance cost plays a similar role as a borrowing limit ensuring that borrowing is bounded at equilibrium. The parameter η determines, for a given stock of capital, the speed at which the cost rises with debt. Thus, it captures the flexibility with which borrowing responds to changing market conditions (e.g., the interest rate). For very high η we have, effectively, a standard borrowing limit, that is, $d_{j,t+1} \leq \kappa_j k_{j,t+1}$. At lower values of η, however, the model allows for an endogenous response of debt to changes in the interest rate. With a hard borrowing limit, instead, the interest rate would not impact the equilibrium debt (unless the limit also changes).

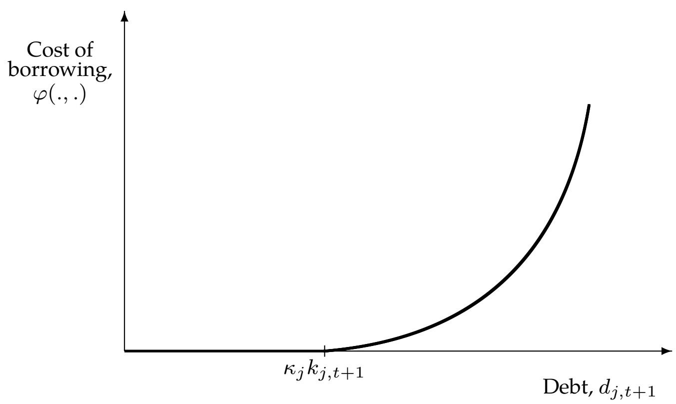

Figure 2: Convex cost of borrowing as a function of debt.

The budget constraint for intermediate-goods firms, after the renegotiation of the debt, is

$$\begin{aligned}\text{div}_{j,t} \;\; &= \;\; p_{j,t} l_{j,t}^{\gamma} k_{j,t}^{1-\gamma} - w_{j,t} l_{j,t} - i_{j,t} - \tilde{d}(d_{j,t}, \ell_{j,t} k_{j,t}) + \frac{d_{j,t+1}}{R_{j,t}} - \\ &\qquad \varphi(d_{j,t+1}, \kappa_j k_{j,t+1}).\end{aligned} \tag{4}$$

where $i_{j,t} = k_{j,t+1} - (1-\tau) k_{j,t}$ is investment and τ the depreciation rate.

The gross interest rate $R_{j,t}$ depends on individual borrowing decisions. If a firm borrows more, relatively to $k_{j,t+1}$, the expected repayment next period falls, and this is reflected in a higher interest rate on the new debt.

generating multiple equilibria in their model relies on the survival of active firms, a number that changes with crises. Our mechanism, instead, relies on the liquidation value of collateral.

Denote by $\overline{R}_{j,t}$ the *expected* gross return from buying a diversified portfolio of debt issued by all intermediate-goods firms in Region j at time t. Since firms are atomistic and financial markets are competitive, the expected return on the debt issued by an individual firm must equal the expected return from the diversified portfolio, that is,

$$\frac{d_{j,t+1}}{R_{j,t}} = \frac{1}{\overline{R}_{j,t}} \mathbb{E}_t \tilde{d}(d_{j,t+1}, \ell_{j,t+1} k_{j,t+1}). \tag{5}$$

The left-hand-side is the amount borrowed in period t while the right-hand-side is the expected repayment in period $t+1$, discounted by the market return $\overline{R}_{j,t}$. Since an intermediate firm renegotiates the debt when $d_{j,t+1} > \ell_{j,t+1} k_{j,t+1}$, the actual repayment $\tilde{d}(d_{j,t+1}, \ell_{j,t+1} k_{j,t+1})$ could be lower than $d_{j,t+1}$. Competition in financial markets requires that the left-hand-side equals the right-hand-side.

Equation (5) determines the interest rate $R_{j,t}$ for an individual borrower. It can also be viewed as determining the spread the borrower pays, $R_{j,t}/\overline{R}_{j,t} = d_{j,t+1}/\mathbb{E}_t \tilde{d}(d_{j,t+1}, \ell_{j,t+1} k_{j,t+1})$. For a firm expected to fully repay with certainty, the spread is zero ($R_{j,t}/\overline{R}_{j,t} = 1$). For a firm that is expected to repay in full only with some probability, $R_{j,t}$ exceeds $\overline{R}_{j,t}$. The higher rate depends on how much the contracted repayment, $d_{j,t+1}$, falls below the expected repayment after renegotiation, that is, $\mathbb{E}_t \tilde{d}(d_{j,t+1}, \ell_{j,t+1} k_{j,t+1})$. At equilibrium, all firms make the same decisions and they all borrow at the same rate. In order to characterize the optimal borrowing, however, we need to allow for individual deviations.

Firms' decisions. Intermediate-goods firms make decisions sequentially. At the beginning of the period they decide whether to default and renegotiate the debt. After that, they choose the input of labor $l_{j,t}$ and produce $x_{j,t}$. Finally, they choose the new debt $d_{j,t+1}$. Since the default and production decisions have already been characterized, we focus here on the optimality condition for the choice of the new debt.

As shown in the Online Appendix C, the first-order condition for $d_{j,t+1}$ is

$$\frac{1}{\overline{R}_{j,t}} = \beta + \Phi\left(\frac{d_{j,t+1}}{\kappa_j k_{j,t+1}}\right). \tag{6}$$

The function $\Phi(\frac{d_{j,t+1}}{\kappa_j k_{j,t+1}})$ is an endogenous object that embeds expectations of future variables (see Online Appendix C for details).[6] The only source of uncertainty in the model is the realization of sunspot shocks. Since future repayments conditional on default and the probability of default are known in advance, we can calculate analytically the

[6]The marginal cost of borrowing moves with $k_{j,t+1}, \ell_{j,t+1}$ because $\Phi(\frac{d_{j,t+1}}{\kappa_j k_{j,t+1}}) = \frac{\partial \varphi(d_{j,t+1}, \kappa_j k_{j,t+1})}{\partial d_{j,t+1}} / \mathbb{E}\left\{\frac{\partial \tilde{d}(d_{j,t+1}, \ell_{j,t+1} k_{j,t+1})}{\partial d_{j,t+1}}\right\}$, which is the ratio of the marginal issuance cost to the expected marginal change in repayment of the new debt. This expression reduces to $\Phi(\frac{d_{j,t+1}}{\kappa_j k_{j,t+1}}) = \left(\frac{1}{1-\lambda}\right)\eta\left[1-\left(\frac{\kappa_j k_{j,t+1}}{d_{j,t+1}}\right)^2\right]$ if $\frac{d_{j,t+1}}{\kappa_j k_{j,t+1}} \geq 1$ and zero otherwise.

expected repayment, which is incorporated into $\Phi(.)$.

$\Phi(.)$ is increasing in the ratio $d_{j,t+1}/\kappa_j k_{j,t+1}$, mirroring the increasing cost of borrowing showed in Figure 2.[7] This ratio is a measure of *effective* leverage: debt over the *lowest* liquidation value of capital. Because $\Phi(.)$ is an increasing function, condition (6) posits a *negative* relationship between the expected cost of the debt (the interest rate) and effective leverage. This relationship is behind the model's prediction that both leverage and financial instability rise if the interest rate falls, which plays a role in our findings showing that higher reserves (public debt) increases (reduces) volatility.

2.2.2 Final goods producers (entrepreneurs)

In each region, there is a unit mass of atomistic entrepreneurs that produce final goods. They maximize logarithmic expected lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \ln(c^e_{j,t}),$$

where $c^e_{j,t}$ denotes the entrepreneur's consumption in Region j at time t. As we will see, the concavity of their utility is helpful because implies that entrepreneurs hold a diversified portfolio of financial assets.

Entrepreneurs are business owners producing homogeneous goods that can be traded internationally. Although they resemble privately-owned firms, we should think of them more broadly and including also some publicly-traded companies. Entrepreneurial consumption, then, can be interpreted as dividend payments and the concave utility could derive from the risk aversion of managers and/or major shareholders. Although not explicitly modeled, the concavity could also reflect, in reduced form, the cost associated with financial distress: even if shareholders and managers are risk-neutral, a convex cost of financial distress would make the objective of the business concave. Since there are no idiosyncratic shocks in the model, we can focus on the representative entrepreneur.

The production function of final-goods producers is linear:

$$y_{j,t} = z_j x_{j,t}, \tag{7}$$

where $y_{j,t}$ is production, z_j is region-specific productivity, and $x_{j,t}$ is the input of intermediate goods purchased from intermediate-goods firms.

Working capital and accumulation of financial resources. Production of final goods also requires financial resources, the need of which increases as more intermediate goods are used to produce. In particular, entrepreneurs accumulate financial wealth $m_{j,t}$ in order

[7]When the cost is zero, i.e., $\eta = 0$, $\Phi(.) = 0$ and the debt issuance decision becomes undetermined.

to satisfy the constraint

$$m_{j,t} \geq \phi_j p_{j,t} x_{j,t}. \tag{8}$$

A narrow interpretation of this constraint is that it represents advanced payment of a fraction ϕ_j of the cost of inputs (working capital). However, we give it a broader interpretation since, in reality, there are other channels through which financial wealth affects production. For example, financial wealth provides insurance against earning risks, increasing the willingness to operate larger firms (Angeletos (2007)). Also, firms with more favorable financial positions may find easier to attract new workers (Monacelli et al. (2023)) or to retain existing workers (Baghai et al. (2021)).

The parameter ϕ_j plays an important role in determining the demand for financial assets, similar to the extra convenience benefits that investors receive in Jiang et al. (2024). The higher the value of ϕ_j, the higher the need for those assets and, hence, the larger the holdings of $m_{j,t}$.

The financial wealth of entrepreneurs is in the form of liabilities issued by intermediate-goods firms (either domestic or foreign) and liabilities issued by the government of advanced economies. Even though we are assuming perfect capital mobility, public and private liabilities have different prices because they have different repayment risks. While private bonds are defaultable, public bonds issued by advanced economies are always repaid in full. We denote by $q_{j,t}$ the price of bonds issued by intermediate-goods firms in Region j, and by $q_{p,t}$ the price of public bonds issued by Region 1 (advanced economies).

Entrepreneurial decisions. The representative entrepreneur in Region j enters period t with bonds issued by firms in Region 1, $b_{1,j,t}$, bonds issued by firms in Region 2, $b_{2,j,t}$, and government bonds issued by advanced economies, $b_{p,j,t}$. The first subscript denotes the issuer (Region 1 or Region 2 for private bonds, and p for public bonds), while the second subscript denotes the residence of the holder. In the event of default, entrepreneurs incur financial losses proportional to their ownership of private bonds (but not public bonds since they are risk-free).

Denote by $\delta_{1,t}$ and $\delta_{2,t}$ the fractions of private bonds repaid, respectively, by Region 1 and Region 2. The post-default values of the two bonds are then $\delta_{1,t} b_{1,j,t}$ and $\delta_{2,t} b_{2,j,t}$. The repayment fractions $\delta_{1,t}$ and $\delta_{2,t}$ are endogenous variables determined in general equilibrium. After observing them at the beginning of the period, the entrepreneur's wealth is

$$m_{j,t} = \delta_{1,t} b_{1,j,t} + \delta_{2,t} b_{2,j,t} + b_{p,j,t}.$$

This is the variable that enters the financial constraint (8).

After production, the end-of-period wealth is

$$a_{j,t} = m_{j,t} + (z_j - p_{j,t}) x_{j,t}.$$

The end-of-period wealth is in part allocated to consumption and in part to new bonds, in accordance to the budget constraint

$$c^e_{j,t} + q_{1,t}b_{1,j,t+1} + q_{2,t}b_{2,j,t+1} + q_{p,t}b_{p,j,t+1} = a_{j,t}. \quad (9)$$

While the production scale depends on $m_{j,t}$ (through constraint (8)), portfolio decisions, $b_{1,j,t+1}$, $b_{2,j,t+1}$ and $b_{p,j,t+1}$, depend on $a_{j,t}$. The following lemma characterizes the production decision.

Lemma 2.1 *If constraint* (8) *binds,* $p_{j,t} < z_j$ *and the demand for intermediate goods chosen by final-goods producers is*

$$x_{j,t} = \left(\frac{1}{\phi_j p_{j,t}}\right) m_{j,t}.$$

If (8) *does not bind,* $p_{j,t} = z_j$ *and the demand for intermediate goods is determined by the supply from intermediate-goods firms.*

Proof 2.1 *Online Appendix A.*

When the marginal productivity of the intermediate goods exceeds their cost, that is, $z_j > p_{j,t}$, the firm makes a profit on each unit of final output (see Online Appendix A). It is then optimal for the entrepreneur to expand the scale of production until the financial constraint binds, that is, $m_{j,t} = \phi_j p_{j,t} x_{j,t}$. Solving the binding constraint for $x_{j,t}$ returns the expression reported in Lemma 2.1.

