Output Concerns and Precautionary Savings in Emerging Markets' Debt and Reserve Accumulation*

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Abstract

We study the joint behavior of external debt, international reserves, and the real interest rate based on a dynamic regime-switching small open economy model that incorporates the salient features of economic crises in emerging markets. Unlike reduced form analyses where contributions from different channels are difficult to delineate, our model allows separately assessing both possible motives behind reserve accumulation: mercantilistic behavior (output externalities) and precautionary savings. Using data from 24 emerging countries for 50 years, we estimate the model and show that both motives matter, but to differing degrees, in many of our sample countries, with international reserves serving as an instrument to sustain higher levels of output and insure against disruptions from crises. The model is quantitatively successful at matching various aspects of the data that exhibit substantial variation across these countries. Importantly, when present sudden stop risk and output externalities both have differing impact on debt and reserve management of different countries because of offsetting income and substitution effects.

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1 Introduction

Governments of many emerging market countries have built up large international reserves in the past two decades. For these countries, this form of government savings can be important for promoting macroeconomic and financial stability, for instance serving as a buffer against external shocks. Given its relationship to the Global Savings Glut (Bernanke, 2005) and the Global Financial Crisis of 2008, this phenomenon has received considerable attention from both academics and policymakers. The literature has put forward two major motives behind the observed reserve accumulation: "mercantilism" where the accumulation takes place perhaps as a result of export-led growth strategy (Dooley et al. 2003; Benigno and Fornaro, 2012; Korinek and Serven, 2016; Choi and Taylor, 2017) and "self-insurance" where it serves as precautionary savings against sudden stops in capital flows or roll-over risk of external debt (Durdu et al. 2009; Jeanne and Ranciere, 2011; Bianchi et al., 2018).[1] Theory and empirical analysis are yet to come together in joint analysis of the two motives and their relative importance across small open economies. In this paper, we fill the gaps in the literature by proposing a quantitative small open economy model where the two motives can be jointly analyzed and take the model to data.

We first provide empirical evidence for the existence of precautionary and mercantilistic motives behind international reserve accumulation. The evidence for the former is based on Indonesia, Korea, and Thailand, three countries that suffered heavily during the Asian Financial Crisis and for which we can more cleanly identify the working of the precautionary channel. Using synthetic control matching, we show that the Asian Financial Crisis "caused" the surge in reserve accumulation thereafter. For Korea, we complement this evidence by constructing an index of media coverage on the issues concerning international reserves and demonstrate that there is a significant increase in public interest on international reserves even long after the crisis is over.

Our findings suggest that these countries started to insure themselves more through international reserve accumulation once they became better informed about sudden stop risk they face against the international financial markets. This can be interpreted as a discovery of a

[1] Another strand of the literature focuses on the role of international reserves in addressing not only an "external drain" (capital flight) but also an "internal drain" (domestic financial instability or bank runs) (Obstfeld et al. 2010; Bocola and Lorenzoni, 2020) and other studies emphasize the liquidity role of reserves (held in the form of US Treasuries) in attracting foreign investments in emerging markets (Jung and Pyun, 2016).

crisis regime that is distinct from normal times, which leads us to consider a regime-switching model in this paper.

Next we provide suggestive evidence for the mercantilistic motive by relating reserve accumulation and GDP growth in emerging markets, as in Benigno and Fornaro (2012). The relationship is positive and highly statistically significant, which, although not causal, suggests a possible role for mercantilistic behavior. The model will help establish causal mechanisms and we build output externalities due to reserves into it so that this channel, if present in the data, will be captured. We use *output externalities* for lack of a better term, as this will encompass mercantilistic behavior, desire for export-led growth, terms of trade concerns, and any other GDP effect of reserves that does not manifest themselves in precautionary motives. Note that these effects need not even be positive. We will treat the signs and sizes of effects for different countries as empirical questions.

Our model, which extends small open economy models of Aguiar and Gopinath (2007), Garcia-Cicco et al. (2010) and Fernandez-Villaverde et al. (2011) among others to include the aforementioned features, allows the joint analysis of debt, international reserves, and the real interest rate. The joint modeling is important because the interest rate premium an emerging market country faces on its external borrowing depends on the profile of debt and reserves (Edwards, 1984). This leads us to consider an interest rate premium process that is compatible with the empirical findings, which is a notable feature of the model. Building on the premium function of Schmitt-Grohe and Uribe (2003), our premium function depends not only on debt but also on reserves, with model agents internalizing the effects of debt and reserves on interest rates. More importantly, it allows debt and reserves to coexist in the model as in the pioneering work of Bianchi et al. (2018), but be agnostic about the exact mechanism, suggesting a viable alternative to fully microfounded models that can be used for a model-based analysis. We will show that our premium process is both tractable and empirically successful.

In this exercise, moving away from microfoundations in the interest rate premium and the output externalities is desirable because we are not testing a specific mechanism but want to document whether any mechanism should be part of open economy models and what the salient features of such models should be. The parsimonious but flexible functional forms we employ allow various types of interplay between the variables of interest and fit a much larger number of moments compared to the previous literature remarkably well. We will see that the variety of functional forms employed here and the flexibility they afford is important given that there are differences between countries not only in terms of the size but also in terms of the sign of some of the key moments. These findings will underpin future fully microfounded models, where some will follow the important work of Bianchi et al. (2018) for countries that have moments similar to Mexico which was studied in that paper, but others will require thinking about alternative mechanisms because one size does not fit all as we show in the paper.

As noted above, our model allows direct output externalities from international reserve accumulation. We consider a variety of functional forms that can accommodate plausible shapes of output externalities in our analysis and select the best functional form for each country in our sample. This approach yields useful insights for understanding reserve dynamics in emerging markets.

To consider precautionary savings against sudden stops, we also introduce regime-switching into the model. There are two regimes in our model: normal times and crises. A crisis takes the form of a sudden stop where (a) output is reduced due to the endowment destruction and the loss of output externalities associated with international reserves and (b) borrowing from international capital markets is hampered through increased interest rate premium. These are key features of a sudden stop episode considered in the literature (Jeanne, 2007; Choi and Taylor, 2017; Bianchi et al., 2018). The occurrence of a sudden stop will be exogenous in our model (for example being triggered by changes in US monetary policy or by sunspots) but its consequences will be endogenous and depend on the prevailing debt and reserves at the time.

Our quantitative analysis, which involves structural estimation of our model, covers 24 emerging market countries for which we can obtain long time series for macroeconomic and financial variables, in a sample from 1970 to 2017. We use the Simulated Method of Moments for estimation. It is a natural extension to the existing literature that calibrates models against a small number of target moments, being more formal and systematic.

We show that both precautionary motive and output externalities matter for international reserve accumulation in many of our sample countries, with the contribution especially from the latter varying substantially in direction and magnitude. The observed heterogeneity informs the debate concerning the two motives behind reserve accumulation and demonstrates the usefulness of model-based inference like ours for studying this issue. We further find that a sudden stop is indeed different from an ordinary negative shock, leading to different responses of debt, reserves, and interest rate not only in the size of the reaction but also in the composition of net reserves. Overall, our results suggest that dynamics of debt and the real interest rate cannot be separated from dynamics of international reserves in emerging markets.

2 Empirical motivations

In this section, we provide empirical motivations for incorporating output externalities and regime-switching into a small open economy DSGE model to study the dynamics of international reserves. The literature has considered two main motives behind international reserve accumulation, mercantilism and precautionary savings. The former strand of the literature emphasizes output externalities associated with the reserve accumulation, for instance growth externalities from exporting activities (Benigno and Fornaro, 2012; Choi and Taylor, 2017; Choi and Pyun, 2019). The latter strand has focused on sudden stops in capital flows and explains the reserve accumulation during the normal times as insurance against sudden liquidity shocks that can dry up external borrowings during the crisis (Jeanne, 2007; Jeanne and Ranciere, 2011; Calvo et al., 2012; Hur and Kondo, 2016). Our structural analysis in the later sections of the paper will allow both motives to compete with\complement each other within the model and informs their contributions to the reserve accumulation. This is similar to the empirical focus of Aizenman and Lee (2007) and Ghosh et al. (2017), but with a model-based approach that allows clearer separation of different channels for reserve accumulation for a large set of countries.

2.1 Evidence for precautionary motives behind international reserve accumulation

We first provide evidence for the precautionary motive behind international reserve accumulation. To be able to argue that it is an increase in (perceived) sudden stop risk that has led to significantly higher levels of international reserves in emerging market countries relative to those in industrialized countries in the past quarter-century, we need to identify an event that is clearly associated with a revision in the risk assessment. For this, the countries that underwent the Asian Financial Crisis (AFC) in 1997 can serve as a useful laboratory. The absence of major economic crises in these countries up until the AFC allows us to investigate whether the AFC, the first major sudden stop episode in the region, triggered a reserve accumulation.

The policy stances in these countries long after the crisis allow us to assess whether the possibility of an abrupt crisis that is now in remembered history is internalized and reflected in the reserve management during normal times. In principle, it is possible to do this also with other emerging market countries in our sample. But this requires going back further in time and identifying a suitable triggering event, which is not as straightforward for these countries due to data availability as well as the lack of clear timing for an event of interest. Hence, we restrict our analysis to the AFC.

We focus on Indonesia, Korea, and Thailand, three countries that suffered heavily during the AFC,[2] for analysis and use the synthetic control matching method of Abadie and Gardeazabal (2003) to estimate what would have happened to reserves in these countries had they not encountered the AFC. These counterfactuals are constructed using countries that did not experience the AFC as control units.

For synthetic control matching, the sample units, in our case countries, are divided into two groups: the treatment group that consists of the units that receive the treatment under consideration, in our case the AFC, and the control group that consists of the units that do not receive the treatment. Each unit in the treatment group is matched with a synthetic counterpart, which is constructed by taking a weighted average of the control units. The weights are chosen so that controlled characteristics of the treatment and synthetic units are as close as possible in the period *before* the treatment. This is the sense in which these weights are optimal. Conditional on successful matching, the weights are applied to the outcome variable of the control units, which in our case is international reserves, to construct the outcome variable for the synthetic treatment unit without the treatment. The path of this variable in the period *after* the treatment serves as the counterfactual for the treatment unit, for instance the path of international reserves for a hypothetical Korea that had not experienced the AFC in 1997.[3] As shown below, the quality of matching can be inspected both numerically and graphically.

Indonesia, Korea, and Thailand are the treatment group and the control group consists of potentially similar countries that were not directly hit by the AFC.[4] The outcome variable

[2] Real GDP contracted by 16% in Indonesia, 8% in Korea, and 12% in Thailand in 1998. See Barro (2001) for a comparative analysis involving a host of macroeconomic variables.

[3] Because the weights are constrained to be non-negative and sum to one, the synthetic control matching method avoids extrapolation unlike regression methods. It is also more general than the standard difference-in-difference technique in not requiring the parallel trend assumption (Abadie, 2021).

[4] We use 25 countries as control units for the synthetic control: Algeria, Argentina, Belize, Brazil, Chile,

is ratio of international reserves to GDP and we use as control variables (log) population size in 1990, the average of (log) real GDP per capita from 1990 to 1996, trade openness in 1990, and the values of the outcome variable before the AFC, as commonly practiced (Abadie et al., 2010). Minimizing the quadratic distance in terms of these control variables between a treatment country and a weighted average of the control countries produces the optimal weights with which the control countries are combined to produce the synthetic treatment country.

Table 1 presents the weights assigned to the control group countries when constructing the synthetic path of international reserves to GDP for Indonesia, Korea, and Thailand. The control countries that receive zero weights in all cases are omitted from the table for brevity. The synthetic Indonesia is given by the weighted average of Pakistan, Mexico, Colombia, China, Belize, Egypt, and Malta, the synthetic Korea by the weighted average of Japan, Tunisia, Belize, Brazil, China, and Malta, and the synthetic Thailand by the weighted average of Egypt, Chile, and Belize, respectively (the control countries are enumerated in decreasing order of their weights). Table 2 compares the treatment countries with their synthetic counterparts that are put together using the weights in Table 1. It demonstrates that the synthetic countries are close to the actual treatment countries in their pre-treatment characteristics, indicating successful matching.