For the financial constraint not to be binding, profits must be zero, that is, $z_j = p_{j,t}$. In this case, the financial wealth $m_{j,t}$ and the financial parameter ϕ_j are irrelevant for the final production chosen by an individual firm. Only the aggregate production is determined in equilibrium (by the supply of intermediate-goods firms).

Under what conditions is constraint (8) binding? In general, it binds when entrepreneurs have low financial wealth ($m_{j,t}$ is small), a larger share of input costs needs to be covered with financial assets (ϕ_j is high), or entrepreneurial firms are more productive (z_j is high). As shown in the Online Appendix 2.1, when this constraint binds, entrepreneurs earn positive profits that are proportional to $m_{j,t}$. This implies that bond holdings have a convenience yield—the profits—over and above the contracted market yield. Note also that when the constraint binds, larger holdings of financial assets improve efficiency by supporting higher demand for inputs.

The next step is to characterize the entrepreneurs' optimal saving and portfolio choices made at the end of the period.

Lemma 2.2 *The entrepreneur allocates the end-of-period wealth $a_{j,t}$ as follows:*

$$\begin{aligned} c^e_{j,t} &= (1-\beta)a_{j,t}, \\ q_{1,t}b_{1,j,t+1} &= \beta\theta_{1,t}a_{j,t}, \\ q_{2,t}b_{2,j,t+1} &= \beta\theta_{2,t}a_{j,t}, \\ q_{p,t}b_{p,j,t+1} &= \beta(1-\theta_{1,t}-\theta_{2,t})a_{j,t}, \end{aligned}$$

where $\theta_{1,t}$ and $\theta_{2,t}$ solve the first-order conditions

$$\begin{aligned} \mathbb{E}_t\left\{\frac{\frac{\delta_{1,t+1}}{q_{1,t}}}{\theta_{1,t}\frac{\delta_{1,t+1}}{q_{1,t}}+\theta_{2,t}\frac{\delta_{2,t+1}}{q_{2,t}}+(1-\theta_{1,t}-\theta_{2,t})\frac{1}{q_{p,t}}}\right\} &= 1, \\ \mathbb{E}_t\left\{\frac{\frac{\delta_{2,t+1}}{q_{2,t}}}{\theta_{1,t}\frac{\delta_{1,t+1}}{q_{1,t}}+\theta_{2,t}\frac{\delta_{2,t+1}}{q_{2,t}}+(1-\theta_{1,t}-\theta_{2,t})\frac{1}{q_{p,t}}}\right\} &= 1. \end{aligned}$$

Proof 2.2 *Online Appendix B.*

Lemma 2.2 establishes that entrepreneurs split the end-of-period wealth between consumption and saving according to the factor β. This derives from the logarithmic specification of the utility function. A fraction $\theta_{1,t}$ of saved wealth, $\beta a_{j,t}$, is then allocated to private bonds issued by Region 1, a fraction $\theta_{2,t}$ to private bonds issued by Region 2, and the remaining fraction $1-\theta_{1,t}-\theta_{2,t}$ to public bonds issued by Region 1 (advanced economies). As stated earlier, the three bonds are not perfect substitutes because they face different probabilities of default. Thus, there is a gain from diversification that explains why the optimal portfolio shares are well defined.

The portfolio shares $\theta_{1,t}$ and $\theta_{2,t}$ change over time as recovery rates and bond prices vary. However, they are the same for entrepreneurs in Region 1 and Region 2. This is indicated by the fact that $\theta_{1,t}$ and $\theta_{2,t}$ do not have the region subscript j. Thus, entrepreneurs in both regions choose the same portfolio composition.[8] This is the case because the three types of bonds are freely traded internationally and default by a country's borrowers reduces equally the repayment to foreign and domestic holders of that debt.

The equilibrium portfolio structure—represented by $\theta_{1,t}$ and $\theta_{2,t}$—plays two key roles. First, the shares of wealth allocated to private bonds of the two regions, $\theta_{1,t}$ and $\theta_{2,t}$, affect the cross-regional spillover of financial crises. If entrepreneurs hold only domestic private bonds, there is no spillover. Second, the share of wealth allocated to public bonds, $1-\theta_{1,t}-\theta_{2,t}$, affects the macroeconomic impact of a financial crisis, which is then transmitted across regions if there is cross-regional ownership of private bonds. If entrepreneurs hold only public debt issued by AEs ($\theta_{1,t}=\theta_{2,t}=0$), there are no crises, since there is no private debt and the AEs public debt is risk free. As we will see, changes in the equilibrium portfolio

[8] It is important to emphasize that, because $\theta_{1,t}$ and $\theta_{2,t}$ do not have the j subscript, the last three conditions in Lemma 2.2 are not just accounting identities.

structure induced by the growth in EMEs reserves and AEs public debt are an important determinant of the resulting effects on financial and macroeonomic volatility.

2.3 Public sector

The government of Region 1 issues risk-free bonds (public debt), and the governments of both regions hold some of these bonds as FX reserves. Governments also pay lump-sum transfers to (or raise taxes from) households in order to balance their budgets.

The reason we focus on public debt issued by advanced economies is in part related to data limitations for emerging economies. More importantly, however, our choice is motivated by two key differences between the public debt issued by the two regions. First, sovereign default in advanced economies is rare and public bonds issued by countries like Germany, Japan, the United Kingdom, and the United States are considered to be risk-free. This makes the public debt of these countries very different from their private debt, which is not risk-free. Because of their negligible repayment risk, these government bonds are important for liquidity and accumulation of FX reserves. U.S. public debt, in particular, represents roughly 60% of the assets held as FX reserves worldwide (see Ito and McCauley (2020)). Also, because the public debt of advanced economies is large relatively to the size of the world economy, it could have important general equilibrium implications.

The second key difference between the public debt of EMEs and AEs is that the EMEs public debt is not risk-free and sovereign default arises often in conjunction with private default.[9] Hence, from the perspective of the entrepreneurs' portfolio choice, there may be less significant differences between private and public debt issued by emerging economies. Total public debt issued by emerging economies is also much smaller than that of advanced economies, so its global equilibrium effects are less relevant.

The budget constraint of the government of Region 1 (AEs) is

$$FX_{1,t} + q_{p,t}D_{p,t+1} = q_{p,t}FX_{1,t+1} + D_{p,t} + T_{1,t}. \tag{10}$$

The left-hand-side includes the sources of funds, and contains two terms. The first is the stock of FX reserves accumulated in the previous period, $FX_{1,t}$. The second is the funds raised with the issuance of new debt $D_{p,t+1}$ sold at price $q_{p,t}$. The right-hand-side contains the uses of funds. The first term is the purchase of new reserves. The second is the repayment of the public debt issued in the previous period. The third is the transfer $T_{1,t}$ to domestic households (or taxes if negative). Notice that reserves are only in the form of public bonds issued by Region 1. Therefore, what matters for the government of Region 1 is the net debt, that is, $D_{p,t} - FX_{1,t}$.[10]

[9] Weaker repayment commitment capacity by EMEs governments can lead to self-fulfilling crises also on public debt, as in Aguiar et al. (2022).

[10] Technically, the reserves of Region 1 are foreign assets, not the repurchase of its own public debt. However, since Region 1 is the aggregation of all advanced economies, it is not possible to clearly distinguish $D_{p,t}$ from $FX_{1,t}$. In reality, the reserves held by some advanced economies (for example European countries)

The budget constraint for the government of Region 2 (EMEs) is

$$FX_{2,t} = q_{p,t}FX_{2,t+1} + T_{2,t}. \quad (11)$$

$D_{p,t}$, $FX_{1,t}$ and $FX_{2,t}$ are time varying but exogenous. In the quantitative analysis, they are set match actual data. $T_{1,t}$ and $T_{2,t}$ take the values needed to balance the government budget constraints.

2.4 General equilibrium

Using capital letters to denote aggregate variables, the aggregate states include the bonds held by entrepreneurs, $B_{1,1,t}$, $B_{2,1,t}$, $B_{p,1,t}$, $B_{1,2,t}$, $B_{2,2,t}$, $B_{p,2,t}$, and the sunspot shocks $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$. Knowing these variables, we can determine the aggregate debt issued by intermediate-goods firms in the previous period as $D_{1,t} = B_{11,t} + B_{12,t}$ and $D_{2,t} = B_{21,t} + B_{22,t}$.

The sequences of public debt and reserves—$D_{p,t}$, $FX_{1,t}$ and $FX_{2,t}$— and capital stocks—$K_{1,t}$ and $K_{2,t}$—are also relevant for the equilibrium. Since these variables are exogenous and perfectly anticipated, their full sequence going into the infinite future is part of the state space. We denote the sequence of a variable from date t to infinity with subscript t and superscript ∞. For example, $K_{j,t}^{\infty}$ represents the sequence of capital in Region j from time t to ∞. To use a compact notation, we denote the state vector as

$$\begin{aligned}\mathbf{s}_t \equiv \; & (D_{p,t}^{\infty}, FX_{1,t}^{\infty}, FX_{2,t}^{\infty}, K_{1,t}^{\infty}, K_{2,t}^{\infty}, \\ & B_{1,1,t}, B_{2,1,t}, B_{p,1,t}, B_{1,2,t}, B_{2,2,t}, B_{p,2,t}, \varepsilon_{1,t}, \varepsilon_{2,t}).\end{aligned}$$

Figure 3 sketches the steps to define an equilibrium by breaking down each period into three sub-periods.

1. **Subperiod 1**: Given the realization of the sunspot shocks $\varepsilon_{j,t}$, intermediate-goods firms choose the fraction of debt to repay

   $$\delta_{j,t} = \begin{cases} \frac{\kappa_j K_{j,t}}{D_{j,t}}, & \text{if} \quad D_{j,t} \geq \kappa_j K_{j,t} \text{ and } \varepsilon_{j,t} = 0 \\ 1, & \text{otherwise} \end{cases}.$$

   A financial crisis, which arises when $\delta_{j,t} < 1$, has a fundamental cause—the level of debt or leverage—and a self-fulfilling cause driven by sunspot shocks.

   Figure 4 plots the probability of a crisis as a function of the debt, $D_{j,t}$. Given the aggregate stock of capital $K_{j,t}$, the probability is zero when the debt $D_{j,t}$ is below the threshold $\kappa_j K_{j,t}$. Above this threshold, the crisis probability becomes λ, which

could be in bonds issued by other advanced economies (for example, the US). Once we aggregate all advanced economies, without netting out the reserves from the public debt, it looks like advanced economies issue public bonds and then repurchase the same bonds as FX reserves.

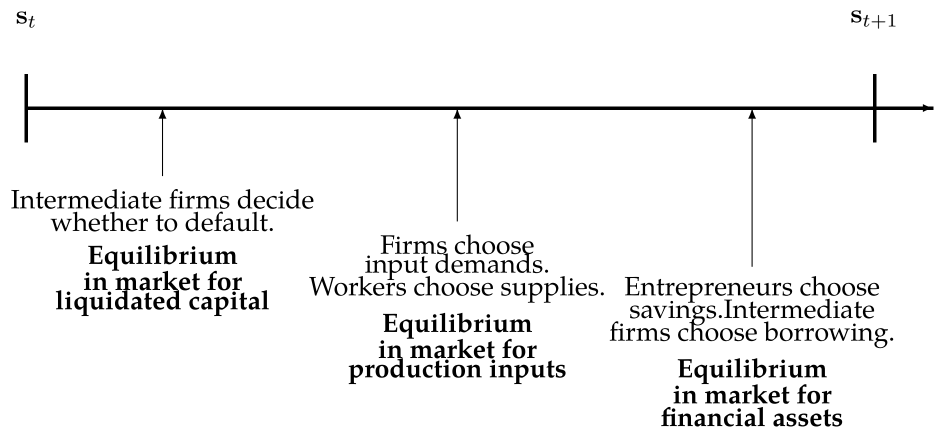

Figure 3: Timing within period t.

corresponds to the probability of drawing the sunspot shock $\varepsilon_{j,t} = 0$. For values of $D_{j,t}$ greater than $K_{j,t}$ the crisis probability becomes 1 because the liquidation value of capital is always smaller than the debt. This shows that a financial crisis is not just the result of a negative sunspot shock but also the consequence of high leverage (the fundamental cause).