[Tables 1 and 2]

Figure 1 plots the actual and counterfactual paths of international reserves to GDP for our treatment countries. The timing of the AFC, which is our treatment, is marked by the vertical line. The plots on the left-hand-side of this line in each figure show that the synthetic treatment unit (dashed red line) successfully matches the actual treatment country (solid blue line) prior to the AFC. The divergence of the two lines occurs following the AFC validates the hypothesis that the AFC "caused" increased accumulation of international reserves in the treatment countries, with their difference giving the treatment effect.[5] The counterfactuals based on the synthetic units suggest that in the absence of the AFC in 1997, the pre-treatment

China, Colombia, Dominican Republic, Egypt, El Salvador, Gabon, Israel, Japan, Malta, Mexico, Morocco, Nigeria, Pakistan, Panama, Peru, South Africa, Tunisia, Turkey, Uruguay, and Venezuela.

[5]Note that while the control countries were not "treated" by the AFC, they clearly observed it and if that observation led them to fear a similar crisis for them, leading to increases in reserve accumulation, we will be estimating a lower bound on the precautionary motive. Even with that possible downward bias, the effect we find is sizable.

trends would have more or less continued to prevail in our treatment countries, at least for the next two or three years.[6] We also see that the actual reserves to GDP did not return to the pre-treatment levels even many years after the crisis had passed, suggesting a crucial role of precautionary motives in driving the reserve accumulation.[7]

[Figure 1]

Useful complementary evidence on the structural break following the AFC is provided by media coverage. Borrowing the idea from Baker et al. (2016) and Huang and Luk (2020), we construct an index for the media coverage of international reserves using articles from four major newspapers in Korea: Chosun Ilbo (the most conservative), Hankook Ilbo, Hankyoreh (the most liberal), and Kyunghyang Shinmun.[8] The sample period is from January 1990 to December 2007, covering roughly seven years before and ten years after the crisis (up to the Global Financial Crisis of 2008). For each newspaper and each month, we count (A) the number of newspaper articles containing the keywords related to international reserves and (B) the total number of newspaper articles. Then we calculate the ratio of the two numbers (A/B) for each newspaper and average these across the newspapers. The index captures the press interest on international reserves, proxying the public interest in the matter.

Figure 2 plots our monthly index of the press coverage on international reserves. The vertical axis is in percentage. As expected, the index surged in November 1997 when the AFC arrived in Korea, and it stayed elevated until March 1999. The index fell again after this period as Korea embarked on the recovery from the crisis, but the figure suggests that it settled on a level higher than that prior to the crisis. We formally test this observation in Table 3, excluding the crisis period from the analysis.[9] The test confirms our visual inspection, which implies that international reserves continued to receive heightened public interest even after

[6]This portion of the post-treatment period is where the estimated treatment effect is expected to be the most precise. Our findings also pass standard robustness tests, for instance leave-one-out tests that caution against disproportionate influences of certain control countries on the estimates (Abadie et al., 2015).

[7]This issue has been taken up in the literature in various ways, for instance by Lee and Luk (2018) who attribute the structural breaks in the reserve accumulation in Korea and Thailand to the increased uncertainty aversion of the policymakers in the aftermath of the AFC. The evidence in this section complements this using a different identification strategy.

[8]We use two sources for the newspaper articles: Big Kinds (https://www.bigkinds.or.kr/), which provides news database and analytics covering several media outlets in Korea, and Chosun Ilbo archive (http://srchdb1.chosun.com/pdf/i_archive/index.jsp). We control for the double counting of the keywords related to international reserves.

[9]Korea graduated from the IMF bail-out program in August 2001 and we take this to be the end of the crisis for conservatism.

the crisis formally ended.[10] This adds further support to our findings concerning the structural break in perception of risk and associated change in reserve management policy after the AFC.

[Figure 2 and Table 3]

The evidence thus far suggests the AFC was the watershed moment for the policymakers in the East Asian countries that were affected by the crisis. In particular, it provides support for the idea that once the policymaker became better informed about the likelihood and consequences of a sudden stop crisis, it was internalized and reflected in the management of the economy even during normal times, through more proactive international reserve accumulation that can serve as insurance against sudden stops, as also argued by Aizenman (2005) and Aizenman and Lee (2007). The practice can also be regarded as a macroprudential policy that sustains external borrowing by reducing exposure to financial crises (Arce et al., 2019) or a substitute for capital controls in pursuit of stable exchange rates (Ilzetzki et al., 2019), in each case foreign reserves serving as a risk management instrument. Our findings here lead us to consider a discrete regime-switching model in the following sections of the paper, where the crisis regime is modeled in the spirit of disaster risk (Barro, 2009). Considering the evidence for the structural break following the AFC, the empirical analysis based on our structural models will make use of only the post-AFC data for the countries in East Asia so that the perceived crisis regime risk is in the data used to fit the model.

2.2 Evidence for output externalities from international reserve accumulation

Finally, we provide suggestive evidence for output externalities associated with international reserve accumulation, albeit weaker than the evidence for the precautionary motive above in it not being causal but hopefully nonetheless informative. Again, we call this "output externalities" for lack of a better term, a catch all for output effects of reserves that do not manifest themselves as insurance payments (spending from reserves during crisis times) and through their effects on risk premia.

[10] In terms of absolute numbers, Chosun Ilbo (the most conservative) reported on average 1.8 articles per month on international reserves before November 1997 but 5.5 articles per month after September 2001. Hankyoreh (the most liberal) reported on average 1.4 articles per month before November 1997 but 3.7 articles per month after September 2001. The test result is not driven by a specific newspaper.

Figure 3 plots the average annual per capita GDP growth (in %) against the average annual reserve accumulation (as % of GDP) for 62 emerging market and developing countries between 1990 and 2007, which replicates Figure 1(c) of Benigno and Fornaro (2012) with our data. The slope coefficient for the OLS fitted line (in red) is 0.14 which is highly statistically significant. The positive relationship is consistent with the well-known argument in the literature that fast growing countries are net exporters of (public) capital because of their reserve accumulation activities (Gourinchas and Jeanne, 2011; Benigno and Fornaro, 2012). This pattern is consistent with the relationship between reserve accumulation and real exchange rate depreciation at one end and real exchange rate depreciation and growth externalities in the tradable sector on the other (Dooley et al., 2003; Choi and Taylor, 2017; Choi and Pyun, 2019), which define a mercantilistic motive. This leads us to consider output externalities from reserve accumulation in our model, and we do this using a variety of functional forms for the externalities as will be shown below.

[Figure 3]

Before moving to the model, it is also worth noting that at least the US Treasury believes countries use international reserves for output-related purposes. Its designation of "currency manipulator" countries is in part based on changes in reserves, with an argument that different countries increase their reserves to keep their currencies undervalued, increasing exports and growth.

3 Model

We model crises as sudden stops of capital flows and let a discrete regime shift capture this. The existence of two regimes, for normal and crisis times, and the transition probabilities are known by the model agents. The regime shifts, interest rate premium that the country has to pay above the world safe rate, and the output externalities are key model mechanisms that are incorporated in flexible forms. Below we first introduce the core mechanisms and functional forms that separate ours from a canonical small open economy model, then briefly discuss the standard dynamic optimization problem of the households that underpin the optimal decisions for debt and international reserves, as in standard open economy DSGE models.

3.1 Key mechanisms: sudden stops and output externalities

In Section 2, we showed that the AFC steered the behavior of the affected countries towards more aggressive management of international reserves, which can be interpreted as recognition and internalization of potential crises in managing the economy during normal times. To make this consideration also reflected in our model, and also highlight the abruptness with which an economic crisis can take place in an emerging market country, we make use of a discrete regime-switching framework in the spirit of disaster risk (Barro, 2009) where a crisis strikes infrequently but potentially destructively. In the model, $\Delta_t = 0$ corresponds to a normal time and $\Delta_t = 1$ a crisis at time period t. The transition law for the regime indicator Δ_t follows the Markov chain

$$\Pi = \begin{bmatrix} \pi_{00} & 1-\pi_{00} \\ 1-\pi_{11} & \pi_{11} \end{bmatrix} \tag{1}$$

where π_{00} (π_{11}) is the probability of being in the normal (crisis) regime next period conditional on being in the normal (crisis) regime currently.[11] A standard DSGE model without regime-switching is a special case where $\Delta_0 = 0$ and $\pi_{00} = 1$. Given our exclusive focus on emerging market countries, we define a crisis as a sudden stop episode where output is reduced and borrowing from international capital markets hampered through heightened interest rates, discretely.

We will work with a standard DSGE setup on the household sector, with output determined by an endowment process, which may be augmented with output externalities from reserves. It is easy to turn the endowment process into a microfounded production economy, but as discussed below, we will still need a flexible ad hoc functional form for the reserve externalities on top of this to capture various possible ways reserves may be affecting output. Hence, we keep the model simple and employ an endowment process with regime switching. Specifically, endowment output follows a first order autoregressive process

$$\log Y_{t+1} = \Delta_t \theta^Y + \rho^Y \log Y_t + \sigma^Y \epsilon^Y_{t+1} \tag{2}$$

where Y_t is output endowment in level and log is the natural logarithm, ϵ^Y_t is white noise with

[11] Here, the regime shift is exogenous hence this is not an optimal default type endogenous crisis but rather a calamity that happens to the country. However, estimating the model country by country as we do will make the transition probabilities reflect country specific factors and, importantly, how the crisis regime plays out will depend on the endogenous selection of debt and reserves.

zero mean and unit variance, $\theta^Y \leq 0$, $-1 < \rho^Y < 1$, and $\sigma^Y > 0$. With θ^Y negative, the crisis regime (where $\Delta_t = 1$) reduces the output endowment by this amount for its entire duration. This is distinguished from an ordinary negative impulse to the economy ($\epsilon_t^Y < 0$), which is a one time realization that is not expected to be repeated in the future. To keep things simple, we make the parameters ρ^Y and σ^Y invariant across the regimes in our model, but this can be easily generalized to be regime-dependent. Ultimately, it is an empirical question whether θ^Y is large enough in absolute value to be meaningful, and we explore this issue in Section 5 by formally estimating the parameter.

Total output in the economy is

$$Y_t^{Tot} = Y_t + (1 - \Delta_t)v_t \tag{3}$$

where $v_t = f(S_t)$ stands for the output externalities associated with international reserves stock at time period t, S_t. Total output, inclusive of the output externalities, is what constrains consumption in the intertemporal budget constraint. Adding this feature to the model allows us to decompose international reserve accumulation into that driven by precautionary and output motives, and informs the key debate in the literature regarding their relative importance. Similar to Choi and Taylor (2017), output externalities are present in normal times. Rather than considering detailed microfoundations for them, we introduce a variety of functional forms to model these, for instance those that can accommodate curvature/sign shifts in the output benefit of the reserves. Doing so allows us to focus on empirics, which this paper is mainly concerned with.

The domestic real interest rate in the model is

$$r_t = r^* + rpre_t \tag{4}$$

where r^* is the risk-free world real interest rate that is constant and taken as given by our small open economy and $rpre_t$ is the interest rate premium. We allow the premium to take the form

$$rpre_t = \varphi_0 \left(e^{\varphi_D(\frac{D_t}{Y_t} - \bar{d}) - \varphi_S(\frac{S_t}{Y_t} - \bar{s}) + \varphi_{DS}(\frac{D_t}{Y_t} - \bar{d})(\frac{S_t}{Y_t} - \bar{s})\Delta_t} - 1 \right) \tag{5}$$

where D_t is debt and S_t is international reserves. The functional form for the premium, which builds on that of Schmitt-Grohe and Uribe (2003),[12] is internally debt and reserve elastic, meaning the effects of debt and reserves on the premium are internalized in formulating capital account policy. φ_0 is a parameter that governs the overall degree of financial frictions, making the premium disappear when it is zero, and φ_D, φ_S, and are φ_{DS} are elasticities. $\bar{d}$ and $\bar{s}$ are technical parameters that facilitate matching model moments to targeted moments (Section 4.1).

The functional form of the interest rate premium function will help in separately determining debt and reserves over wide regions of parameter space where $\varphi_0, \varphi_D, \varphi_S > 0$.[13] For an expositional purpose, let us consider the normal regime (where $\Delta_t = 0$). The first and second own partial derivatives of equation (5) are both positive for debt and negative and positive for reserves, respectively. This takes away incentives to over-accumulate debt and reserves: the derivatives imply that the cost of incurring more debt rises and the benefit of accumulating more reserves falls as the quantities of these increase (Schmitt-Grohe and Uribe, 2017, chs. 4-5). The determinacy critically depends on the relative sizes of φ_D and φ_S: with a sufficiently large value for φ_S, the reduction of the premium can be achieved more efficiently by accumulating reserves rather than deleveraging,[14] and this ensures the uniqueness of the debt-reserve profile. This can be deduced from the cross partial derivative of equation (5) which is negative. The trade-off also remains in the long-run, which makes the deterministic steady state of the model also unique (Section 4.1). Appendix A provides a formal analysis of these issues.

The sudden stop enters the interest rate premium in equation (5) through the last term in the exponent. This term, which is not operative at the normal regime ($\Delta_t = 0$), is triggered upon entering a crisis ($\Delta_t = 1$) and contributes positively to the interest rate premium on impact if $\varphi_{DS}(\frac{D_t}{Y_t} - \bar{d})(\frac{S_t}{Y_t} - \bar{s}) > 0$.[15] Because φ_{DS} is estimated to be positive for all sample

[12] $\varphi_D = Y_t = 1$ and $\varphi_S = \varphi_{DS} = 0$ give their premium function. International reserves are not considered in their model. However, Edwards (1984) empirically demonstrates that the interest rate premium or spread is increasing in debt to output and decreasing in international reserves to output. The effects are large and statistically significant across different regression specifications, with the coefficient of reserves to output (in absolute value) exceeding that of debt to output in all cases. The premium function in equation (5) is motivated by this and the subsequent empirical literature, in particular Gumus (2011), whose analysis covers 16 of our 24 sample countries. Edwards also shows that equation (5) can be microfounded as a logistic probability model of sovereign default based on no arbitrate reasoning.

[13] This is similar to Devereux and Sutherland (2010) in resolving (local) equilibrium indeterminacy through a non-linear portfolio problem, in our case using the premium function in equation (5).

[14] Edwards (1984) and Bianchi and Sosa-Padilla (2020) find that debt-financed reserve accumulation does not necessarily lead to an increase in the interest rate premium and can contribute to debt sustainability. We provide evidence for this type of policy response based on an impulse response analysis in Section 5.3.

[15] Interest rates are highly countercyclical in emerging market economies, typically spiking during crises. See Neumeyer and Perri (2005), Uribe and Yue (2006), and Arellano (2008). The interest rate premium shock in

countries (Section 5.1) and $(\frac{D_t}{Y_t} - \bar{d})(\frac{S_t}{Y_t} - \bar{s})$ is almost always positive along simulation paths, the effect of entering the crisis regime on the premium is positive, leading to the spiking of the premium. However, this can occur along with markedly different responses of debt and reserves under different parametrizations of the model, which is of interest given the heterogeneity of our sample countries.

We will demonstrate this with impulse response functions that the regime shock is indeed different from the output shock in equation (2) in its consequences. The specification of this cross term (φ_{DS}) also captures the idea that even though the occurrence of a sudden stop crisis is exogenous to a small open economy, its impact–the magnitude of the crisis–depends on its portfolio of debt and reserves at the time. This, then, is a model where a small open economy faces an increased borrowing friction during a sudden stop episode, and we estimate the parameters in equation (5) to examine the strength of this channel. It will be shown that this premium process is both highly tractable and empirically successful.

The model features described above are indeed key components of theoretical models in the literature (Jeanne, 2007; Jeanne and Ranciere, 2011; Bianchi et al., 2018). Our contribution is to demonstrate how they fit together and work in a fully dynamic setting where these mechanisms are also allowed to have their own dynamics. This allows assessing their relative contributions to debt and international reserve management.

3.2 The rest of the model

The remaining blocks of the model are standard. The asset markets are incomplete due to the absence of state-contingent assets (Schmitt-Grohe and Uribe, 2003; Garcia-Cicco et al., 2010). The representative household has Constant Relative Risk Aversion (CRRA) preferences

$$U_t = E_t \sum_{\tau=0}^{\infty} \beta^{\tau} \frac{C_{t+\tau}^{1-\gamma} - 1}{1-\gamma} \tag{6}$$

where C_t is consumption at time period t, $0 < \beta \leq 1$ is the time discount factor, and $\gamma \geq 0$ is the coefficient of relative risk aversion.[16] The representative household faces the budget

equation (5) is similar in effect to the risk premium shock in Bianchi et al. (2018) which helps capture this observation.

[16] In Appendix B, we consider recursive preferences à la Epstein and Zin (1989) where the elasticity of intertemporal substitution is not necessarily restricted to be the reciprocal of the relative risk aversion as above.

constraint

$$C_t + (1 + r_t)D_t + S_{t+1} = Y_t + (1 - \Delta_t)v_t + D_{t+1} + (1 + r^*)S_t \tag{7}$$

which reflects the assumption that international reserves are safe assets earning risk-free returns. They maximize the utility in equation (6) subject to the constraint in equation (7) by choosing S_t and D_t. Trade balance in the model is the difference between total output in equation (3) and consumption, and for this reason the output externalities can also be interpreted as the trade externalities in the model.

We will demonstrate that this rather simple setup is quantitatively successful at matching the target moments involving debt, international reserves, and interest rate premium for emerging market countries in our sample.

3.3 Equilibrium

The equilibrium consists of the two first order conditions, with respect to D_t,

$$C_t^{-\gamma} = \beta E_t \left[\begin{pmatrix} 1 + r_{t+1} + \frac{D_{t+1}}{Y_{t+1}}\varphi_0(\varphi_D + \varphi_{DS}(\frac{S_{t+1}}{Y_{t+1}} - \bar{s})\Delta_{t+1}) \\ \times e^{\varphi_D(\frac{D_{t+1}}{Y_{t+1}} - \bar{d}) - \varphi_S(\frac{S_{t+1}}{Y_{t+1}} - \bar{s}) + \varphi_{DS}(\frac{D_{t+1}}{Y_{t+1}} - \bar{d})(\frac{S_{t+1}}{Y_{t+1}} - \bar{s})\Delta_{t+1}} \end{pmatrix} C_{t+1}^{-\gamma} \right] \tag{8}$$

and with respect to S_t,

$$C_t^{-\gamma} = \beta E_t \left[\begin{pmatrix} 1 + r^* + (1 - \Delta_{t+1})\frac{dv_{t+1}}{dS_{t+1}} + \frac{D_{t+1}}{Y_{t+1}}\varphi_0(\varphi_S - \varphi_{DS}(\frac{D_{t+1}}{Y_{t+1}} - \bar{d})\Delta_{t+1}) \\ \times e^{\varphi_D(\frac{D_{t+1}}{Y_{t+1}} - \bar{d}) - \varphi_S(\frac{S_{t+1}}{Y_{t+1}} - \bar{s}) + \varphi_{DS}(\frac{D_{t+1}}{Y_{t+1}} - \bar{d})(\frac{S_{t+1}}{Y_{t+1}} - \bar{s})\Delta_{t+1}} \end{pmatrix} C_{t+1}^{-\gamma} \right] \tag{9}$$

and (1), (2), (4), (5), and (7) above. The first order conditions reflect internal elasticities of debt and international reserves for the interest rate premium, respectively, with reserves also being shaped by the externality. As explained in Section 3.1, these allow debt and international reserves to be determinate in the model, both in the short-run and the long-run.

3.4 A demonstration of the model

Before proceeding to explain how we solve and estimate the model, we first demonstrate its empirical relevance by comparing its performance against select data moments and a standard model in the literature. To this end, we choose annual Mexican data and the model of Bianchi et al. (2018), which is calibrated to match these data. The model, which contains essential elements for studying international reserve management in relation to sudden stops, is more elaborate than our model in microfoundations, and more difficult to estimate for the same reason. Given that the literature has used the Mexican data for training and improving theoretical models, this exercise represents a necessary first hurdle for our model.

There is no clear guidance on how to model output externalities and which functional forms are relevant so we treat this as an empirical question to be studied and consider the following functional forms for the output externalities of international reserves in equation (3):

$$\text{Cobb-Douglas: } v_t = \phi_S(\frac{S_t}{Y_t} - s^*)^{\alpha_S} \tag{10}$$

$$\text{Exponential: } v_t = \phi_S e^{-\frac{\alpha_S}{2}(\frac{S_t}{Y_t} - s^*)^2} \tag{11}$$

$$\text{Logistic: } v_t = \frac{\phi_S}{1 + e^{-\alpha_S(\frac{S_t}{Y_t} - s^*)}} \tag{12}$$

$$\text{Gompertz: } v_t = \alpha_S \phi_S e^{\left(\phi_S + \alpha_S \frac{S_t}{Y_t} - \phi_S e^{\alpha_S \frac{S_t}{Y_t}}\right)} \tag{13}$$

The first three specifications involve three parameters ϕ_S, α_S, and s^* and the last specification two parameters ϕ_S and α_S.

These functional forms are flexible and cover many plausible shapes of the externalities. For demonstration, we fix $\phi_S = 0.0145$ and $s^* = 0$ and vary α_S for the first three specifications and fix $\alpha_S = 0.005$ and vary ϕ_S for the last specification and plot the resulting externality in Figure 4. It shows that these functions can produce various types of output externalities, with the Cobb-Douglas and logistic specifications being increasing in international reserves and the exponential specification being decreasing in international reserves for positive values of the reserves. For the Gompertz specification, the sign of the slope depends on the value of ϕ_S.[17]

These functions subsume some functional forms that have been studied in the literature. For instance, setting $\alpha_S = 1$ and $s^* = 0$ for the Cobb-Douglas specification essentially gives the model of Lee and Luk (2018) where the output externalities are linear in reserves. When $\phi_S = 0$, the externalities disappear in all specifications. For comparability with Bianchi et

[17] For example, the trade-off between the output benefit from international reserve accumulation and the social cost of public capital (Rodrik, 2006) can manifest as different shapes or forms of (net) output externalities. The externality function would be decreasing in reserves if the debt cost rises rapidly, as governed by the interest rate premium. In a microfounded model, the Marshall-Lerner condition will also affect the sign of the externality.

al. (2018), we look at (a) standard deviation of consumption to standard deviation of total output, (b) mean debt to total output and mean reserves to total output, (c) mean and standard deviation of interest rate premium, (d) correlations of total output with interest rate premium and consumption respectively. Table 4 gives the calibrated parameter values across these specifications. β is set to match the world real interest rate of 2.5% per annum, which also depends on other parameters that are fixed or calibrated (more on this in Section 4.1). d^* is the value of debt at the deterministic steady state of the model. The first seven parameters, ϕ_S, and α_S are fixed. The rest are set by simulation.

[Figure 4 and Table 4]

Table 5 shows how our models perform against annual Mexican data as well as Bianchi et al.'s (2018) model (both from Table 3 of their paper). Our simulated moments are generated using a long simulation (10,000 periods) starting from the deterministic steady state of the model. The results indicate that our models, even though simpler than the fully microfounded model of Bianchi et al., are empirically successful as far as these moments are concerned. Note that the exponential, logistic, and Gompertz specifications perform better than the Cobb-Douglas specification. These also do not lead to a low value of β, with its value being well within the range used in the literature for emerging market countries (for instance, $\beta = 0.92$ from Bianchi et al.).