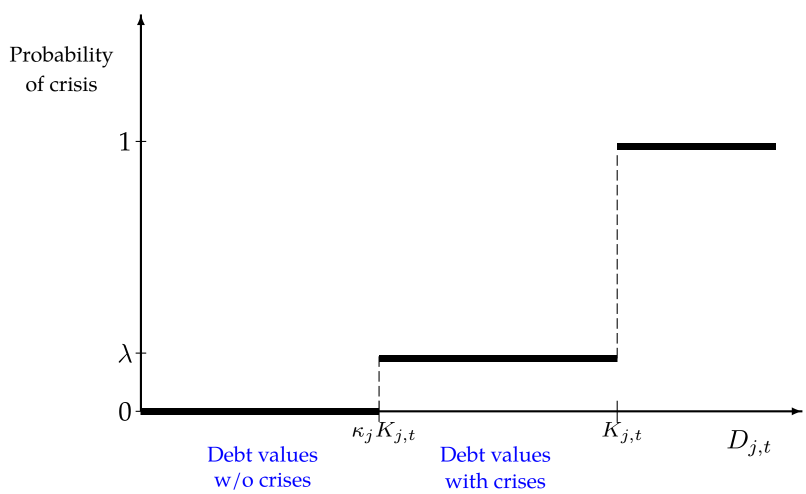

Figure 4: Probability of crisis: debt values with and without crises.

After the default decision, the aggregate wealth of entrepreneurs is

$$M_{j,t} = \delta_{1,t} B_{1j,t} + \delta_{2,t} B_{2j,t} + B_{p,j,t}.$$

2. **Subperiod 2**: Intermediate-goods firms choose labor demand, entrepreneurs choose their demand for intermediate goods, and households choose the supply of labor.

The demand for labor is

$$L_{j,t} = \left(\frac{\gamma p_{j,t}}{w_{j,t}}\right)^{\frac{1}{1-\gamma}} K_{j,t}. \tag{12}$$

Lemma 2.1 established that the demand for intermediate goods depends on whether constraint (8) is binding or nonbinding. When binding, the aggregate demand for intermediate goods is

$$X_{j,t} = \left(\frac{1}{\phi_j p_{j,t}}\right) M_{j,t}.$$

If constraint (8) is not binding, the demand is determined by the supply chosen by intermediate producers, that is,

$$X_{j,t} = L_{j,t}^{\gamma} K_{j,t}^{1-\gamma}.$$

The aggregate supply of labor is derived from the household's firs-order condition (1), which we can re-arrange as

$$H_{j,t} = \left(\frac{w_{j,t}}{\mu_j}\right)^{\nu}. \tag{13}$$

The stock of capital evolves exogenously. Market-clearing in the labor market and in the intermediate-goods market determine the wage rate $w_{j,t}$ and the price of intermediate goods $p_{j,t}$, respectively.

3. **Subperiod 3**: The end-of-period wealth of entrepreneurs is

$$A_{j,t} = M_{j,t} + z_j X_{j,t} - p_{j,t} X_{j,t}.$$

According to Lemma 2.2, a fraction $1-\beta$ is consumed while the remaining fraction β is saved in new bonds: A fraction $\theta_{1,t}$ in private bonds issued by Region 1, a fraction $\theta_{2,t}$ in private bonds issued by Region 2, and the remaining fraction $1-\theta_{1,t}-\theta_{2,t}$ in public bonds issued by the government of Region 1. Intermediate firms choose the new debt $D_{j,t+1}$.

Market-clearing in the three financial markets requires

$$B_{1,1,t+1} + B_{1,2,t+1} = D_{1,t+1}, \tag{14}$$

$$B_{2,1,t+1} + B_{2,2,t+1} = D_{2,t+1}, \tag{15}$$

$$B_{p,1,t+1} + B_{p,2,t+1} + FX_{1,t+1} + FX_{2,t+1} = D_{p,t+1}. \tag{16}$$

Because of capital mobility and cross-region heterogeneity, the net foreign asset positions could be different from zero. Formally, in Region 1 we could have $B_{1,1,t+1} + B_{2,1,t+1} + B_{p,1,t+1} + FX_{1,t+1} - D_{1,t+1} - D_{p,t+1} \neq 0$, and in Region 2 we could have

$B_{1,2,t+1} + B_{2,2,t+1} + B_{p,2,t+1} + FX_{2,t+1} - D_{2,t+1} \neq 0$.

Competition in financial markets implies that the price of private debt is consistent with the interest rate, that is,

$$q_{j,t} = \frac{\mathbb{E}_{t+1}\delta_{j,t+1}}{\overline{R}_{j,t}}. \tag{17}$$

This relates the price of private bonds $q_{j,t}$ to their expected return. A similar condition applies to public bonds, that is, $q_{p,t} = \frac{1}{\overline{R}_{j,t}}$.

The supply of private bonds follows from the Euler equation governing the borrowing decisions of intermediate-goods firms (eq. (6)),

$$\frac{1}{\overline{R}_{j,t}} = \beta + \Phi\left(\frac{D_{j,t+1}}{\kappa_j K_{j,t+1}}\right).$$

Using equation (17), we can rewrite this condition as

$$q_{j,t} = \left[\beta + \Phi\left(\frac{D_{j,t+1}}{\kappa_j K_{j,t+1}}\right)\right]\mathbb{E}\delta_{j,t+1}. \tag{18}$$

Since intermediate-goods firms may default, the economy displays stochastic dynamics driven by the sunspot shocks. The sunspot shocks can take two values: $\varepsilon_{j,t} = 0$ (with *possible* market freeze in the market for liquidated capital) and $\varepsilon_{j,t} = 1$ (no market freeze). A market freeze occurs when $\varepsilon_{j,t} = 0$ *and* the leverage of the region is sufficiently high. This in turn leads to a financial crisis in which bonds are only partially repaid. The crisis redistributes wealth from lenders (final-goods firms) to borrowers (intermediate-goods firms). The decline in entrepreneurs' wealth $M_{j,t}$, then, reduces the demand for intermediate goods which in turn lowers its price $p_{j,t}$. Intermediate-goods firms respond to the price drop by reducing their demand for labor and, at equilibrium, there is lower employment and production. This is the mechanism through which financial crises have real macroeconomic consequences.

2.5 Sequential property of the equilibrium

The particular structure of the model allows us to solve for the equilibrium at time t independently of future equilibria as if the model were static. More precisely, given the states s_t, we can find the values of all equilibrium variables at time t by solving the system of nonlinear equations listed in the Online Appendix E. This allows us to solve the model sequentially. For example, in the quantitative application, we will solve for the sequence of equilibria from $t = 1991$ to $t = 2020$. To do so we first solve for the equilibrium at $t = 1991$, then at $t = 1992$, and continue until $t = 2020$. This property would not hold if investment were endogenous and/or households were risk-averse. Thus, these two simplifying assumptions are key for making the analytic characterization of the model possible.

The sequential property of the equilibrium allows us to reduce the sufficient set of state variables. In general, the equilibrium depends on the full time-varying sequences $D_{p,t}^{\infty}, FX_{1,t}^{\infty}, FX_{2,t}^{\infty}, K_{1,t}^{\infty}, K_{2,t}^{\infty}$, as we explained earlier. Thanks to the sequential property, however, the date-t equilibrium depends only on $FX_{j,t+1}$, $D_{p,t+1}$, $K_{j,t}$ and $K_{j,t+1}$. Hence, we redefine the sufficient set of state variables as

$$\begin{aligned}\mathbf{s}_t \quad \equiv \quad & \big(FX_{1,t+1}, FX_{2,t+1}, D_{p,t+1}, K_{1,t}, K_{2,t}, K_{1,t+1}, K_{2,t+1}, \\ & \qquad B_{1,1,t}, B_{2,1,t}, B_{p,1,t}, B_{1,2,t}, B_{2,2,t}, B_{p,2,t}, \varepsilon_{1,t}, \varepsilon_{2,t}\big).\end{aligned}$$

2.6 Anatomy of a crisis

Using the model's tractable structure, we can provide an analytic characterization of how a crisis impacts the economy. Substituting the demand and supply of labor (equations (12) and (13)) in the market-clearing condition for the labor market ($L_{j,t} = H_{j,t}$), we derive the wage rate and employment,

$$\begin{aligned} w_{j,t} &= \mu_j^{\frac{\nu(1-\gamma)}{1+\nu(1-\gamma)}} \left(\gamma p_{j,t} K_{j,t}^{1-\gamma}\right)^{\frac{1}{1+\nu(1-\gamma)}} \\ L_{j,t} &= \left(\frac{\gamma p_{j,t} K_{j,t}^{1-\gamma}}{\mu_j}\right)^{\frac{\nu}{1+\nu(1-\gamma)}} \end{aligned}$$

Both variables depend positively on the price of intermediate goods $p_{j,t}$: if the price rises, intermediate firms hire more labor which in turn leads to a higher wage rate.

Using the above equations to eliminate $L_{j,t}$ in the intermediate-goods production (where $X_{j,t} = L_{j,t}^{\gamma} K_{j,t}^{1-\gamma}$), and using the resulting expression in the production function for final-goods ($Y_{j,t} = z_j X_{j,t}$), we can write final-goods output in Region j as

$$Y_{j,t} = z_j \left(\frac{\gamma p_{j,t}}{\mu_j}\right)^{\frac{\nu\gamma}{1+\nu(1-\gamma)}} K_{j,t}^{\frac{1+\nu(1-\gamma)-\gamma}{1+\nu(1-\gamma)}}. \tag{19}$$

Given $K_{j,t}$, final-goods output depends positively on the intermediate-goods price $p_{j,t}$. This dependence on the price has the same intuition outlined above for employment: a higher $p_{j,t}$ increases the production of intermediate goods and, therefore, final production.

The dependence of final output on the price of intermediate goods is the key for understanding the effects of the model's financial frictions on the real economy. Recall that final-goods firms choose $x_{j,t}$ to maximize profits $\pi_{j,t} = z_j x_{j,t} - p_{j,t} x_{j,t}$, subject to the constraint $m_{j,t} \geq \phi_j p_{j,t} x_{j,t}$. The Online Appendix C shows that the demand for intermediate goods can be written as:

$$z_j = (1 + \hat{\xi}_{j,t}\phi_j) p_{j,t},$$

where $\hat{\xi}_{j,t}$ is the Lagrange multiplier associated with the working capital constraint, expressed in units of final goods. This condition shows that, given current productivity z_j, the price of intermediate goods is inversely related to the tightness of the constraint, the multiplier $\hat{\xi}_{j,t}$. Moreover, since profits of final-goods producers can be expressed as $\pi_{j,t} = \hat{\xi}_{j,t} m_{j,t}$, they are *positively* related to the tightness of the constraint, and thus negatively related to $p_{j,t}$.

Intuitively, low intermediate-goods prices, relatively to z_j, increase profits. Higher profits increase the incentive of final-goods firms to expand production by increasing demand for $x_{j,t}$. However, their demand for $x_{j,t}$ is limited by the working capital constraint $m_{j,t} \geq \phi_j p_{j,t} x_{j,t}$. Provided that profits are positive, entrepreneurs expand production until the working capital constraint binds. Then, relaxing the working capital constraint faced by an individual entrepreneur with an increase in financial wealth allows more profits. The increase in profits allowed by the increase in wealth is bigger when the price $p_{j,t}$ is low. Thus, relaxing the working capital constraint when $p_{j,t}$ is low has a higher value for the entrepreneur. This is captured by a higher value of the multiplier $\hat{\xi}_{j,t}$.

Consider now what happens at equilibrium when the wealth of all entrepreneurs, denoted by $M_{j,t}$, declines as a result of default. The working capital constraint implies that the demand for intermediate goods falls, which in turn reduces $p_{j,t}$. This, of course, makes the entrepreneurs' wealth even more valuable, which is captured by a higher value of $\hat{\xi}_{j,t}$. But the lower $p_{j,t}$ also means that aggregate production drops as we can see from equation (19). Notice that default, by itself, does not have any direct macroeconomic effect. It only redistributes wealth from final producers to intermediate producers (and, ultimately, households who are the owners of intermediate firms). It is the destruction of entrepreneurial wealth associated with this redistribution that causes the output drop.

It is important to note that, even if default generates financial gains for borrowers (since part of their debt is not repaid), they still experience larger revenue losses than final producers. More precisely, the revenue from sales of intermediate goods producers is $p_t X_t$ and that of final-goods producers is $z_t X_t$. A financial crises causes a drop in both p_t and X_t. Thus, the sales of intermediate-goods producers decline because both X_t and p_t drop, while the sales of final-goods producers are only affected by X_t. This property, which derives from the production complementarity of intermediate and final producers, is consistent with empirical studies showing that more leveraged firms display higher sensitive to financial shocks.

To summarize, a financial crisis is associated with a macroeconomic downturn and a tighter financial condition captured by the multiplier $\hat{\xi}_{j,t}$. This multiplier is the analog of the interest rate spread that plays an important role in models used to study business cycles in emerging markets, for example Neumeyer and Perri (2005) and Uribe and Yue (2006). In these models, a higher spread increases factor costs and causes a recession because of the need to finance working capital. Similarly, here, a higher $\hat{\xi}_{j,t}$ increases the factor costs and causes a macroeconomic contraction.[11]

[11] The analogy would be even clearer if instead of imposing a strict working capital constraint, we allow entrepreneurs to relax the working capital constraint by borrowing at a cost that increases with the size of the loan. Then, when the entrepreneur's wealth drops, he/she borrows more, increasing the interest rate spread endogenously.