[Table 5]

As noted before, it is to be expected that a model with flexible functional forms fit the data. But the model here is quite parsimonious and its good fit is not due to under identification. Understanding what the data requires of the model will help think about the next generation of fully microfounded models, which this paper endeavors to accomplish.

The positive findings here motivate us to go one step further and formally estimate these models, this time utilizing a broader set of moments including first two moments of international reserves, debt, interest rate premium, and trade balance. We take up this task in the following sections.

4 Solution and estimation

The regime-switching block of our model makes standard perturbation methods inapplicable because these cannot handle discrete shocks like the regime shocks. For this reason, we adopt the Taylor projection method of Levintal (2018). The method is more flexible than a perturbation method and faster than a projection method, which makes it ideal for the purpose of structural estimation. We also introduce our data set, which covers up to five decades of annual data for 24 emerging market countries, and explain our empirical strategy.

4.1 Solution

Our model economy is characterized by regime-switching: it switches between the normal regime and the crisis regime according to the transition probability in equation (1). Because standard perturbation methods can handle only continuous shocks, they are not applicable for solving our model where discontinuous regime shocks move the economy from one regime to another. As explained above, the crisis regime (where $\Delta_t = 1$) potentially alters the output endowment (equation 2), the output externalities (equation 3), and the interest rate premium (equation 5). For this reason, we need a solution method that produces an accurate solution against this non-linearity, which can take the model far away from the steady state at times. Levintal's (2018) Taylor projection method is one such solution method.

The Taylor projection method is a hybrid of projection and perturbation methods. It works with the residual function of a model (which is the case for any projection method) and obtains the solution by (a) approximating the residual function around an evaluation point and (b) finding the solution coefficients that make the approximated residual function and its derivatives zero. However, unlike projection methods that evaluate the residual function at a grid of points, the Taylor projection evaluates it at one chosen point. This feature makes it similar to perturbation methods.[18] Levintal (2018) shows that the Taylor projection method delivers a good trade-off between accuracy and speed in relation to other well-known solution methods. This is crucial for our purpose as we need to solve the model at least thousands of

[18]In fact, this is a special case of the Taylor projection method which (i) is not confined to use the deterministic steady state as an evaluation point for the approximation and (ii) does not require the volatility parameter to be set to zero for obtaining the solution. The two methods give an identical solution for a deterministic model evaluated at the steady state. In general, the Taylor projection solution is more accurate than the perturbation solution when the model features strong non-linearity and volatility. The perturbation solution is still important for solving our model as it serves as the initial guess for the Taylor projection solution.

times to estimate the parameters.

The simulation exercise in Section 3.4 above, which motivates formal estimation in the following section, was based on the fourth order Taylor projection solution. We continue to use the solution based on the fourth order approximation for the remainder of the paper. We use the deterministic steady state (denoted by dropping the time subscript from the variables) as an approximation point because it turns out the solution is not so sensitive to the choice of an evaluation point. The deterministic steady state is obtained by solving the following equations, which are the counterparts to equations (1) to (5) and (7) to (9):

$$\Delta = 0 \tag{14}$$

$$Y = 1 \tag{15}$$

$$D = d^* \text{ (set to debt to GDP in data)} \tag{16}$$

$$(1+(\varphi_D-\varphi_S)\frac{D}{Y})\varphi_0 e^{\varphi_D(\frac{D}{Y}-\bar{d})-\varphi_S(\frac{S}{Y}-\bar{s})} - \varphi_0 - \frac{dv_{t+1}}{dS_{t+1}}|_{S_{t+1}=S} = 0 \text{ (solve for } S \text{ numerically)} \tag{17}$$

$$r^* = \text{the world real interest rate} \tag{18}$$

$$r = r^* + \varphi_0 \left(e^{\varphi_D(\frac{D}{Y}-\bar{d})-\varphi_S(\frac{S}{Y}-\bar{s})} - 1 \right) \tag{19}$$

$$\beta = \frac{1}{\frac{dv_{t+1}}{dS_{t+1}}|_{S_{t+1}=S} + (1+r^*) + \frac{D}{Y}\varphi_0\varphi_S e^{\varphi_D(\frac{D}{Y}-\bar{d})-\varphi_S(\frac{S}{Y}-\bar{s})}} \tag{20}$$

$$C = Y + v(S) + r^* S - rD \tag{21}$$

Equation (17) is obtained from equating the two Euler equations in (8) and (9). d^* in equation (16) is set to the value of the average debt to GDP in our data for each country as this facilitates keeping the model counterpart close to this value (Fernandez-Villaverde et al., 2011). The parameters $\bar{d}$ and $\bar{s}$ that appear in equations (17) and (19) also help orienting the model variables towards targeted values. Equation (20) gives β that is consistent with a selected value for the world real interest rate r^* as discussed in Section 3.4 above, which also depends on estimated parameters related to output externalities and interest rate premium.

4.2 Data

For our empirical analysis based on the small open economy DSGE model above, we consider 24 emerging market countries for which we have sufficiently long time series across our variables of interest. The sample period is from 1970 to 2017, but for some variables/countries we use shorter samples due to data limitations. This is summarized in Table 6. For the East Asian countries in our sample, we use only the data after 1997 in light of the evidence for the structural break in Section 2.1.[19]

For a measure of interest rate premium, we use J. P. Morgan's Emerging Markets Bond Index Plus (EMBI+) spread. This is the average yield spread of US dollar denominated external debt securities of an emerging country government over debt securities of the US government.[20] For annual data on external debt, GDP, international reserves, and trade balance, we use the IMF's World Economic Outlook and the World Bank's World Development Indicators. Finally, to estimate the regime-switching probabilities in equation (1), we use the entire history of Laeven and Valencia's (2020) data set which provides the timings of crises in our sample countries between 1970 and 2017.

[Table 6]

4.3 Structural estimation

Using the data described in the previous subsection, we estimate our benchmark models. This continues from the calibration exercise in Section 3.4, this time using a broader set of target moments. In light of the findings there, as well as the results from an exploratory analysis, we consider only the exponential specification (equation 11), the logistic specification (equation 12), and the Gompertz specification (equation 13) for the output externalities from international reserves as the Cobb-Douglas specification (equation 10) is dominated by these in performance.

Our target moments are (a) means and standard deviations of external debt to GDP, in-

[19] Indonesia, Korea, Malaysia, the Philippines, and Thailand which Barro (2001) also classifies as "Asian-crisis countries." We also do this for Georgia and Russia as they were heavily affected by the Russian crisis that immediately followed. For these countries, using the post-crisis data ensures that the estimates we produce incorporate the knowledge that such crises are possible.

[20] Because the underlying securities are US dollar denominated, this can be used as a measure of real spread. For Argentina, Brazil, and Mexico, we extend back the data up to 1993 using Neumeyer and Perri's (2005) data set.

ternational reserves to GDP, trade balance to GDP, and interest rate spread, (b) correlations of interest rate spread with external debt to GDP and international reserves to GDP respectively, and (c) correlation of external debt to GDP and international reserves to GDP, 11 moments in total, with GDP in the model being total output in equation (3).[21] These involve variables that are demonstrated to be important for understanding reserves, debt, and interest rate spread in the empirical literature (Edwards, 1984; Aizenman and Lee, 2007; Ghosh et al., 2017) so they form natural target moments for our model-based analysis. The number of moments here is also greater than what we consider in Section 3.4 (but these do not subsume the target moments in Section 3.4 given the different focus), hence being more demanding on the model. As shown in Table 6, in some cases we are constrained by the availability of EMBI+ and external debt data. In these cases, we restrict the data range to that for the more limited series for computing joint moments.

We use the Simulated Method of Moments (SMM) (Lee and Ingram, 1991; Duffie and Singleton, 1993), matching the moments from the actual data as closely as possible to the moments from the simulated data to estimate the model parameters by minimizing the weighted quadratic distance between these. The method is applicable when the moment functions are not known analytically as in our model. Moreover, it performs well with a strongly nonlinear model like ours. Ruge-Murcia (2012) shows that the method is accurate even when the simulated series are relatively short, which is an important concern for us as we use annual frequency data for estimation, and computationally efficient which is consequential for us as we estimate the model for 24 countries across the three specifications for the output externalities and doing so requires heavy computation.

Because we do not prioritize a particular target moment over others, we use the identity matrix for the weighting matrix with the difference between the empirical and simulated moments scaled by the former. The simulated moments are generated using 1,000 simulation rounds that are 1,048 periods long each, with the initial 1,000 periods in each round discarded as the burn-in sample (48 is the maximum length of our annual data).

The transition probabilities π_{00} and π_{11} in equation (1) are estimated using the maximum-

[21] Our choice of target moments allows us to circumvent the issue of filtering as the input variables for the calculations are either as a share of GDP or a risk premium. Canova (1998) shows that business cycle facts can vary widely depending on detrending methods used. An alternative is to consider a variety of detrending methods as Schmitt-Grohe and Uribe (2017) do, but this can be computationally burdensome in a setting like ours that examines many countries across different model specifications.

likelihood method based on Laeven and Valencia's (2020) coding of crises.[22] As in Section 3.4, we fix $r^* = 0.025$, the value of the average risk-free US real interest rate that proxies for the risk-free world real interest rate. d^* is set to the value of the average external debt to GDP in the data as explained in Section 4.1. Finally, we set $\alpha_S = 1$ and $s^* = 0$ for the exponential and logistic specifications and $\alpha_S = 0.005$ for the Gompertz specification for output externalities, focusing on estimating ϕ_S that ultimately determines whether the externalities exist. This leaves the parameters to be estimated to be $\Theta = (\theta^Y, \rho^Y, \sigma^Y, \gamma, \varphi_0, \varphi_D, \varphi_S, \varphi_{DS}, \bar{d}, \bar{s}, \phi_S)$, 11 in total. Hence, the estimation using the SMM is just-identified (11 target moments for estimating 11 parameters). β is pinned down through equation (20) once the estimates of the elements of Θ are obtained.

5 Results

In presenting the results of the structural estimation, we first provide overall assessments of our sample countries to establish broad empirical patterns or regularities. Then, we discuss some of these countries in more detail to further our understanding of external debt, international reserve, and interest rate premium dynamics.

5.1 Model specifications and parameter estimates

Table 7 gives the specification for output externalities that is favored by data and the associated parameter estimates for each country. "E" under "Spec" stands for the exponential specification (equation 11), "L" for the logistic specification (equation 12), "G" for the Gompertz specification (equation 13), and "N" for none because the parameter ϕ_S is estimated to be practically zero in this case (i.e., the output externalities during normal times ($\Delta_t = 0$) are nil). The last two rows provide the regime-switching probabilities in equation (1) that are estimated separately as explained in Section 4.3.

[22] To achieve systematic crisis dating, we assume that a sovereign debt crisis ends with debt restructuring. For most debt crises, restructurings mark the end because they restore debt sustainability (Das et al., 2014). Even though this convention possibly overstates the duration of a crisis for a crisis-prone country, it is appropriate for our purpose as this accommodates a setting where a sudden stop pushes the economy into a regime marked by lower income and increased financial frictions until its resolution, akin to Latin America's *La Década Perdida* (The Lost Decade) in the 1980s (Ocampo, 2014). For a country with infrequent crises, this still possibly understates the perceived likelihood and duration of a crisis, for instance East Asian countries whose first and last major crisis was the AFC (more on this in Section 5.2).

[Table 7]

Our estimates of the risk aversion coefficient γ are consistent with what are commonly found (ranging from 0 to 5). Overall, the values of the discount factor β are also within a reasonable range. Turning to the interest rate premium function in equation (5), first note that φ_0 is positive in all sample countries. This indicates the presence of financial frictions which drive a wedge between the world real interest rate r^* and the domestic real interest rate r_t.

Note also that in all except for one sample country (South Africa), the estimate of φ_S in the interest rate premium function is larger than φ_D, for some countries the former being two to three times larger than the latter. This corroborates the regression-based finding of the empirical literature (Edwards, 1984; Gumus, 2011) that reserves are more effective than debt in managing the interest rate spread and makes a further case for the importance of international reserves in understanding the real interest rate dynamics in emerging market countries.

The effect of a sudden stop on the economy is rather nuanced. For all countries, φ_{DS} in equation (5) is positive. This suggests that a sudden stop has an independent effect on the interest rate premium over and above what goes on during normal times. However, the direct output effect of a sudden stop, which is determined by θ^Y in equation (2), is practically zero in some countries (Colombia, Dominican Republic, Indonesia, Turkey, and Venezuela). These countries are characterized by large estimates for σ^Y, which implies that output volatility is high even during normal times.[23] For these countries, the effect of a sudden stop mainly operates through the interest rate premium and augments the effect of volatile output shocks ϵ_t^Y. The total effect of a sudden stop episode on debt, reserves, and interest rate premium also depends on the estimates of other parameters in equations (2) and (5), which can make the sign, size, and timing of the effect heterogeneous across countries. We will explore this issue in the following subsections.

Finally, we turn to output externalities from international reserve accumulation. As discussed in Section 3.4, the externalities are not present in our model if $\phi_S = 0$. Table 7 suggests that this is the case for only four countries in our sample, which are labeled "N" under "Spec"

[23]For Indonesia, this is driven by high external debt volatility in the years following the AFC. Omitting these years leads to a lower estimate of σ^Y and a higher estimate of ρ^Y. We keep these data points for constructing target moments to implement a uniform procedure across our East Asian sample countries.

(Brazil, Dominican Republic, Indonesia, and Venezuela). For the rest, ϕ_S is positive, implying positive output externalities from reserve accumulation for all externality functions considered. In Section 5.4, we will examine how the behavior of debt, international reserves, and the interest rate premium changes when we shut off the externalities in these countries by setting $\phi_S = 0$.

In essence, the parameter estimates above suggest that both precautionary savings against sudden stops and output externalities matter in many of our sample countries, with international reserves serving as the main vehicle for these purposes. Below, we will use the model to decompose the relative importances of the two motives for sample countries.

5.2 Simulated moments

Using the model specification and the parameter estimates in Table 7, we simulate the model to generate artificial data to show that even though it is more difficult to fit well when the number of target moments increases, the model matches the data quite well in the dimensions we care about and can be used for analysis. Table 8 compares the target moments based on these (under "Model") to those based on the observed data (under "Actual"). As explained in Section 4.3, the model-based moments are averages of 1,000 simulation rounds. GDP in the model is total output in equation (3). "TB" stands for trade balance and $\sigma(.)$ for standard deviation. Other notation is identical to those in the previous sections. All numbers except for correlations, which are denoted by $corr(.)$, are in percentage.

[Table 8]

Overall, the model performs very well, especially considering its simple structure involving only two shocks: a white noise output shock ϵ_t^Y in equation (2) and a regime shock Δ_t that follows the Markov chain in equation (1).

First, the model matches levels of average external debt to GDP, international reserves to GDP, and interest rate premium in the data quite well. As expected from the parsimony of the interest rate premium function in equation (5), the model does better with debt to GDP and reserves to GDP than interest rate premium, but even so it behaves similarly to the data for the latter in most countries. It also does very well with the standard deviations. The performance for trade balance to GDP is relatively poorer, which is not surprising given that the model is not designed to fit well in this respect.

Debt to GDP, international reserves to GDP, and interest rate premium are of interest given the empirical literature that investigates the relationship between these variables. Recent studies that examine a positive correlation between private external debt and international reserves and relate this to a macroprudential policy where international reserves serve as a policy instrument (Arce et al., 2019) are also relevant here.

Note that our external debt series is broader and contains private external debt as a subcomponent. As shown in Table 8, the correlation between reserves to GDP and debt to GDP is positive for 14 countries and negative for 10 countries in the data. Our model, despite being simple, matches the sign of the correlation in the data correctly in all 24 sample countries, with the size of the correlation also very close in most countries. To a somewhat lesser degree, this is also the case for the correlations of reserves to GDP and debt to GDP with interest rate premium, respectively.

As mentioned above, we consider a larger number of target moments relative to the previous literature, which, conditional on keeping the model the same, makes a good fit less likely. Increasing the number of moments to be matched reduces the risk that the fit is good because of under identification but makes a good fit more difficult. The model proposed in this paper nonetheless fits well, making it a suitable tool for empirical analysis.

Finally, the results for Korea and Thailand, two countries studied in Section 2 to motivate the discrete regime-switching model in the paper, suggest that even though our model is broadly successful, it still faces a difficult time matching the large reserve buildup in East Asia, a difficulty also noted by Jeanne and Ranciere (2011). This not surprising given that the crisis probabilities estimated by the maximum-likelihood method are likely to understate the crisis probabilities perceived by policymakers in countries with relatively few crisis experiences. A better fit in this dimension can be achieved in the present model by increasing the likelihood and the persistence of the crisis regime in equation (1) above the values estimated from the data, or by introducing aversion to Knightian uncertainty as in Lee and Luk (2018). Despite the limitation of our approach–that equates subjective expectations of crises with objective ones in small samples, ignoring real and perceived peso problems, the results still indicate that the precautionary channel mattered in these countries.

Despite the simplicity, our models can account for a large number of target moments across our heterogeneous sample countries, validating our empirically motivated modeling strategy. Taking the findings here to be an indicator of model adequacy, in what follows we consider a variety of numerical experiments based on our models that inform the existing discourse in the literature.[24]

5.3 An impulse response analysis

To study shock propagation in our model we focus on impulse responses estimated for Argentina and Morocco. Even though both countries experienced severe and prolonged economic crises in the 1980s, their experiences diverged subsequently, with Morocco avoiding another major economic crisis since unlike Argentina which continued to encounter major crises in the following decades. Because they share the same exponential specification for the output externalities as shown in Table 7, this exercise can serve to further demonstrate the flexibility of our modeling approach to the extent that the two countries exhibit different adjustment patterns to shocks even though their underlying model specifications are identical.

Figure 5 presents the impulse response functions. In both cases, the initial condition is the stochastic steady state of the normal regime (where $\Delta_t = 0$) and the variables appear as either percentage change (consumption) or percentage point change (the rest) from their steady state values. The upper panel presents responses to one standard deviation negative output shock (ϵ_t^Y in equation (2)) and the lower panel to the regime shock that pushes the economy into a crisis (where $\Delta_t = 1$) that lasts for two periods, which in our case corresponds to two years (hence being on the milder end in duration).

[Figure 5]

In both countries, consumption declines and interest rate premium increases in response to either shock, with the premium increasing by disproportionately more following the regime shock. This is mainly driven by the term $\varphi_{DS}\left(\frac{D_t}{Y_t} - \bar{d}\right)\left(\frac{S_t}{Y_t} - \bar{s}\right)$ in equation (5), which is positive and sizable in both countries, hence spikes the premium over and above that for the i.i.d. shock.

Whereas Argentina responds to both shocks by increasing both debt and reserves relative to GDP, a pattern that was actually observed following the 2001 crisis, Morocco responds by

[24] Appendix B shows for select countries how the simulated moments change as the Elasticity of Intertemporal Substitution (EIS) deviates from the estimated value in Table 7, holding other parameters constant at their estimated values. We use Epstein-Zin preferences for this exercise so that it is possible to change the EIS without also changing the Relative Risk Aversion (RRA). As explained there, this exercise is well-defined because the CRRA utility function in equation (6) is a special case of the Epstein-Zin utility function where these two numbers restricted to be the inverse of one another, in which case the model FOCs are identical to those in Section 3.

drawing down on its reserve stock, with the magnitude being significantly larger in response to the regime shock. This is partly because Morocco holds more reserves than Argentina as a fraction of GDP (around twice as much on average) hence can afford to do this, and partly because its interest rate premium function is much less sensitive than Argentina's. This is due to the fact that the interest rate premium is both larger (and noisier) for Argentina than Morocco in the data, which is targeted in estimation. Moreover, the correlation between the premium and reserves to GDP is positive for Argentina but negative for Morocco due to reserves in Argentina being debt-financed and the debt increasing faster than reserves, increasing the premium. This captures debt-financing of reserves, which in the end shows up as the positive correlation between debt to GDP and reserves to GDP in the data for Argentina. For these to be reconciled in the model, (a) φ_0 needs to be higher in Argentina as it governs the overall sensitivity of the premium and (b) φ_D and φ_S need to be closer to each other in Argentina so that debt-financing of reserves is not as effective in decreasing the premium there. This is indeed what we see in our estimates in Table 7. This makes drawing down on reserves less costly in Morocco than Argentina, which leads to the differential response noted above. Finally, reserves bounce back quickly to the pre-crisis level in both countries once the crisis is over, a pattern noted by Dominguez et al. (2012) in relation to the 2008 global financial crisis.

Because the correlation between debt to GDP and reserves to GDP is negative for Morocco, targeting this in estimation shows up as debt to GDP increasing in response to the output shock in the model. This is not surprising given that the output shock is the only source of impulse in the normal regime which is more frequently visited according to our regime probability estimates. However, given that the negative correlation is only moderate, this needs to be offset by an opposing movement, which in this case produces parameter estimates that lead to debt to GDP decreasing in response to the regime shock. For instance, the estimates of φ_{DS} and β for Morocco are relatively large, which makes the expected future utility loss from an increased debt burden considerable if the crisis persists. This is reinforced by the fact that π_{11}, the probability of remaining in the crisis regime next period, is estimated to be relatively high in Morocco. Because Morocco experienced no further crisis since a long spell of economic problems in the 1980s in our sample, this can be taken to be a model prediction of what policy response would be if it were to face a sudden stop crisis, to some degree reflecting the peso problems akin to those for Korea and Thailand as discussed in Section 5.2.

The differences in the responses to the shocks are reflected in the simulated moments in

Table 8 above: whereas the correlation between (a) reserves to GDP and debt to GDP and (b) interest rate premium and reserves to GDP are positive in Argentina, they are negative in Morocco. Note that both adjustment patterns are optimal conditional on the interest rate premium functions (whose parametrizations reflect prevailing financial frictions) and the output externality functions in the model and contribute to macro-financial stability as measured by the premium. It is worth reemphasizing that these contrasting responses can be accommodated by our simple model, thus making it useful for model-based empirical analysis.

5.4 Shutting off output externalities or regime-switching

What is the quantitative significance of output externalities and sudden stops, the key features of our model, for external debt, international reserves, and interest premium? We address this question in this section, starting with output externalities.

Recall that output externalities disappear from the model when $\phi_S = 0$. To address the first half of the question, we select six countries whose output externalities are estimated to be non-zero, and perform a numerical counterfactual experiment of taking away the externalities by setting $\phi_S = 0$ while still allowing for regime-switching. The selected countries are Argentina, Jordan, Korea, Morocco, Thailand, and Turkey, which represent different stages of economic development as well as different parts of the world. Recall that Korea and Thailand are two of the AFC countries studied in Section 2.1 and Argentina and Morocco served as laboratories for studying shock propagation in Section 5.3.

In this exercise, it is not clear ex-ante what the direction of the effect should be. This depends on the relative magnitudes of income and substitution effects from output externalities. On the one hand, a weaker external effect makes the return from each unit of international reserves lower, which provides incentives to accumulate more reserves to maintain the desired level of consumption (income effect). On the other hand, a weaker external effect makes reserves more costly to accumulate, which disincentivizes the reserve accumulation (substitution effect). In any case, the larger the change in reserves to GDP is (whether positive or negative), the more important output externalities are in the model. Because in our setting reserve accumulation interacts with the interest rate premium, the analysis can be complicated.