2.7 Additional remarks

Another property of the equilibrium worth noting is that the risk-free interest rate is on average lower than the rate of time preference (or, equivalently, the price of a risk-free bond exceeds the subjective discount factor β). In models with precautionary savings, this property derives from the self-insurance incentive. In contrast, in our model it derives from the willingness of entrepreneurs to hold private and public debt because of its inside money-convenience yield property: it is a financial asset that facilitates production. When constraint (8) binds, entrepreneurs receive a benefit from holding bonds in addition to the market yield.[12] This becomes evident by noting that, with a binding working capital constraint, entrepreneurs's profits are positive and given by $\pi_{j,t} = \hat{\xi}_{j,t} m_{j,t}$. Thus, the tightness of the constraint—captured by $\hat{\xi}$—measures the convenience yield on $m_{j,t}$.

The equilibrium property by which final-goods firms are net savers and intermediate-goods firms are borrowers is important for the macroeconomic consequences of a financial crisis. Because final-goods producers have a positive financial position, a crisis redistributes wealth away from them and toward intermediate-goods producers. The drop in entrepreneurial net worth causes a decline in the demand for $x_{j,t}$ which, in turn, reduces labor demand and generates a macroeconomic contraction. If final-goods producers were net borrowers, the lower debt repayments associated with a financial crisis would increase the net worth of these firms and would have the opposite macroeconomic consequence.[13]

Having some producers with a positive financial position is consistent with recent changes in the financial structure of US corporations showing higher holdings of financial assets. As a result, the proportion of financially dependent firms has declined over time as documented in Shourideh and Zetlin-Jones (2017) and Eisfeldt and Muir (2016).

The large accumulation of financial assets by producers—often referred to 'cash'—is related to the significance of business savings. Although the rising savings of US corporations has attracted considerable attention in the literature (see, for example, Riddick and Whited (2009) and Begenau and Palazzo (2021)), this is not just a US phenomenon. Busso et al. (2016) document the share of savings done by firms both in advanced and emerging economies and present evidence that in Latin America this share is even larger than in advanced economies. The importance of business savings is also documented in Bebczuk and Cavallo (2016). This study uses data for 47 countries over 1995–2013 and shows that the contribution of businesses to national savings is more than 50%.

The increase in corporate cash suggests that more and more firms borrow less than what could be available to them. Our entrepreneurial sector captures the growing importance of these firms. It also captures the significant heterogeneity among corporate firms

[12] Borrowers also trade at an interest rate such that $\beta\overline{R}_{j,t} < 1$ (see equation (6)).

[13] It is possible to rewrite the model so that intermediate-goods firms are net lenders and final-goods firms are net borrowers. What matters, however, is that (i) a crisis redistributes wealth from units that have a higher marginal value of wealth to those with a lower marginal value of wealth, and (ii) the productions of the two units are complementary. If the productions of the two units were substitutable, the contraction of adversely affected firms could be offset by the expansion of firms that were positively affected.

as many of them are net borrowers and have become more leveraged over time. Most likely, those are firms that own substantial tangible assets. In our model, they are represented by intermediate-goods producers while corporations that own large amounts of cash are represented by final-goods producers.[14]

3 Quantitative analysis

In this section, we assess quantitatively how the *observed* accumulation of FX reserves and issuance of public debt affected credit-market conditions and impacted financial and macroeconomic volatility. We start with a calibration of the model that targets key moments from the year 1991.

In this quantitative application, the model is viewed as a detrended version of the world economy. We assume exogenous long-run balanced growth driven by standard labor-augmenting technological change. Productivity grows at the common rate g in both regions, and the implied long-run balanced-growth rate of macro variables, except labor, is $\bar{g} = (1+g)^{1/\gamma} - 1$.[15] Consistently, empirical variables that display secular growth are detrended by their long-run growth rate, which we proxy with the average growth rate of GDP in advanced economies over the period 1991-2020.

Once the model is calibrated, we simulate it over the period 1991-2020 under two scenarios (keeping all structural parameters, productivity and capital unchanged):

> **Scenario I:** Detrended FX reserves and public debt are kept constant (i.e., their ratios relative to GDP remain at their 1991 values).[16]
>
> **Scenario II:** Detrended FX reserves *and/or* public debt take the values observed in the data in each year over the period 1991-2020.

The comparison of these two scenarios addresses an important and well-defined question: how were the macroeconomic dynamics of advanced and emerging economies affected by the observed increase in FX reserves and public debt?

Of course, during this period, both advanced and emerging economies experienced many structural changes that contributed, in different ways, to the observed dynamics of the two regions. Thus, we do not expect the model to replicate the exact dynamics observed in the data when we only allow FX reserves and public debt to change. The exercise, however, aims to quantify the *contributions* of reserves and public debt to some of the changes observed in the world economy during this period and to changes in the model's predicted financial and macroeconomic volatility.

[14] See Kalemli-Ozcan et al. (2012) for stylized facts of bank and firm leverage in international micro data.

[15] The model's variables are detrended in standard fashion. We define $G_t \equiv (1+\bar{g})^t$, and then construct date-t measures of detrended output, capital and financial variables (including reserves and public debt) by dividing by G_t. In addition, we set $\mu_j = z_j^{1/\gamma}$.

[16] The model displays stochastic fluctuations driven by the sunspot shocks around an exogenous balanced-growth path, hence these GDP ratios represent detrended reserves and public debt, respectively.

3.1 Calibration of structural parameters

The model is calibrated at an annual frequency and the discount factor is set to $\beta = 0.93$, implying an annual intertemporal discount rate of about 7%. We set the elasticity of labor supply to $\nu = 1$, the labor share parameter in production to $\gamma = 0.6$, and the depreciation rate to $\tau = 0.08$.

The probability that the liquidation price of capital drops to κ_j (i.e., the probability of a realization of the sunspot shock $\varepsilon_j = 0$) is $\lambda = 0.04$. This is in the range of empirical measures of crisis probabilities in the literature (e.g., Bianchi and Mendoza (2018)). It implies that crises are low probability events, every 25 years on average. Since sunspot shocks are region-specific and independent across regions, a *global* financial crisis is even rarer, with a probability of $0.04 \times 0.04 = 0.0016$. Still, a financial crisis that originates in one region affects the other region through the international diversification of portfolios.

The parameter η determines the sensitivity of the borrowing cost to private debt issuance. Since we have limited information to pin down this parameter, we set it to $\eta = 0.1$ and then provide a sensitivity analysis to gauge its relevance in the Online Appendix F.

The stock of capital K_j in each region is set to its 1991 value. To construct capital stock measures, we use the perpetual inventories method.[17]

The parameter values that remain to be set are z_j, ϕ_j, κ_j, and, for Scenario I, the 1991 values of reserves and public debt, FX_j, and D_p. Thus, we need to set the values of nine items (six structural parameters and three government variables). We chose their values so that the baseline model replicates nine empirical moments observed in 1991, as described below.

It is important to note that even if FX reserves and public debt remain constant, the model does not converge to a deterministic steady state because of the sunspot shocks. This also implies that the moments generated by the model are stochastic. Hence, we use the *averages* generated by the model to target the nine empirical targets. We compute the model's averages by repeating the stochastic simulation of the model 10,000 times. Each simulation is for 130 years and the simulated data are the response to randomly drawn sunspot shocks. The first 100 years are needed to eliminate the impact of initial states, and the remaining 30 years represent the 1991-2020 period. This is the period in which we evaluate the impact of reserves and public debt. The simulation is repeated 10,000 times in order to generate an approximation to the invariant distribution.[18]

[17] We apply the perpetual inventories method using an iterative procedure with data going back to 1980. We have data on investment, $I_{j,t}$, and depreciation, $DEP_{j,t}$, from the *World Development Indicators*. We start the iterations in 1980 with the guess of the initial value of capital, $K_{j,1980}$. We then compute $K_{j,1981} = K_{j,1980} - DEP_{j,1980} + I_{j,1980}$. Given the calculated value of $K_{j,1981}$, we move to the second stage and compute $K_{j,1982} = K_{j,1981} - DEP_{j,1981} + I_{j,1981}$. We continue until 2020. At this point we check whether the capital-GDP ratio displays no trend over the whole iteration period 1980-2020. If it does, we change the initial guess for $K_{j,1980}$ and repeat the iteration. The capital stocks in the calibrated model are set to the 1991 values obtain from this procedure.

[18] The moments generated by the model that are matched to the empirical targets are the averages of the 10,000 cross-sectional realizations from the repeated simulations in period 101, which correspond to 1991.

Table 1 lists the nine empirical moments for the year 1991 of the variables targeted in the calibration and their corresponding data sources. The target moments are the 1991 values of GDP, credit to the private sector, and foreign reserves in AEs and EMEs, the net foreign asset position and public debt of AEs, and the world real interest rate. The data come from different sources: the World Bank's *World Development Indicators*, the International Monetary Fund's *Global Debt Database*, the *External Wealth of Nations* database from Lane and Milesi-Ferretti (2018), and the FRED database from St. Louis Fed. Aggregate variables for each region (AEs and EMEs) are constructed by aggregating individual country variables. To construct aggregate GDP and other variables for advanced economies, we sum the values of the specific variable for all countries included in AEs. We do the same to compute aggregate EMEs variables. The countries included in AEs and EMEs are listed at the bottom of Table 1.

Table 1: Calibration Targets.

Moment	*Value in 1991* (*Trillions USD at 2015 prices*)	*Source*
Aggregate GDP AEs	26.03	*World Development Indicators*
Aggregate GDP EMEs	7.74	*World Development Indicators*
Private domestic credit AEs	28.51	*World Development Indicators*
Private domestic credit EMEs	3.62	*World Development Indicators*
Net foreign asset position AEs	-0.72	*Wealth of Nations*
FX reserves AEs	0.79	*Wealth of Nations*
FX reserves EMEs	0.58	*Wealth of Nations*
Public debt AEs	11.97	*Global Debt Database*
World interest rate	3.93%	*FRED*

Advanced economies: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States. **Emerging economies**: Algeria, Argentina, Brazil, Bulgaria, Chile, China, Czech Republic, Colombia, Estonia, Hong Kong, Hungary, India, Indonesia, Israel, South Korea, Latvia, Lithuania, Malaysia, Mexico, Pakistan, Peru, Philippines, Poland, Romania, Russia, Saudi Arabia, Singapore, South Africa, Thailand, Turkey, Ukraine, Venezuela. Data on public debt is from IMF Global Debt Database. We use the series Central Government Debt which is available for thirteen countries: Canada, Finland, France, Germany, Italy, Japan, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States. The Global Debt Database provides two series: 'Central Government Debt' and 'General Government Debt'. We use the former. Data for all years 1991-2020 are available only for thirteen of the advanced economies (listed above). Hence, our measure of public debt issued by AEs is derived from data on debt-to-GDP ratio for of these thirteen countries.

Although the values of the six parameters and the three government variables all contribute, interdependently, to determine the model averages for the nine targeted moments, some parameters have a more direct impact than others on a specific moment. Productivity z_j is important for determining aggregate output (the first two moments in Table 1). The value of z_j is determined by inverting the aggregate production function evaluated at the calibration year 1991, after consolidating the intermediate and final sectors. Since intermediate-goods production is $X_{j,1991} = L_{j,1991}^{\gamma} K_{j,1991}^{1-\gamma}$, replacing X_{1991} in the final-goods production yields

$$Y_{j,1991} = z_j L_{j,1991}^{\gamma} K_{j,1991}^{1-\gamma}.$$

Hence, we can compute z_j using a procedure analogous to that used to construct Solow residuals. This requires measures of production inputs and outputs for 1991. For output, we use GDP at nominal exchange rates, not PPP. Since nominal exchange rates affect the purchasing power of a country in the acquisition of foreign assets, our productivity measure should also reflect the exchange rates. Another factor that contributes to generate differences in aggregate GDP is the size of population. Since population is not explicitly modeled, productivity will also capture population differences.

Denote by $P_{j,1991}$ the nominal price index for country j expressed in US dollars. This is calculated by multiplying the price in local currency with the dollar exchange rate. We can then define the nominal (dollar) aggregate output of country j as

$$P_{j,1991}Y_{j,1991} = P_{j,1991}\hat{z}_j L^{\gamma}_{j,1991}K^{1-\gamma}_{j,1991}N_{j,1991},$$

where $\hat{z}_j$ is actual productivity, $L_{j,1991}$ is per-capita employment, $K_{j,1991}$ is the per-capita stock of capital, and $N_{j,1991}$ is population.