For expositional convenience, consider the case where a country starts from a state without output externalities due to reserve accumulation. When the externalities suddenly appear, they do not only increase the rate of return on reserves (which are savings) but also raises incomes in all non-crisis periods (because the externalities are positive for all positive values of reserves). The size of increase is sensitive to the functional form of the externality, which is either exponential (equation 11) or logistic (equation 12) for the countries considered here. When the externalities are upward-sloping, as with the logistic function, reserves are very useful for increasing output, so one does not require so many units of reserves for this purpose and may even consider decreasing their stock. But reducing reserves comes at the cost of increasing the interest rate premium. It is possible that the increased income from externalities is more than sufficient to cover higher interest payments at the margin, leading to a lower level of reserves. This is a case where the income effect dominates as savings in the form of reserves decrease.

When the externalities are downward-sloping, as in the case of the exponential function, reserves are not as useful for increasing output as their output benefits are decreasing in the level of accumulation. This does not mean that they are not attractive because the additional income from the externalities can still be used to reduce the interest rate premium, which in turn helps with managing interest payments on debt. Hence, the stock of reserves may increase in the end. This is a case where the substitution effect dominates as savings in the form of reserves increase. So, the key trade-off involves the consideration for the interest rate premium, which makes the analysis more involved. Because debt also plays a role in this analysis, the actual mechanism is more complicated than what is discussed here, but this captures the thrust of the issue. Finally, reversing the direction of the change for the externalities makes the statement here consistent with that two paragraphs above.

Table 9 presents the results of the counterfactual experiment. "Baseline" gives the results for the case where the output externalities remain as estimated in Table 7 (which are copied from Table 8 for the ease of reference) and "No Ext" for the case where $\phi_S = 0$. As before, all numbers except for correlations are in percentage. The results are averages of 1,000 simulation rounds.

[Table 9]

Overall, the results are heterogeneous as expected from our selection of countries. For Argentina, Jordan, and Korea, both reserves to GDP and debt to GDP increase if the output externalities are closed off. This allows keeping the interest rate premium at a sustainable level, if not lower. Net reserves increase substantially for Jordan and Korea, which lead to a decrease in the interest rate premium. These are countries with the logistic output externalities, confirming the prediction that the income effect may dominate with this specification. However, for Morocco, Thailand, and Turkey, reserves to GDP decreases and debt to GDP increases, which inevitably decreases net reserves and raises the interest rate premium. These are countries with the exponential output externalities, where the substitution effect may dominate.

The magnitude of the change is varied, for instance ranging from -7.5 percentage points in Thailand to 36.1 percentage points in Korea for the reserves to GDP ratio. The numbers are rather modest for Argentina and Morocco, leaving the behavior of the economy nearly unchanged. This is not surprising given that their estimates of ϕ_S are much smaller than those of other countries also with the exponential specification. For these two countries, the precautionary motive clearly dominates output externalities, a proposition for which we will provide additional evidence below. These mixed findings may be why some authors have not found economically significant effects of mercantilistic variables for explaining reserve dynamics (Aizenman and Lee, 2007) aside from the issues concerning the availability of a suitable measurement for mercantilism (Ghosh et al., 2017). Also note that shutting off the externalities can alter the behavior of the economy qualitatively, with the correlation between reserves to GDP and debt to GDP turning negative in Turkey and the correlation between interest rate premium and reserves to GDP turning positive in Korea.

Next, we present the results for the experiment where regime-switching (hence the precautionary channel of reserve accumulation against sudden stops) is shut off instead, by setting $\Delta_0 = 0$ and $\pi_{00} = 1$ in equation (1), while still allowing for the output externalities from international reserve accumulation ($\phi_S \neq 0$). The results are provided under "No Prec" in Table 9.

Shutting off regime-switching increases both debt and reserves in Argentina, Morocco, and Thailand, increases reserves but decreases debt in Jordan, and decreases both debt and reserves in Korea. Because removing the possibility of the crisis regime by setting $\Delta_0 = 0$ and $\pi_{00} = 1$ eliminates the occasional spikes in the interest rate premium (which take place only inside the crisis regime; see equation 5), both the means and standard deviations of the interest premium decrease in all countries. This makes external borrowing cheaper and the management of the premium through reserve accumulation more predictable. It also raises the output endowment by removing the negative effect of the crisis through θ^Y (see equation 2), which can put upward pressure on reserves because it is their ratio that enters the premium function. Moreover, this removes the important risk due to the disappearance of the output externalities inside the crisis regime, increasing the expected return from the externalities with these now being ever-present.

For Argentina, Morocco, and Thailand, the countries with the exponential specification, this makes maintaining a larger gross position attractive in part because of the lower borrowing cost and in part due to the dominant substitution effect. The prediction for Turkey must be similar (which also has the exponential specification), but the results for Turkey are not available because removing the possibility of the crisis regime from the model makes total output too unstable and brings about explosive dynamics (hence the moments cannot be computed). This is not unexpected given that Turkey has a very large estimate for ϕ_S, which makes the output externalities unstably large. In the absence of occasional cleansing crises, this leads to the violation of the transversality condition.

The case for Korea, which has the logistic specification, is consistent with the dominant income effect, with reserve accumulation further declining. The case for Jordan, which also has the logistic specification, is more complicated because in this case the optimal decision is to accumulate more reserves to lower the premium. This is partly due to a relatively low value of ϕ_S which means the relatively weak income effect and partly due to the relatively high value of θ^Y which means the considerable output endowment gain, leading to more reserves and less debt to maintain the preferred level of the premium. The discussion so far confirms the point raised above, that the analysis can be complicated due to the interaction of debt and reserves with the premium function that is highly non-linear. Finally, for Argentina and Morocco, we observe significant reductions in net reserves, which is consistent with the precautionary motive playing a more important role for reserve accumulation in these countries as discussed above. Yet the analysis in Section 5.3 indicates that the responses to the regime shock are markedly different for these countries, which in conjunction with the results here illuminates the substantial heterogeneity across our sample countries.

6 Conclusion

We study the joint behavior of debt, international reserves, and the real interest rate in emerging markets. To this end, we propose a simple regime-switching small open economy model that incorporates the salient features of sudden stops, including an interest rate premium process that is flexible and highly tractable. We estimate the model for 24 emerging market countries and demonstrate that our simple model can successfully match various key stylized facts in the data.

We find that reserve accumulation is driven by both precautionary motive and output externalities in many of our sample countries, with the contribution from the latter varying in direction and magnitude. Overall, our results suggest that dynamics of international reserves are essential for understanding dynamics of debt and interest rate in emerging markets, and that such understanding is afforded by even a relatively small model, provided that functional forms of interest rate premium and output exernalities are chosen appropriately.

Our findings show that countries are differentially affected by debt and reserves. Thus, reduced form, cross-country regressions involving these variables likely are affected by the heterogeneity in responses. This set of results opens the door to thinking about the specifics of these economies to properly understand which features of these countries lead to the empirical findings presented here. Why are externality functions different across countries? Why are the responses of interest rate premia to debt and reserves different? What are the primitives and what are subject to policy? Documenting the empirical facts, as we have done in this paper, allows now asking these questions.

7 References

1. Abadie, A. (2021). Using Synthetic Controls: Feasibility, Data Requirements, and Methodological Aspects. *Journal of Economic Literature* 59(2), 391-425.

2. Abadie A. and Gardeazabal, J. (2003). The Economic Costs of Conflict: A Case Study of the Basque Country. *American Economic Review* 93, 113-132.

3. Abadie, A., Diamond, A. and Hainmueller, J. (2010). Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program. *Journal of the American Statistical Association* 105, 493-505.

4. Abadie, A., Diamond, A., and Hainmueller, J. (2015). Comparative Politics and the Synthetic Control Method. *American Journal of Political Science* 59(2), 495-510.

5. Aguiar, M. and Gopinath, G. (2007). Emerging Market Business Cycles: The Cycle Is the Trend. *Journal of Political Economy* 115(1), 69-102.

6. Aizenman, J. (2005). International Reserves. In: S. N. Durlauf and L. E. Blume (ed.), The New Palgrave Dictionary of Economics, Palgrave Macmillan.

7. Aizenman, J. and Lee, J. (2007). International Reserves: Precautionary Versus Mercantilist Views, Theory and Evidence. *Open Economies Review* 18(2), 191-214.

8. Arce, F., Bengui, J. and Bianchi, J. (2019). A Macroprudential Theory of Foreign Reserve Accumulation. NBER Working Paper 26236.

9. Arellano, C. (2008). Default Risk and Income Fluctuations in Emerging Economies. *American Economic Review* 98(3), 690-712.

10. Baker, S., Bloom, N. and Davis, S. (2016). Measuring Economic Policy Uncertainty. *The Quarterly Journal of Economics* 131(4), 1593-1636.

11. Barro, R. J. (2001). Economic Growth in East Asia before and after the Financial Crisis. NBER Working Paper 8330.

12. Barro, R. J. (2009). Rare Disasters, Asset Prices, and Welfare Costs. *American Economic Review* 99(1), 243-264.

13. Benigno, G. and Fornaro, L. (2012). Reserve Accumulation, Growth and Financial Crises. CEPR Discussion Paper 9224.

14. Bernanke, B. S. (2005). The Global Savings Glut and the U.S. Current Account Deficit. Speech 77, Board of Governors of the Federal Reserve System (U.S.).

15. Bianchi, J., Hatchondo, J. C. and Martinez, L. (2018). International Reserves and Rollover Risk. *American Economic Review* 108(9), 2629-2670.

16. Bianchi, J. and Sosa-Padilla, C. (2020). Reserve Accumulation, Macroeconomic Stabilization, and Sovereign Risk. NBER Working Paper 27323.

17. Bocola, L. and Lorenzoni, G. (2020). Financial Crises, Dollarization, and Lending of Last Resort in Open Economies. *American Economic Review* 110(8), 2524-57.

18. Calvo, G. A., Izquierdo, A. and Loo-Kung, R. (2012). Optimal Holding of International Reserves: Self-insurance against Sudden Stop. NBER Working Paper 18219.

19. Canova, F. (1998). Detrending and Business Cycle Facts. *Journal of Monetary Economics* 41(3), 475-512.

20. Choi, W. J. and Pyun, J. H. (2019). Catching Up by Deglobalization: Capital Account Policy and Economic Growth. Available at SSRN 3516385.

21. Choi, W. J. and Taylor, A. M. (2017). Precaution Versus Mercantilism: Reserve Accumulation, Capital Controls, and the Real Exchange Rate. NBER Working Paper 23341.

22. Das, U. S., Papaioannou, M. G. and Trebesch, C. (2014). Restructuring Sovereign Debt: Lessons from Recent History. In: Stijn Claessens, M. Ayhan Kose, Luc Laeven and Fabian Valencia (ed.), *Financial Crises: Causes, Consequences, and Policy Responses*, chapter 19, 593-620.

23. Devereux, M. B. and Sutherland, A. (2010). Country Portfolio Dynamics. *Journal of Economic Dynamics and Control* 34(7), 1325-1342.

24. Dominguez, K. M. E., Hashimoto, Y. and Ito, T. (2012). International Reserves and the Global Financial Crisis. *Journal of International Economics* 88(2), 388-406.

25. Dooley, M. P., Folkerts-Landau, D. and Garber, P. (2003). An Essay on the Revived Bretton Woods System. NBER Working Paper 9971.

26. Duffie, D. and Singleton, K. J. (1993). Simulated Method of Moments Estimation of Markov Models of Asset Prices. *Econometrica* 61(4), 929-952.

27. Durdu, C. B., Mendoza, E. G. and Terrones, M.E. (2009). Precautionary Demand for Foreign Assets in Sudden Stop Economies: An Assessment of the New Mercantilism. *Journal of Development Economics* 89(2), 194-209

28. Edwards, S. (1984). LDC Foreign Borrowing and Default Risk: An Empirical Investigation. *American Economic Review* 74(4), 726-734.

29. Epstein, L. G. and Zin, S. E. (1989). Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework. *Econometrica* 57(4), 937-969.