Deflating nominal GDP in both regions by $P_{1,1991}$, we obtain

$$Y_{1,1991} = \hat{z}_{1,1991}L^{\gamma}_{1,1991}K^{1-\gamma}_{1,1991}N_{1,1991},$$

$$\frac{P_{2,1991}Y_{2,1991}}{P_{1,1991}} = \left(\frac{P_{2,1991}\hat{z}_{2,1991}}{P_{1,1991}}\right)L^{\gamma}_{2,1991}K^{1-\gamma}_{2,1991}N_{2,1991},$$

Thus, aggregate productivities in the model correspond to

$$z_1 = \hat{z}_1 N_{1,1991},$$
$$z_2 = \hat{z}_2(P_{2,1991}/P_{1,1991})N_{2,1991}.$$

Since $P_{2,1991}$ is the dollar price of output in EMEs, the ratio $P_{2,1991}/P_{1,1991}$ corresponds to the real exchange rate. Thus, the above expressions show that z_1 and z_2 reflect cross-regional differences in real exchange rates and population, in addition to actual TFP.

The productivity values for the model are calculated from the data as

$$z_1 = \frac{Y_{1,1991}}{L^{\gamma}_{1,1991}K^{1-\gamma}_{1,1991}}, \quad (20)$$

$$z_2 = \frac{(P_{2,1991}/P_{1,1991})Y_{2,1991}}{L^{\gamma}_{2,1991}K^{1-\gamma}_{2,1991}}. \quad (21)$$

We use empirical counterparts for $Y_{1,1991}$, $L_{1,1991}$, $(P_{2,1991}/P_{1,1991})Y_{2,1991}$, $L_{2,1991}$, $K_{1,1991}$, and $K_{2,1991}$ from the *World Development Indicators*. $Y_{1,1991}$ and $P_{2,1991}Y_{2,1991}/P_{1,1991}$ are computed by aggregating the GDP of countries in advanced and emerging economies, respectively, both expressed in constant US dollars. For labor input $L_{j,1991}$ we use the employment-to-population ratio (population over 15 years of age). The values of $K_{j,1991}$ were constructed as described earlier in footnote 17.

The above procedure yields $z_{1,1991} = 0.474, z_{2,1991} = 0.205$. Hence, the calibration implies that in the year 1991 the measured TFP of AEs was roughly 2.3 times that of EMEs.

The (four) parameters ϕ_j and κ_j are important for determining private domestic credit, net foreign assets and the interest rate. More specifically, ϕ_j has a direct impact on the *demand* for financial assets: Higher values of ϕ_j increase the demand because more financial assets are needed for production (working capital, etc.). The parameter κ_j has a direct impact on the *supply* of financial assets: Higher values of κ_j strengthen the incentive for intermediate firms to borrow. In general, higher values of these two parameters lead to higher volume of private domestic credit. However, they have different effects on the interest rate and NFA. A higher value of ϕ_j (higher supply of credit) lowers the interest rate and increases NFA of country j. This is because the country demands more assets than those created domestically. The difference must then be filled with foreign assets. An increase in the value of κ_j (higher demand for credit) raises the interest rate and decreases NFA of country j. Since the country creates more assets than demanded domestically, part of it is sold to foreigners. Data for private domestic credit, NFA and interest rate were obtained from, respectively, *World Development Indicators*, *Wealth of Nations*, and *FRED*.

The 1991 values of foreign reserves are from the *Wealth of Nations* and data for public debt issued by advanced economies are from the IMF *Global Debt Database*. Table 2 provides the full list of calibrated parameters.

Table 2: Parameter values.

Description	*Parameter*	*Value*
Discount factor	β	0.930
Share of labor in production	γ	0.600
Depreciation rate	τ	0.080
Elasticity of labor supply	ν	1.000
Probability of crises (low sunspot shock)	λ	0.040
Cost of borrowing	η	0.100
Long-run growth rate of productivity	g	0.010
Productivity	z_1, z_2	0.474, 0.205
Working capital	ϕ_1, ϕ_2	1.658, 0.543
Liquidation value of capital	κ_1, κ_2	0.422, 0.184

The precise equations that link the nine empirical targets to the corresponding variables in the model are as follows:

$$\text{GDP AEs} = Y_{1,1991} = z_1^{\frac{1-\nu\gamma}{1+\nu(1-\gamma)}} (\gamma p_{1,1991})^{\frac{\nu\gamma}{1+\nu(1-\gamma)}}, \tag{22}$$

$$\text{GDP EMEs} = Y_{2,1991} = z_2^{\frac{1-\nu\gamma}{1+\nu(1-\gamma)}} (\gamma p_{2,1991})^{\frac{\nu\gamma}{1+\nu(1-\gamma)}}, \tag{23}$$

$$\text{Private Credit AEs} = q_{1,1991} D_{1,1991}, \tag{24}$$

$$\text{Private Credit EMEs} = q_{2,1991} D_{2,1991}, \tag{25}$$

$$\text{NFA in AEs} = q_{1,1991} B_{1,1,1991} + q_{2,t} B_{2,1,1991} + q_{p,1991} B_{p,1,1991} + \tag{26}$$

$$q_{p,1991} FX_{1,1991} - q_{1,1991} D_{1,1991} - q_{p,1991} D_{p,1991}, \tag{27}$$

$$\text{US real interest rate} = \frac{1}{q_{p,1991}} - 1. \tag{28}$$

$$\text{FX reserve AEs} = q_{p,1991} FX_{1,1991}, \tag{29}$$

$$\text{FX reserve EMEs} = q_{p,1991} FX_{2,1991}, \tag{30}$$

$$\text{Public Debt AEs} = q_{p,1991} D_{p,1991}, \tag{31}$$

The terms in the right-hand-side are equilibrium objects we compute from the model, given the values of z_j, ϕ_j, κ_j, FX_j and D_p. Thanks to the sequential property of the equilibrium (see Section 2.5), we find the equilibrium in period t by solving the system of equations listed in the Online Appendix E. We solve for ϕ_j and κ_j by applying two nested nonlinear solvers. The inner solver finds the equilibrium given the values of ϕ_j and κ_j. The outer solver uses the inner solution to check whether the equilibrium associated with the particular values of ϕ_j and κ_j satisfies conditions (24)-(28). We then update the values of ϕ_j and κ_j until conditions (24)-(28) are satisfied.

The calibration procedure yields $\phi_{1,1991} = 1.658$, $\phi_{2,1991} = 0.543$ and $\kappa_{1,1991} = 0.422$, $\kappa_{2,1991} = 0.184$. Hence, as of 1991, the need for financial assets in entrepreneurial activity was three times larger in AEs than in EMEs, and the "borrowing capacity" of AE borrowers was about 2.3 times larger.

3.2 Simulation results

We now address the question of how the observed increases in reserves and public debt affected the macroeconomic dynamics of advanced and emerging economies. As noted earlier, we do this by comparing simulations of the calibrated model under two scenarios:

Scenario I: Detrended reserves and public debt remain constant at their 1991 values. Since the calibration matches the GDP values of 1991, the GDP ratios of reserves and public debt are kept constant at the 1991 values shown in Figure 1.

Scenario II: Detrended reserves and/or public debt take the data values observed during the period 1991-2020. In this case, we use the observed time-series of FX reserves and public debt over that sample period, allowing their ratios to GDP to vary endogenously.[19]

[19] The detrended values of FX reserves and public debt enter the model as exogenous variables. However, since output is endogenous, the ratios are endogenous in the model.

In Scenario I, we impose that detrended FX reserves and public debt remain constant over the full 130 years of each of the 10,000 simulations. In Scenario II, detrended FX reserves and detrended public debt remain constant during the first 100 years, and after that they take the values observed in the data in the remaining 30 years. Since the simulation over 130 years is repeated 10,000 times, we have a cross-section of 10,000 simulated values of each variable of interest for each year. We can then calculate summary statistics for each variable, in each year, using these 10,000 points.

The impact of FX reserves. Figure 5 plots the time-series of the means of the simulated variables (in the cross-section of 10,000 repeated simulations for each year) under the two scenarios. The dashed line is for scenario I, where FX reserves and public debt remain constant. The continuous line is for scenario II, where FX reserves take the values observed in the data over the period 1991-2020. In both scenarios, the public debt issued by AEs remains constant. For private credit, NFA of AEs and the interest rate (panels (a)-(d)), the figure also plots the actual data (dotted-dashed line).

The comparison between the continuous and dashed lines illustrates the impact of the increased accumulation of FX reserves by EMEs. Panels (a) and (b) show that private credit, as a percentage of output, increases in response to the surge in FX reserves. The increase is lower than in the data but it is not negligible (roughly 20 and 10 percentage points of GDP between 1991 and 2020 in AEs and EMEs, respectively).

Panel (d) shows what explains the growth in credit: with growing FX reserves, the cost of borrowing (the interest rate) falls and the private sector borrows more. Panels (e) and (f) then show that effective leverage—the ratio of private debt to the liquidation value of capital during crises—rises. This is important for understanding the implications of higher FX reserves on macro volatility, as we will discuss shortly.

Looking now at panel (c), we observe that the accumulation of reserves leads to a large decline in NFA of advanced economies. This is because most of the increase in FX reserves comes from emerging economies, which increases the foreign demand for AEs' public debt. The surge in reserves contributes to explain about half of the observed decline in the interest rate, but it yields a drop in NFA of a similar magnitude as in the data.

Clearly, the results in Figure 5 also indicate that considering only the surge in FX reserves still leaves a non-trivial part of the observed rise in private credit of both regions and the drop in the world interest rate unexplained. As noted earlier, however, the aim of this experiment is only to isolate the contribution of FX reserves, setting aside other factors that contributed to the observed data dynamics (e.g., productivity growth, demographic transition, and changes in financial structure).

The last two panels of Figure 5 show how the surge in EMEs' foreign reserves affected the entrepreneurs' portfolios. Panel (g) shows that the expected losses on private bonds as a fraction of total bond holding increased over time. This follows from the rise in leverage shown in panels (e) and (f). Panel (h) indicates that the share of risky private bonds

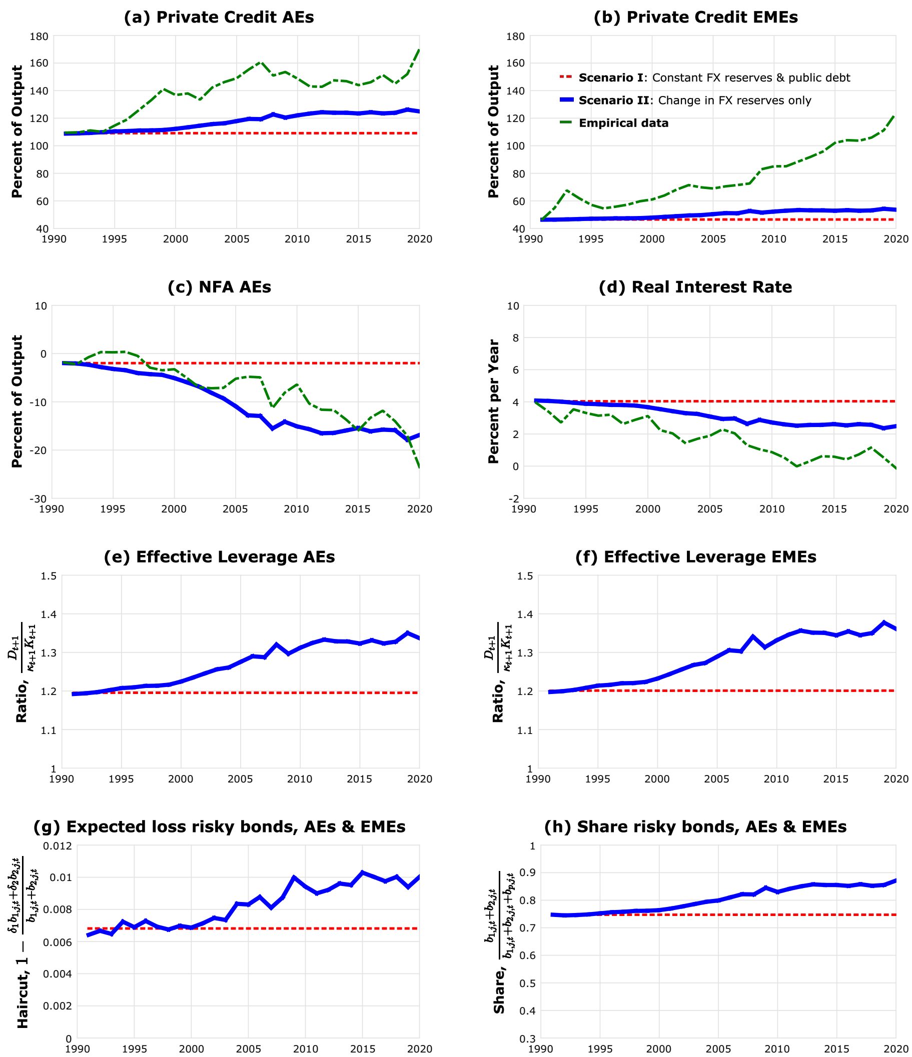

Figure 5: Simulation with changing FX reserves, 1991-2020.

in the portfolios also increased over time.[20] This occurs because government purchases of reserves (maintaining the supply of risk-free public debt of AEs unchanged) crowds out public bonds available to the private sector. Thus, the increase in reserves raises the riskiness of entrepreneurs' financial wealth because they hold a larger share of private bonds (panel (h)), and these bonds become riskier (panel (g)). As we will show later, this is key for explaining the effect of reserves on aggregate volatility.