30. Farmer, R. E. A., Waggoner, D. F. and Zha, T. (2011). Minimal State Variable Solutions to Markov-switching Rational Expectations Models. *Journal of Economic Dynamics Control* 35(12), 2150-2166.

31. Fernandez-Villaverde, J., Guerron-Quintana, P., Rubio-Ramirez, J. F. and Uribe, M. (2011). Risk Matters: The Real Effects of Volatility Shocks. *American Economic Review* 101(6), 2530-2561.

32. Gandelman, N. and Hernandez-Murillo, R. (2015). Risk Aversion at the Country Level. *Review*, Federal Reserve Bank of St. Louis 97(1), 53-66.

33. Garcia-Cicco, J., Pancrazi, R. and Uribe, M. (2010). Real Business Cycles in Emerging Countries?. *American Economic Review* 100(5), 2510-2531.

34. Ghosh, A. R., Ostry, J. D. and Tsangarides, C. G. (2017). Shifting Motives: Explaining the Buildup in Official Reserves in Emerging Markets since the 1980s. *IMF Economic Review* 65(2), 308-364.

35. Gourinchas, P.-O. and Jeanne, O. (2011). Capital Flows to Developing Countries: The Allocation Puzzles. *The Review of Economic Studies* 80(4), 1484-1515.

36. Gumus, I. (2011). Exchange Rate Policy and Sovereign Spreads in Emerging Market Economies. *Review of International Economics* 19(4), 649-663.

37. Huang, Y. and Luk, P. (2020). Measuring Economic Policy Uncertainty in China. *China Economic Review* 59, 101367.

38. Hur, S. and Kondo, I. O. (2016). A Theory of Rollover Risk, Sudden Stops, and Foreign Reserves. *Journal of International Economics* 103(C), 44-63.

39. Ilzetzki, E., Reinhart, C. M. and Rogoff, K. S. (2019). Exchange Arrangements Entering the Twenty-first Century: Which Anchor Will Hold. *The Quarterly Journal of Economics* 134(2), 599-646.

40. Jeanne, O. (2007). International Reserves in Emerging Market Countries: Too Much of a Good Thing? *Brookings Papers on Economic Activity* 38(1), 1-80.

41. Jeanne, O. and Ranciere, R. (2011). The Optimal Level of International Reserves for Emerging Market Countries: A New Formula and Some Applications. *Economic Journal* 121(555), 905-930.

42. Jung, K. M. and Pyun, J. H. (2016). International Reserves for Emerging Economies: A Liquidity Approach. *Journal of International Money and Finance* 68, 230-257.

43. Korinek, A. and Serven, L. (2016). Undervaluation through Foreign Reserve Accumulation: Static Losses, Dynamic Gains. *Journal of International Money and Finance* 64, 104-136.

44. Laeven, L. and Valencia, F. (2020). Systemic Banking Crises Database II. *IMF Economic Review* 68, 307-361.

45. Lee. B.-S. and Ingram, B. F. (1991). Simulation Estimation of Time-series Models. *Journal of Econometrics* 47(2-3), 197-205.

46. Lee, S. S. and Luk, P. (2018). The Asian Financial Crisis and International Reserve Accumulation: A Robust Control Approach. *Journal of Economic Dynamics and Control* 90, 284-309.

47. Levintal, O. (2018). Taylor Projection: A New Solution Method for Dynamic General Equilibrium Models. *International Economic Review* 59, 1345-1373.

48. Neumeyer, P. A. and Perri, F. (2005). Business Cycles in Emerging Economies: The Role of Interest Rates. *Journal of Monetary Economics* 52(2), 345-380.

49. Obstfeld, M., Shambaugh, J. C. and Taylor, A. M. (2010). Financial Stability, the Trilemma, and International Reserves. *American Economic Journal: Macroeconomics* 2(2), 57-94.

50. Ocampo, J. A. (2014). The Latin American Debt Crisis in Historical Perspective. In: Joseph E. Stiglitz and Daniel Heymann (ed.), *The Origins and Resolutions of Debt Crises*, chapter 2, 87-115.

51. Rodrik, D. (2006). The Social Cost of Foreign Exchange Reserves. *International Economic Journal* 20(3), 253-266.

52. Ruge-Murcia, F. (2012). Estimating Nonlinear DSGE Models by the Simulated Method of Moments: With an Application to Business Cycles. *Journal of Economic Dynamics and Control* 36(6), 914-938.

53. Schmitt-Grohe, S. and Uribe, M. (2003). Closing Small Open Economy Models. *Journal of International Economics* 61, 163-185.

54. Schmitt-Grohe, S. and Uribe, M. (2017). *Open Economy Macroeconomics.* Princeton University Press.

55. Uribe, M. and Yue, V. Z. (2006). Country Spreads and Emerging Countries: Who Drives Whom? *Journal of International Economics* 69(1), 6-36.

Tables and Figures

Table 1: The weights for constructing the synthetic treatment countries

	Indonesia	Korea	Thailand
Belize	0.130	0.068	0.242
Brazil	0	0.059	0
Chile	0	0	0.372
China	0.131	0.001	0
Colombia	0.135	0	0
Egypt	0.053	0	0.385
Japan	0	0.502	0
Malta	0.012	0.001	0
Mexico	0.225	0	0
Pakistan	0.314	0	0
Tunisia	0	0.369	0

Note: The treatment countries are Indonesia, Korea, and Thailand, and the row entries provide the synthetic control weights assigned to the control countries for constructing the synthetic treatment countries.

Table 2: The comparison of the actual and synthetic treatment countries

Indonesia		
	Actual	Synthetic
Log Population in 1990	19.016	17.669
Average Log GDP per Capita	8.592	8.603
Trade Openness in 1990 (in %)	52.892	49.461
Reserves to GDP in 1987 (in %)	7.365	7.261
Reserves to GDP in 1991 (in %)	7.938	8.158
Reserves to GDP in 1992 (in %)	8.161	7.676
Reserves to GDP in 1994 (in %)	6.859	7.478
Korea		
	Actual	Synthetic
Log Population in 1990	17.574	17.199
Average Log GDP per Capita	9.571	9.570
Trade Openness in 1990 (in %)	51.261	54.015
Reserves to GDP in 1985 (in %)	2.862	2.835
Reserves to GDP in 1988 (in %)	6.268	6.199
Reserves to GDP in 1991 (in %)	4.206	4.194
Reserves to GDP in 1994 (in %)	5.628	5.608
Thailand		
	Actual	Synthetic
Log Population in 1990	17.851	15.917
Average Log GDP per Capita	9.006	8.915
Trade Openness in 1990 (in %)	75.782	72.875
Reserves to GDP in 1985 (in %)	5.630	7.741
Reserves to GDP in 1988 (in %)	9.886	9.872
Reserves to GDP in 1991 (in %)	17.832	15.354
Reserves to GDP in 1994 (in %)	19.997	19.979

Note: The table compares the pre-treatment characteristics of the actual and synthetic treatment countries (that are constructed using the weights in Table 1).

Table 3: The test for equality of means (two sample t-test with unequal variances)

	Mean	Std. Dev.
Before the AFC (BAFC) Jan 1990 to Oct 1997	0.063	0.064
After the AFC (AAFC) Sep 2001 to Dec 2007	0.107	0.047
mean(BAFC) - mean(AAFC)	-0.044	
Standard error	0.009	
T-test statistic	-5.123	
H_0: Difference = 0 (p-value)	8.282E-07	
H_0: Difference < 0 (p-value)	0.999	

Note: The table tests the equality of means of monthly index of the press coverage on international reserves for Korea before and after the AFC.

Table 4: Model calibrations under different output externality functions

Parameters	Cobb-Douglas	Exponential	Logistic	Gompertz
π_{00}	0.95			
π_{11}	0.5			
θ^Y	-0.04			
ρ^Y	0.95			
σ^Y	0.025			
γ	2			
r^*	0.025			
β	0.8848	0.9245	0.9279	0.9260
φ_0	0.2482	0.125	0.108	0.109
φ_D	0.699	0.5	0.5	0.5
φ_S	0.763	0.75	0.79	0.852
φ_{DS}	0.5	1	1	1.07
$\bar{d}$	0.68	0.7	0.73	0.7
$\bar{s}$	0.44	0.49	0.51	0.462
ϕ_S	0.0145			1
α_S	1			0.005
s^*	0.02	0.412	0.47	n/a
d^*	0.44	0.48	0.48	0.48

Note: See the text for the model descriptions and parameter definitions.

Table 5: Actual and simulated moments

Moments	Mexican Data	Bianchi et al.	Cobb-Douglas	Exponential	Logistic	Gompertz
SD of Consumption to SD of Total Output	1	1	1	1	1	1
Mean of Debt to Total Output	43%	43.5%	42%	42%	42.5%	43%
Mean of International Reserves to Total Output	8.5%	6%	8.2%	8.6%	8.5%	8.5%
Mean of Interest Rate Premium	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
SD of Interest Rate Premium	0.9%	2%	0.6%	0.9%	0.8%	0.8%
Corr of Interest Rate Premium and Total Output	-0.5	-0.7	-0.5	-0.5	-0.5	-0.5
Corr of Consumption and Total Output	0.8	0.9	0.99	0.99	0.99	0.99

Note: "SD" stands for standard deviation and "Corr" for correlation. See the text for the model descriptions.

Table 6: Data coverage

Country	EMBI+	External Debt	GDP	International Reserves	Trade Balance
Argentina	1993-2017	1970-2017	1970-2017	1970-2017	1970-2017
Belize	2007-2017	1970-2017	1970-2017	1976-2017	1980-2017
Brazil	1994-2017	1970-2017	1970-2017	1970-2017	1970-2017
Chile	1999-2017	1996-2015	1970-2017	1970-2017	1970-2017
Colombia	1997-2017	1970-2017	1970-2017	1970-2017	1970-2017
Dominican Republic	2001-2017	1970-2017	1970-2017	1970-2017	1970-2017
Ecuador	1995-2017	1970-2017	1970-2017	1970-2017	1970-2017
Georgia	2008-2017	1992-2017	1990-2017	1995-2017	1987-2017
Indonesia	2004-2017	1970-2017	1970-2017	1970-2017	1970-2017
Jordan	2011-2017	1970-2017	1970-2017	1970-2017	1976-2017
Korea	1997-2004	1980-2015	1970-2017	1970-2017	1970-2017
Malaysia	1997-2017	1970-2017	1970-2017	1970-2017	1970-2017
Mexico	1994-2017	1970-2017	1970-2017	1970-2017	1970-2017
Morocco	1997-2006 2012-2017	1970-2017	1970-2017	1970-2017	1970-2017
Panama	1997-2017	1970-2017	1970-2017	1970-2017	1970-2017
Peru	1997-2017	1970-2017	1970-2017	1970-2017	1970-2017
Philippines	1997-2017	1970-2017	1970-2017	1970-2017	1970-2017
Poland	1997-2017	1994-2015	1970-2017	1984-2017	1990-2017
Russia	1997-2017	1997-2017	1997-2017	1997-2017	1997-2017
South Africa	1997-2017	1970-2017	1970-2017	1970-2017	1970-2017
Thailand	1997-2006	1970-2017	1970-2017	1970-2017	1970-2017
Turkey	1996-2017	1970-2017	1970-2017	1970-2017	1970-2017
Uruguay	2001-2017	1982-2015	1970-2017	1970-2017	1970-2017
Venezuela	1997-2017	1970-2014	1970-2014	1970-2014	1970-2014

Note: See the text for the data sources.