We can separate the contributions to the change in the riskiness of the entrepreneurs' wealth coming from the two components as follows. The expected portfolio losses, as a fraction of wealth, can be written as $Loss_t = \varrho_t \times \varsigma_t$, where ϱ_t denotes the expected

[20]The ratios shown in panels (g) and (h) are the same in the two regions because at equilibrium the entrepreneurs of both regions choose the same portfolio shares, face the same bond prices, and the same haircut rates on defaulted private bonds.

losses on the risky component of wealth (private bonds) and ς_t is the share of the risky portfolio (share of private bonds in total wealth). Using the approximation $Loss_t - Loss_0 \approx (\varrho_t - \varrho_0) \times \varsigma_0 + (\varsigma_t - \varsigma_0) \times \varrho_0$, the contribution of the change in the share of the risky portfolio to the change in expected losses is $(\varsigma_t - \varsigma_0) \times \varrho_0 / (Loss_t - Loss_0)$. Its complement measures the contribution of the change in the risk of private bonds. In the counterfactual with the observed growth in reserves, the average contributions over all years of these two components are 17.4% and 82.6%, respectively.

The impact of public debt. Figure 6 plots the simulated variables under the two scenarios described earlier but now for measuring the impact of AEs' public debt instead of the surge in FX reserves. In the first scenario (dashed line), both FX reserves and public debt remain constant. In the second (continuous line), public debt takes the values observed in the data during the 1991-2020 period, while FX reserves remain constant.

Panels (a) and (b) show that the increase in AEs public debt induces a decline in private credit as a percentage of output. This is the consequence of the increase in the interest rate shown by the continuous line in Panel (d). Notice that the equilibrium interest rate cannot be bigger than the intertemporal discount rate $1/\beta - 1 \approx 0.075$. Intermediate-goods firms are risk neutral and when the interest rate equals the discount rate, they become indifferent between borrowing and lending.

The increase in public debt issued by AEs has a negligible impact on their NFA position (see Panel (c)). Although part of the public debt is purchased by entrepreneurs in emerging economies, the financial portfolios of entrepreneurs in EMEs are relatively small. As a consequence, the contribution of EMEs to the NFA of advanced economies is not large. As was the case with FX reserves, the growing public debt issued by AEs leaves sizable portions of the actual movements of all variables unexplained.

Following the decline in private domestic credit, Panels (e) and (f) show that effective leverage decreases. The riskiness of the entrepreneurs' portfolios also declines because private bonds become less risky (due to the lower leverage of borrowing firms), and because entrepreneurs allocate a smaller share of their wealth to risky bonds. The average contributions coming from the changes in the share of the risky portfolio and the risk of private bonds are 21.9% and 78.1%, respectively.

The combined impact of FX reserves & public debt. Figure 7 plots the simulated variables when Scenario II allows both reserves and public debt to take their actual data values.

With the exception of the NFA in advanced economies, which still declines sharply (see panel (c)), the effects of the growing public debt dominate those of higher FX reserves. As a result, private credit declines in both regions (Panels (a) and (b)), the world interest rate increases (Panel (d)), and effective leverage shrinks in both regions (Panels (e) and (f)). We also see that entrepreneurs' portfolios become less risky because both the risk of private bonds and the share of the portfolio allocated to them fall (Panels (g)-(h)). The

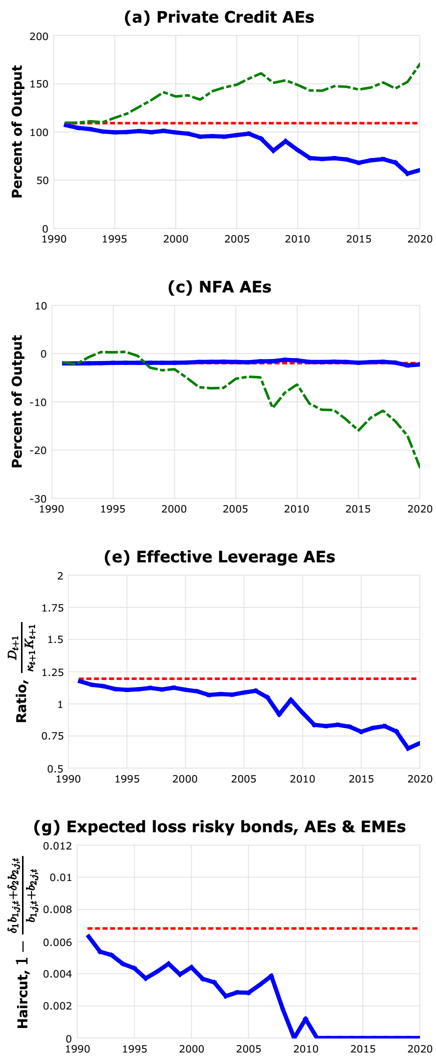

Figure 6: Simulation with changing public debt issued by AEs, 1991-2020.

average contributions coming from the lower share of the risky portfolio and the lower risk of private bonds are 18.2% and 81.8%, respectively.

4 Financial and macroeconomic volatility

We now explore the main question addressed in this paper: how did the surges in EMEs' reserves and AEs' public debt impacted macroeconomic volatility in the last three decades? Focusing on aggregate output, we measure volatility using the following indicator:

$$VOL_{j,t} = \left(\frac{P_{j,t}(95) - P_{j,t}(5)}{\overline{Y}_{j,t}} \right) \times 100. \tag{32}$$

The variables $P_{j,t}(5)$ and $P_{j,t}(95)$ are, respectively, the 5th and 95th percentiles of the

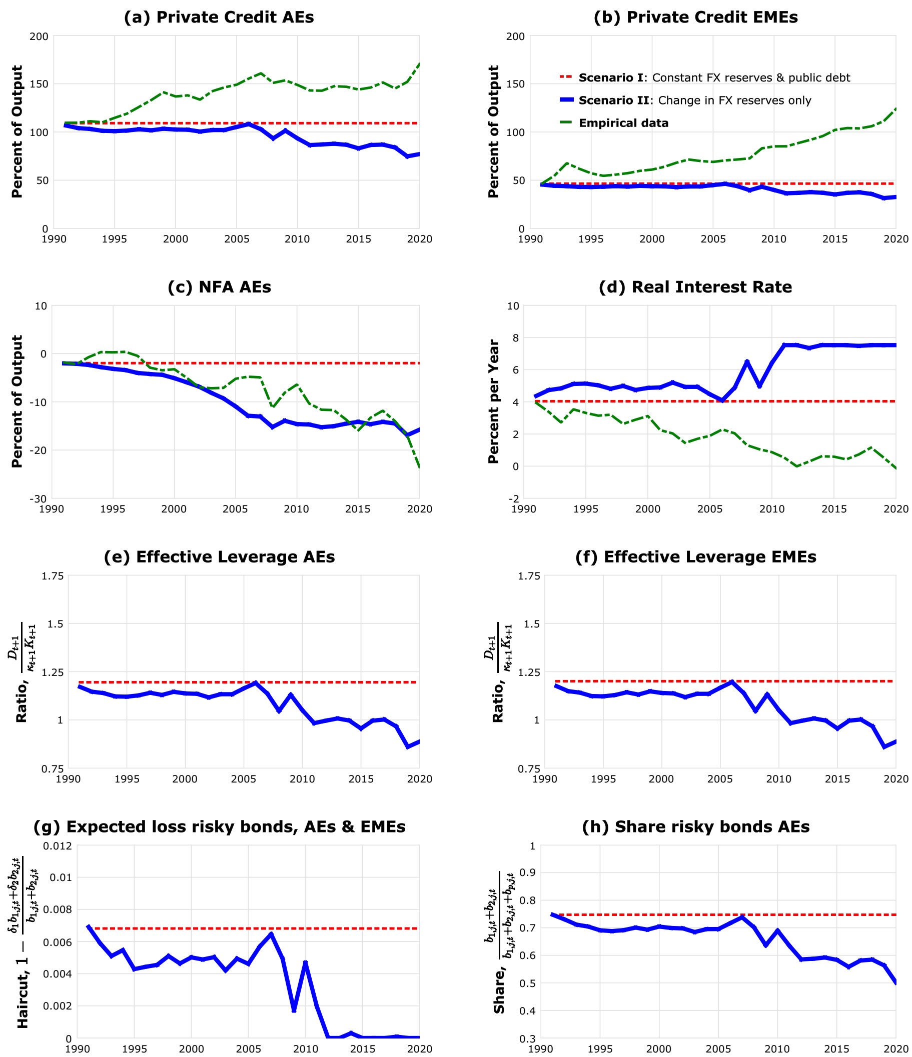

Figure 7: Simulation with changing FX reserves and public debt, 1991-2020.

10,000 cross-sectional output values generated by the repeated simulations for year t in region j. Hence, the percentiles are the values of $P_{j,t}(5)$ and $P_{j,t}(95)$ that solve the equations

$$\frac{1}{10,000}\sum_{i}^{10,000}\left(1\middle|Y_{j,t}^{i}<P_{j,t}(5)\right)=0.05, \qquad \frac{1}{10,000}\sum_{i}^{10,000}\left(1\middle|Y_{j,t}^{i}<P_{j,t}(95)\right)=0.95.$$

The variable $\overline{Y}_{j,t}$ is the arithmetic average of the 10,000 data values for output obtained from the repeated simulations, that is,

$$\overline{Y}_{j,t}=\frac{1}{10,000}\sum_{i=1}^{10,000}Y_{j,t}^{i}.$$

The time-varying index of output volatility is the difference between the 5th and 95th percentiles, normalized by the mean. This volatility index for the counterfactual experiments we examined earlier is plotted in Figure 8. The dashed lines in all the panels are for Scenario I in which reserves and public debt remain constant throughout the whole simulation period. The continuous lines are for the different variants of Scenario II, where reserves and/or public debt take the values observed in the data. Panels (a)-(b) are for the reserves experiment, (c)-(d) for the AEs' public debt experiment, and (e)-(f) for the experiment that combines both.

Panels (a) and (b) illustrate the impact of the surge in reserves on output volatility in AEs and EMEs, respectively. As can be seen, the surge in reserves contributed to increase volatility in both regions. Especially in AEs where it nearly doubled.

To understand this result, we should look back at Figure 5. The increase in reserves represents an increase in the demand for risk-free assets which raises their price and, therefore, lowers the interest rate (Panel (d)). This makes borrowing cheaper for intermediate firms and, as a result, their leverage increases (Panels (e) and (f)). In turn, higher leverage implies that, in the event of default, a smaller fraction of their debt is repaid. On the entrepreneurs' side, as we saw, their portfolios become riskier because private bonds become riskier (Panel (g)) and a larger share is allocated to risky bonds (Panel (h)). Hence, financial crises generate larger wealth losses for entrepreneurs, which, in turn, lead to greater drops in demand for intermediate goods and labor and in GDP. The overall outcome is that crises become more likely over time (as leverage rises and moves into the crisis interval) and when they happen output falls more, thus increasing output volatility.

The effects described above are larger in AEs than in EMEs because the former have a higher value of ϕ. This implies that entrepreneurs in AEs hold more financial wealth relatively to production and the financial losses have a stronger impact on the demand for intermediate goods.

Consider now the volatility effects of public debt. The continuous lines in Panels (c) and (d) shows how output volatility changes when the public debt issued by advanced economies takes the values observed in the data. Volatility drops significantly, especially after the 2008 financial crisis, that is, after AEs expanded substantially their public borrowing in the data.

The intuition for this result is simple and can be explained by looking at the previous Figure 6. When the governments of AEs issue more debt, the increased supply of risk-free bonds causes their price to drop, which results in higher interest rates (Panel (d)). Intuitively, AEs' governments have to pay a higher interest rate to attract investors. The higher interest rate makes borrowing more costly for intermediate firms and leverage declines (Panels (e) and (f)). With lower leverage, haircuts in the event of default are smaller. Moreover, the entrepreneurs' wealth becomes safer because they hold more risk-free public bonds and private bonds become less risky (Panels (g)-(h)). This is consistent with Krishnamurthy and Vissing-Jorgensen (2015), who showed that government debt crowds out financial sector lending. As a result, financial crises generate smaller wealth losses for entrepreneurs, which in turn have smaller macroeconomic effects.

Figure 8 shows that volatility falls to zero in the latter years of Panels (c)-(f). This is

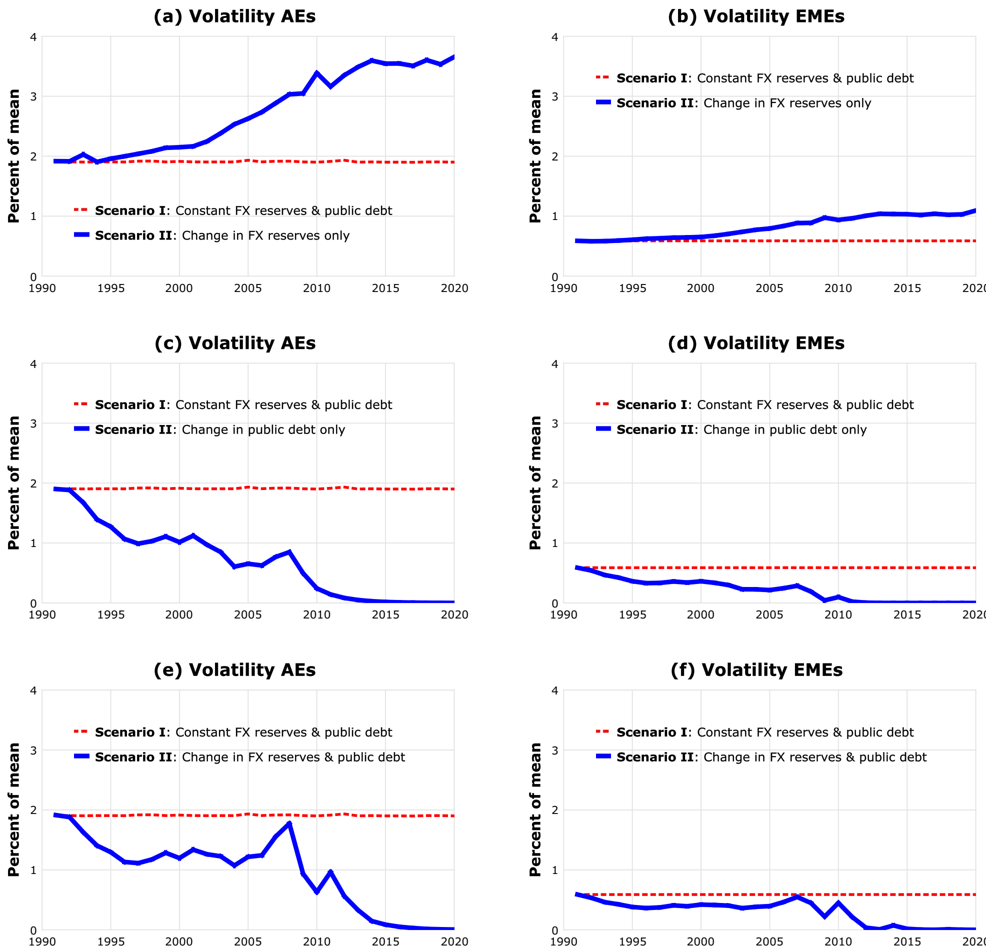

Figure 8: Output volatility over the period 1991-2020. The volatility measure is the difference between the 5th and 95th percentiles of output, as a percentage of average output, computed from the values generated by 10,000 repeated simulations.

because the interest rate rises to reach the subjective discount rate.[21] At this point firms do not issue debt above the liquidation value of capital and entrepreneurs hold only risk-free debt. Without private debt exposed to default risk, there are no defaults and no haircuts to the entrepreneurs' financial wealth that cause output to drop. This is when the effect of the higher supply of AEs' public debt making financial portfolios safer is the strongest.

Of course, we should keep in mind that the model abstracts from other important consequences of a larger public debt. The distortions induced by higher taxes needed to service the debt, for instance, are detrimental even for AEs.

The last two panels of Figure 8 show the impact of the combined changes in both EMEs' reserves and AEs' public debt. The impact of the latter again dominates and, as a result,

[21]The interest rate cannot exceed the inter-temporal discount rate, otherwise the problem of the firm is not well defined. This is because with $R > 1/\beta$, firms would issue equity (negative dividends) to buy bonds (rather than lending) without bound.

output volatility declines in both regions. It again reaches zero in the latter years, but this occurs later than when only the increase in AEs' public debt is considered, because of the offsetting effect of the surge in reserves.

It is important to note that there are significant cross-country spillovers in all of these experiments. These spillovers arise due to cross-border holdings of financial assets. The wealth redistribution resulting from defaulted private debt spreads across regions because of these cross-border holdings.

5 Government bailout policies

Thus far, we have examined a setup in which reserves do not have a direct impact on the macroeconomic performance of the region that accumulates them. Their impact is only through general equilibrium effects. Reserves, however, are a form of publicly-owned liquidity that facilitates government interventions when desirable, as is the case during financial crises. For instance, Bocola and Lorenzoni (2020) provide a rationale for reserves to improve the credibility of domestic authorities to intervene in financial panics, and Amador et al. (2016) show that they can shield a country from speculative attacks.

In this section, we extend the model by assuming that governments use reserves to provide liquidity and thereby contribute to stabilize the economy. In particular, since the main channel through which a financial crisis has negative real effects is by depleting entrepreneurial wealth, we assume that the government uses FX reserves to bail out a fraction of the financial losses incurred by entrepreneurs. For simplicity, we do not attempt to characterize the *optimal* accumulation of reserves and bailout policy. Instead, we specify the bailout mechanism as an exogenous rule and focus on quantifying its ability to reduce macro volatility.

5.1 Bailout mechanism

With the bailout mechanism, the government of region j makes transfers to domestic entrepreneurs, denoted $Bail_{j,t}$. With the bailout transfers, the government budget constraint in Region 1 (AEs) becomes

$$FX_{1,t} + q_{p,t}D_{p,t+1} = q_{p,t}FX_{1,t+1} + D_{p,t} + T_{1,t} + Bail_{1,t}. \tag{33}$$

This is the same budget constraint as in equation (10) but with $Bail_{1,t}$ added in the right-hand-side as a new use of funds. A similar modification applies to the government budget constraint of Region 2 (EMEs),

$$FX_{2,t} = q_{p,t}FX_{2,t+1} + T_{2,t} + Bail_{2,t}. \tag{34}$$

To specify the rule setting the bailout transfers, consider first the aggregate losses incurred by entrepreneurs in region j,

$$Loss_{j,t} = (1-\delta_{1,t})B_{1,j,t} + (1-\delta_{2,t})B_{2,j,t}. \tag{35}$$

The government of region j uses part of its FX reserves to cover the losses according to the following rule:

$$Bail_{j,t} = Loss_{j,t} \cdot \left[1 - e^{-\alpha\left(\frac{FX_{j,t}}{Loss_{j,t}}\right)}\right]. \tag{36}$$

The term in square brackets is the fraction of losses covered by the bailout. This fraction is always smaller than 1 and converges to 1 as $FX_{j,t}$ converges to infinity. The overall bailout spending is zero when either the losses are zero or the reserves are zero. The parameter α captures the easiness with which the region can use the accumulated reserves for a bailout. Provided that $\alpha \leq 1$, the size of the bailout transfer, $Bail_{j,t}$, is always smaller than the reserves, $FX_{j,t}$. When $\alpha = 0$, we get back to the model without bailouts.

The bailout transfers are paid to entrepreneurs in proportion to their after-default wealth. Denote by $\chi_{j,t}$ the transfer rate. The transfer paid to an individual entrepreneur in region j is $\chi_{j,t}[\delta_{1,t}b_{1,j,t} + \delta_{2,t}b_{2,j,t} + b_{p,j,t}]$. The transfer rate $\chi_{j,t}$ is then determined so that the total funds allocated to a bailout, $Bail_{j,t}$, are equal to the total transfers paid to entrepreneurs, $\chi_{j,t}[\delta_{1,t}B_{1,j,t} + \delta_{2,t}B_{2,j,t} + B_{p,j,t}]$. Equalizing these two terms we obtain:

$$\chi_{j,t} = \frac{Bail_{j,t}}{\delta_{1,t}B_{1,j,t} + \delta_{2,t}B_{2,j,t} + B_{p,j,t}}. \tag{37}$$

Notice that the total bailout transfers, $Bail_{j,t}$, are zero if there is no default, that is, $\delta_{1,t} = \delta_{2,t} = 1$.

This bailout mechanism features two assumptions for analytical tractability. First, bailout transfers are proportional to the 'individual' wealth of entrepreneurs. Second, the transfer rate $\chi_{j,t}$ does not depend on 'individual' composition of portfolios. Under these assumptions, entrepreneurs in the two regions continue choose the same portfolio shares.[22]

The variables $FX_{1,t}$, $FX_{2,t}$ and $D_{p,t}$ remain time-varying and exogenous, but the bailout transfers $Bail_{1,t}$ and $Bail_{2,t}$ are endogenously determined by condition (36). The households' transfers (or taxes) $T_{j,t}$ are again set to balance the government budget constraints, but now inclusive of the bailouts (eqs. (33) and (34).

This setup can be justified by assuming that in subperiod 1—when default occurs and entrepreneurs are bailed out—the government uses $FX_{j,t}$ to pay for the bailout (recall that the bailout rule implies $Bail_{j,t} \leq FX_{j,t}$). Then, in subperiod 3, the government adjusts $T_{j,t}$ as needed so that the exogenous $FX_{j,t+1}$ is still attained at the end of the period

[22] An alternative assumption would be that the entrepreneurs' losses are covered with lump-sum bailout transfers. Under this assumption, however, entrepreneurs in different regions would choose different portfolio compositions, which complicates significantly the characterization of the equilibrium. Another possible assumption is that the transfers are proportional to the bond holdings that generated the losses. Again, this would lead to non-symmetric portfolio choices with significant analytical complications.

(i.e., reserves are only used within-the-period to finance the bailout). See Figure 3 for the definition of the three subperiods.

The specification of what happens in subperiod 1 and subperiod 3 formalizes the idea that changing $T_{j,t}$ requires time. By the time governments succeed in raising funds, bailouts may no longer be needed. By holding liquid reserves, instead, governments have the flexibility to intervene in a timely fashion. More generally, we could envisage a situation more akin to reality in which the change in $T_{j,t}$ (i.e., the tax hike needed to fund bailouts) occurs over time, so that the stock of FX reserves drops in the short run after the government intervention. The specification proposed here is a limiting case of this scenario in which taxes cannot adjust in subperiod 1 but they can adjust in subperiod 3.[23]

5.2 Entrepreneurs' wealth & portfolio choice

As before, the representative entrepreneur in Region j enters period t with $b_{1,j,t}$, $b_{2,j,t}$, and $b_{p,j,t}$, and, if intermediate firms default, entrepreneurs incur financial losses that reduce their collected bond repayments to $\delta_{1,t}b_{1,j,t}$ and $\delta_{2,t}b_{2,j,t}$. But now the government bails out entrepreneurs by covering some of their losses with transfers $\chi_{j,t}[\delta_{1,t}b_{1,j,t} + \delta_{2,t}b_{2,j,t} + b_{p,j,t}]$. Thus, the entrepreneur's wealth after bailout is

$$m_{j,t} = \Big[\delta_{1,t}b_{1,j,t} + \delta_{2,t}b_{2,j,t} + b_{p,j,t}\Big](1 + \chi_{j,t}).$$

Besides this, all the conditions that define the entrepreneur's problem remain unchanged, including the end-of-period wealth $a_{j,t} = m_{j,t} + (z_j - p_{j,t})x_{j,t}$. We can also show that Lemmas 2.1 and 2.2 still apply. This is also true for all equilibrium conditions derived earlier.

5.3 Quantitative results

We simulate the extended model under the same scenarios as before. We use the same parameter values and examine results for alternative values of the bailout parameter α.

Simulation results. Figure 9 plots the output volatility measures for advanced and emerging economies. Panels (a)-(b) are for the scenario in which reserves take the values observed in the data with public debt constant. Panels (c)-(d) are for the scenario in which public debt takes the values observed in the data with reserves constant.

The continuous lines in each plot are for the baseline solutions without bailouts (i.e., the same as the continuous lines in Figure 8). The dashed lines are for the model with bailouts with $\alpha = 0.1$, and the dash-dotted lines are for $\alpha = 0.3$. As explained earlier, α

[23]We could assume that households' transfers $T_{j,t}$ are unchanged and $FX_{j,t+1}$ responds endogenously after the bailout. Although we did not adopt it for simplicity, the assumption raises the question of why FX reserves are needed and whether the government could not just reduce transfers (or raise taxes) directly to fund the bailout.

captures the extent to which the government uses FX reserves to bail out entrepreneurs during financial crises. Given the accumulated reserves, higher α implies larger bailouts.

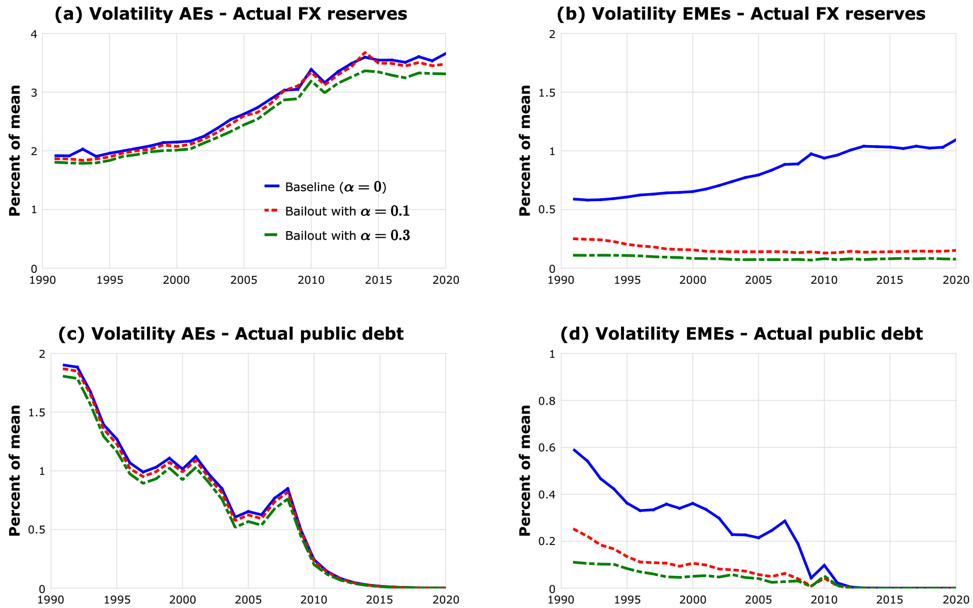

Figure 9: Counterfactual simulation when FX reserves are used for bailouts, 1991-2020.

Panels (a) and (c) show that, for advanced economies, volatility is only marginally affected by the bailouts at the three values of α. This is a straightforward result because AEs do not hold large stocks of reserves relatively to their economic size. Therefore, bailouts are relatively small. Keep in mind, however, that even if AEs do not have many reserves, they may still have some flexibility in using public borrowing to fund a bailout. For example, they can swap defaulted private obligations for newly-issued (risk-free) public debt paid for with future taxes (akin to the 2008 TARP program of the U.S. treasury). This flexibility is not equally available to all advanced economies, as demonstrated by the 2012 European debt crisis. However, even though our simulation does not account for it, the use of public debt during crisis episodes remains a potentially useful tool for AEs.

For emerging economies, however, the results are quite different (see Panels (b) and (d)). Even with $\alpha = 0.1$ (dashed line), aggregate volatility drops sharply with the bailouts. With $\alpha = 0.3$ (dash-dotted line), volatility drops to less than half of what it was without bailouts. The larger reserves held by EMEs give them a bigger liquidity buffer for reserves-funded bailouts than AEs. Consider also that EMEs generally have limited ability to use their own public debt to fund bailouts, because of hefty default risk premia and freezes in public debt markets during financial crises and because their capacity to raise future taxes for debt-financed bailouts is limited. Moreover, reserves are also more useful than domestic public debt for providing liquidity during crises in EMEs because of "liability dollarization" (i.e., the extent to which private financial liabilities are denominated in hard currencies).

5.4 Bailout policies and moral hazard

Although bailouts can mitigate the consequences of crises, their anticipation may create unintended distortions. The standard argument is that the belief that some investment losses will be covered by the government may lead investors to demand a lower expected return from borrowers. This, in turn, reduces the cost of borrowing and encourages higher leverage, ultimately making financial crises more severe.

We can analyze the potential effects of this mechanism within our model. The key question is whether the anticipation of bailouts influences equilibrium borrowing.

Our results indicate that, in the model, the expectation of bailouts has only a minor effect on the interest rate and, consequently, on equilibrium debt. This is partly because bailouts are contingent on the occurrence of a financial crisis, which is a low-probability event. However, there is another important factor at play.

When a crisis occurs, entrepreneurs receive additional funds, some of which are saved for the next period. This should theoretically lower the interest rate, at least in the aftermath of a crisis. However, because entrepreneurs have more funds, they can purchase more intermediate inputs (which is the intended purpose of the bailout), driving up their prices. This reduces entrepreneurs' profits and, consequently, the end-of-period net worth available for savings. Interestingly, these two effects—government transfers and lower profits per unit of wealth—almost offset each other. As a result, the impact on the equilibrium interest rate remains negligible.

6 Welfare implications

We conducted a quantitative welfare analysis to explore the normative implications of our findings. Because there are two types of agents (households who own intermediate-goods firms, and entrepreneurs who own final-goods firms), the welfare effects are computed separately for each.

The quantitative welfare measure is a standard compensating variation in consumption that compares, as of year 1991, the expected *lifetime* utility of living in Scenario I (constant reserves and public debt) relative to one of the variants of Scenario II (reserves and/or public debt take their actual 1991-2020 values). Hence, the welfare effect is a percent change in consumption in all periods when living in scenario I, such that the agent's expected lifetime utility equals that attained in scenario II. A positive result indicates a welfare gain in II compared to I, and a negative result a welfare loss. Full details are provided in the Online Appendix G.

Table 3 shows the welfare results. Row a) compares Scenario I with the variant of Scenario II in which reserves grow as in the data. This captures the welfare effects induced by the observed accumulation of reserves in the two regions vis-a-vis keeping them constant at their 1991 levels.

Consider first the welfare effects on AEs. Households gain 0.34% but entrepreneurs

Table 3: Welfare effects of moving from Scenario I to Scenario II in absence of bailouts ($\alpha = 0$). Gains are in percent of consumption in Scenario I.

	AEs		EMEs	
	Hous.	*Entr.*	*Hous.*	*Entr.*
a) **Effects of FX Reserves**	0.34	-1.82	-0.71	0.10
Scenario I: Constant Res. & Debt				
Scenario II: Actual Res & constant Debt				
b) **Effects of Public Debt**	0.03	0.19	2.12	-0.30
Scenario I: Constant Res & Debt				
Scenario II: Constant Res & actual Debt				
c) **Effects of FX Reserves & Public Debt**	0.28	-0.62	1.75	-0.23
Scenario I: Constant Res & Debt				
Scenario II: Actual Res & Debt				

lose -1.82%, over five times what households gain. The households' gain is primarily due to a reduced tax burden. As the interest rate falls, AEs make lower interest payments to EMEs, and since AE governments pay interest on public debt by taxing domestic households, the tax burden falls and household welfare rises.

The entrepreneurs' losses derive from two opposing effects, a gain due to higher profits and losses due to reduced financial income and higher volatility. Profits increase because entrepreneurs hold less financial wealth and this reduces the price of intermediate goods, since they can only buy fewer of them with lower financial wealth.[24] The entrepreneurs' financial income falls because they earn lower interest on their financial wealth. The higher volatility reduces welfare because of the concavity of their utility function. The welfare losses from these two forces sharply outweigh the gains from the higher profits.

For EMEs, the results are the opposite, and the welfare loss of households (-0.71%) is about 7 times larger than the entrepreneurs' gain (0.1%). The welfare loss of households occurs because the accumulation of reserves is akin to forced savings: the government taxes households to purchase reserves. Since the interest rate is lower than the rate of time preference, saving is undesirable for households. The entrepreneurs' small gain is due to the same two effects described above, but here the positive effect dominates. This happens because entrepreneurs' financial wealth in EMEs is lower than in AEs. Hence, their profits raise more, and the negative effects via financial income and volatility are smaller.

These results, together with the volatility results, show that while the surge in EMEs reserves increased their own output volatility and caused global spillovers that increased volatility in AEs as well, the welfare implications are ambiguous. Households are better off and entrepreneurs worse off in AEs, while in EMEs the opposite is true. The magnitudes of the welfare gains and losses are sizable, keeping in mind that the classic Lucas

[24]In partial equilibrium, with p constant, holding less financial wealth hurts individual entrepreneurs by tightening their working capital constraint forcing them to produce less. In general equilibrium, however, lower aggregate demand for inputs causes a decline in p which props up the entrepreneurs' profits. With our calibrated parameters, the net result of the fall in both p and X is an increase in profits.

result about the cost of U.S. business cycle is about 0.1%, and estimates of the welfare gains of fully eliminating distortionary capital taxes are about 1-2%. Spillover effects on welfare are sizable too (e.g., the increase in reserves causes a -1.8% drop in the welfare of entrepreneurs in AEs).

The welfare effects of the increase in public debt of AEs are shown in row b) of Table 3. In AEs, both households and entrepreneurs are only marginally affected. The welfare of households is nearly unchanged because of conflicting effects that almost cancel each other. They gain because they are indirectly borrowing via intermediate firms at an interest rate lower than the rate of time preference, and because they produce more since entrepreneurs hold more financial assets and thus demand more intermediate goods, which in turn increases the intermediate firms' labor demand and production. They lose because the public debt has to pay a higher interest rate, which again implies higher taxes. Entrepreneurs make a modest gain of 0.19%. Also in this case there are two effects. The negative effect from lower profits, and the positive effect from higher interest earned on financial assets and lower volatility. The second effect dominates.

In contrast, in EMEs, households have a large gain (2.12%) nearly 7 times larger than the losses of entrepreneurs (-0.3%). Households gain because the higher interest rate raises the return on reserves that is paid back to households as transfers. They also gain from higher wage income induced by the higher production. Entrepreneurs, instead, experience welfare losses because they accumulate more financial wealth, which increases the demand for intermediate inputs and lowers profits. Entrepreneurs also earn more interests on bonds and benefit from reduced output volatility. The first effect, however, is stronger. Also here the global spillover effects on welfare are large: In EMEs, households (entrepreneurs) increase (reduce) their welfare by 2.12% (-0.3%) because of increased borrowing by AE governments.

Row c) of Table 3 reports welfare outcomes for the case in which both FX reserves and public debt increase as in the data. The welfare effects are now the combined result of the forces at work in the previous two cases. The gain of EME households (1.75%) remains markedly larger than both the loss of EME entrepreneurs (-0.23%) and the gains and losses of AE households and entrepreneurs, at 0.28% and -0.62%, respectively.

In Online Appendix G, Table 5, we also report the welfare effects when the bailouts are active ($\alpha > 0$). Overall, bailouts have a modest impact on welfare. This is because financial crises are rare events and the welfare numbers are averages over the infinite future. Conditional on a crisis, the welfare impact of bailouts would be much bigger.

7 Discussion and conclusion

In this paper, we examine the macroeconomic and financial implications of the surge in foreign reserves accumulated by EMEs and the sharp increase in public debt issued by AEs since the 1990s through the lens of a world general equilibrium model. The model features public debt issued by AEs, which is safe, and privately issued debt that can be defaulted on.

The key element of the model is that both public and private debt have a productive use for entrepreneurs and a drop in their value leads to a macroeconomic contraction. Since private debt is risky while the public debt issued by AEs is safe, the macroeconomic consequences of a financial crisis depend on the entrepreneurs' portfolio composition: a lower share of public debt and a higher risk of private debt increase vulnerability to crises and lead to greater macroeconomic instability.

While an increase in EMEs' reserves causes an increase in financial and macroeconomic volatility (by inducing riskier portfolio holdings), an increase in public debt issued by AEs reduces volatility (by inducing safer portfolio holdings). Quantitatively, the effect of the observed increase in public debt outweighs the effect of the accumulation of reserves. As a result, the net contribution of both changes was to reduce the macroeconomic vulnerability to financial crises in both advanced and emerging economies.

In our counterfactual exercises, we used changes in FX reserves and public debt as exogenous inputs. Since we showed that these changes have non-negligible welfare effects, it would be interesting to explore how governments choose these policies. If a single country increases its FX reserves, especially if the country is small, its economy could become more stable. However, if many countries implement a similar policy, the world interest rate would fall, inducing more leverage and higher macroeconomic instability. This suggests that there could be over-accumulation of reserves, a point also emphasized in Steiner (2014) and Das et al. (2023).

However, there is also another side to the story. Low interest rates may encourage the governments of advanced economies to issue more public debt, which would move the world interest rate in the opposite direction. Thus, the study of the welfare implications and optimality of FX reserves accumulation should be complemented with the optimal issuance of public debt by advanced economies in response to the increasing demand coming from emerging economies. This is especially important when reserve-issuing countries take advantage of their market power, a feature that Choi et al. (2024) showed to be relevant for the US.

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