Table 7: The specification for output externalities and parameter estimates

Country	Argentina	Belize	Brazil	Chile	Colombia	Dom Rep	Ecuador	Georgia	Indonesia	Jordan	Korea	Malaysia
Spec	E	L	N	E	E	N	E	L	N	L	L	L
γ	3.6643	4.2126	2.6154	2.4259	0.2581	0.0478	2.5128	1.8680	0.0070	0.0747	0.1197	1.0599
φ_0	0.5244	0.1465	0.1841	0.2073	0.1035	0.1647	0.1041	0.1483	0.0190	0.0222	0.0684	0.0498
φ_D	0.5201	0.5891	0.5331	0.4577	0.4637	0.4547	0.4811	0.4880	0.4805	0.2206	0.4333	0.4730
φ_S	0.5740	0.6103	1.6774	1.0070	0.7945	0.9538	0.6963	0.8046	1.6033	0.7128	0.5719	0.8702
φ_{DS}	0.5736	0.3296	2.1784	0.7920	1.5438	2.0042	0.9366	1.9949	1.5370	0.6927	1.3772	1.5391
$\bar{s}$	0.7084	0.5427	0.1802	0.3287	0.5321	0.3562	0.5339	0.3922	0.7615	1.0580	0.6776	0.8082
$\bar{d}$	0.9740	0.8149	0.1408	0.4471	0.8987	0.5306	0.8814	0.4842	0.6572	0.3135	0.3889	0.4392
ϕ_S	0.0048	0.0103	0.0000	0.0170	0.0526	0.0000	0.0207	0.0171	0.0000	0.0066	0.0617	0.0293
ρ^Y	0.5435	0.9891	0.9927	0.9947	0.7114	0.3797	0.9972	0.9996	0.2489	0.9977	0.8367	0.8142
σ^Y	0.0553	0.0248	0.0470	0.0255	0.1902	0.3489	0.0292	0.0192	0.5171	0.0112	0.1534	0.0624
θ^Y	-0.0003	-0.0143	-0.0230	-0.0080	0.0000	0.0000	-0.0070	-0.0096	0.0000	-0.0126	-0.0078	-0.0009
β	0.8640	0.9291	0.8686	0.9581	0.9582	0.9186	0.9445	0.8828	0.9395	0.9518	0.9560	0.9394
π_{00}	0.7904	0.9337	0.9014	0.9024	0.9308	0.9442	0.8981	0.9488	0.9787	0.9783	0.9787	0.9786
π_{11}	0.7845	0.3237	0.8344	0.7358	0.3920	0.8597	0.8415	0.0000	0.4902	0.7856	0.4902	0.6540

Country	Mexico	Morocco	Panama	Peru	Philippines	Poland	Russia	S Africa	Thailand	Turkey	Uruguay	Venezuela
Spec	E	E	L	E	E	L	G	L	E	E	G	N
γ	2.3567	2.8938	1.5867	4.0801	2.3870	1.4059	3.6418	0.1772	3.3263	0.1175	2.0533	0.2070
φ_0	0.0333	0.2071	0.1034	0.0658	0.2156	0.1218	0.3388	0.6373	0.1532	0.1697	0.1096	0.9681
φ_D	0.4562	0.1406	0.3799	0.2521	0.1986	0.4610	0.1919	0.8275	0.1699	0.6209	0.5123	0.1385
φ_S	0.7416	0.3138	0.5891	0.4832	0.4843	0.8842	0.7481	0.6769	0.5170	1.1925	0.8918	0.3526
φ_{DS}	1.2690	0.8047	1.2720	0.6106	0.3969	0.9211	2.4523	0.1655	0.9935	0.4900	1.1456	1.0306
$\bar{s}$	0.4465	0.4899	0.4669	0.5376	0.4192	0.4302	0.4433	0.4008	0.3756	0.4632	0.4618	0.4967
$\bar{d}$	0.7439	0.6609	0.7595	0.9541	0.2980	0.5594	0.0011	0.3956	0.2013	0.8375	0.6371	0.4873
ϕ_S	0.0172	0.0042	0.0168	0.0273	0.0142	0.0268	0.0167	0.0256	0.0285	0.1534	1.0266	0.0000
ρ^Y	0.7053	0.8448	0.9952	0.8022	0.9170	0.9969	0.8564	0.9973	0.6526	0.4381	0.9729	0.2328
σ^Y	0.0368	0.0768	0.0275	0.0539	0.0977	0.0297	0.0932	0.0030	0.0575	0.3153	0.0263	0.2124
θ^Y	-0.0112	-0.0094	-0.0131	-0.0108	-0.0127	-0.0135	-0.0017	-0.0205	-0.0006	0.0000	-0.0112	0.0000
β	0.9713	0.9431	0.9164	0.9688	0.9271	0.9535	0.8703	0.9186	0.9477	0.9165	0.9600	0.8526
π_{00}	0.9165	0.9771	0.9761	0.9381	0.9454	0.9761	0.8126	0.9498	0.9546	0.8943	0.9121	0.8486
π_{11}	0.7710	0.8946	0.9143	0.8846	0.8514	0.9143	0.3822	0.8033	0.5883	0.6239	0.7974	0.7334

Note: See the text for the model descriptions and parameter definitions. "E" stands for exponential, "G" for Gompertz, and "L" for logistic specification for the output externalities from international reserve accumulation. "N" stands for none which means the country does not exhibit the output externalities.

Table 8: Actual and simulated target moments

Country	Argentina		Belize		Brazil		Chile		Colombia		Dominican Rep	
Moments	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model
mean(S/GDP)	6.274	6.390	11.500	12.648	7.176	6.996	12.962	13.082	9.601	9.924	4.168	4.233
mean(D/GDP)	43.293	25.160	53.009	43.538	27.863	23.291	9.562	7.997	31.563	20.883	33.656	27.702
mean(rpre)	13.700	7.278	10.220	0.556	5.356	5.473	1.504	0.906	3.343	0.881	4.967	4.549
mean(TB/GDP)	1.863	2.347	-7.607	1.028	-0.017	-0.017	1.504	-0.070	-1.251	-0.189	-6.488	1.219
σ(S/GDP)	4.172	3.307	6.034	7.516	4.964	4.817	6.380	0.269	3.632	2.983	2.143	2.347
σ(D/GDP)	27.402	8.053	29.457	8.262	9.867	3.668	5.366	0.409	7.713	11.644	14.548	11.905
σ(rpre)	16.044	7.889	4.088	0.285	3.515	1.657	0.462	0.477	1.824	1.958	2.491	2.041
σ(TB/GDP)	3.564	3.664	6.496	0.425	2.509	2.606	4.580	0.183	3.701	4.812	3.056	3.784
corr(S/GDP,D/GDP)	0.326	0.296	0.360	0.999	-0.287	-0.282	-0.138	-0.142	0.028	0.028	0.141	0.141
corr(rpre,S/GDP)	0.278	0.297	0.122	-0.015	-0.635	-0.624	0.378	0.395	-0.212	-0.216	-0.419	-0.406
corr(rpre,D/GDP)	0.930	0.359	-0.096	-0.002	0.739	0.797	-0.024	-0.024	0.553	0.220	-0.043	-0.043
Country	Ecuador		Georgia		Indonesia		Jordan		Korea		Malaysia	
Moments	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model
mean(S/GDP)	4.268	4.776	12.096	13.997	13.408	12.102	29.877	29.452	22.169	7.827	39.051	40.552
mean(D/GDP)	46.449	18.309	66.565	64.536	52.728	46.723	83.503	96.384	11.574	10.444	52.174	49.141
mean(rpre)	11.606	2.640	5.195	5.204	2.676	3.111	3.679	1.940	1.966	1.740	1.807	2.289
mean(TB/GDP)	-1.435	-0.292	-18.612	4.706	3.664	2.852	-30.584	3.743	3.463	-0.045	15.694	1.186
σ(S/GDP)	1.815	2.914	6.360	0.727	3.541	3.843	12.265	7.921	5.903	6.949	8.403	4.153
σ(D/GDP)	25.010	3.451	24.237	1.727	33.318	20.733	46.369	27.401	4.258	3.958	7.463	10.951
σ(rpre)	6.491	6.951	2.900	2.901	0.930	0.820	0.532	0.626	1.340	0.470	0.964	0.540
σ(TB/GDP)	2.892	0.780	4.756	0.575	3.592	3.767	10.835	12.218	2.759	2.598	6.700	2.994
corr(S/GDP,D/GDP)	0.436	0.481	0.709	0.573	0.870	0.739	-0.160	-0.151	0.447	0.402	-0.250	-0.152
corr(rpre,S/GDP)	0.438	0.417	-0.369	-0.491	-0.598	-0.319	-0.668	-0.538	-0.254	-0.247	-0.312	-0.493
corr(rpre,D/GDP)	0.589	0.547	-0.553	0.120	-0.149	-0.159	-0.509	-0.423	0.781	0.648	0.398	0.651

Note: Continued on the next page.

Country	Mexico		Morocco		Panama		Peru		Philippines		Poland	
Moments	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model
mean(S/GDP)	5.959	9.484	11.799	12.136	5.315	5.559	14.377	20.285	20.271	22.226	13.921	5.686
mean(D/GDP)	32.813	14.848	50.533	33.220	81.285	92.995	51.975	14.921	47.576	33.059	14.143	3.889
mean(rpre)	3.665	0.257	3.238	2.176	2.778	3.049	3.207	0.242	3.058	2.281	1.508	1.538
mean(TB/GDP)	-0.496	0.082	-7.723	1.051	-7.671	5.310	-0.437	-0.253	-5.061	1.031	-0.888	-0.821
σ(S/GDP)	4.397	5.278	9.551	8.980	2.944	4.172	9.820	11.869	5.944	5.467	5.253	6.249
σ(D/GDP)	14.657	12.672	23.096	21.397	44.151	12.880	20.025	17.418	20.735	16.480	7.306	3.655
σ(rpre)	2.940	0.530	1.758	1.839	1.124	0.712	1.817	0.972	1.557	1.309	0.708	0.596
σ(TB/GDP)	2.926	3.334	4.790	5.238	4.091	2.965	4.432	5.102	3.101	3.880	3.255	1.221
$corr$(S/GDP,D/GDP)	-0.064	-0.067	-0.538	-0.591	0.412	0.354	-0.601	-0.480	-0.822	-0.754	0.701	0.645
$corr$(rpre,S/GDP)	-0.543	-0.264	-0.708	-0.797	0.202	0.162	-0.807	-0.826	-0.747	-0.838	-0.089	-0.093
$corr$(rpre,D/GDP)	0.596	0.394	0.825	0.532	-0.568	0.087	0.927	0.460	0.927	0.893	-0.533	0.315

Country	Russia		South Africa		Thailand		Turkey		Uruguay		Venezuela	
Moments	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model	Actual	Model
mean(S/GDP)	19.476	19.277	4.305	4.317	33.993	20.716	6.285	6.312	10.714	13.288	12.118	11.805
mean(D/GDP)	38.468	34.717	13.394	13.720	41.205	37.439	35.609	27.054	16.039	11.611	39.633	32.249
mean(rpre)	6.450	7.782	2.451	2.317	1.534	1.829	3.843	2.957	3.545	0.956	11.403	14.693
mean(TB/GDP)	9.424	3.127	1.993	1.999	6.382	0.941	-3.326	0.826	-0.119	0.052	5.366	3.649
σ(S/GDP)	9.498	9.461	4.536	5.766	8.764	7.665	3.877	3.903	9.044	2.063	5.835	5.856
σ(D/GDP)	15.877	11.774	15.460	3.240	19.417	10.332	11.660	10.736	7.967	2.753	19.197	11.453
σ(rpre)	9.046	5.686	0.961	1.012	1.093	0.919	1.889	1.597	2.455	0.872	7.544	6.612
σ(TB/GDP)	4.252	4.883	3.445	2.724	4.580	4.693	2.422	3.035	3.041	1.112	8.073	8.151
$corr$(S/GDP,D/GDP)	-0.638	-0.847	0.921	0.934	-0.645	-0.665	0.563	0.482	0.797	-0.228	0.105	0.106
$corr$(rpre,S/GDP)	-0.681	-0.398	-0.093	-0.093	-0.469	-0.756	-0.300	-0.271	-0.643	0.677	-0.636	-0.584
$corr$(rpre,D/GDP)	0.947	0.620	0.109	0.110	0.949	0.829	0.533	0.434	-0.198	0.195	-0.414	-0.373

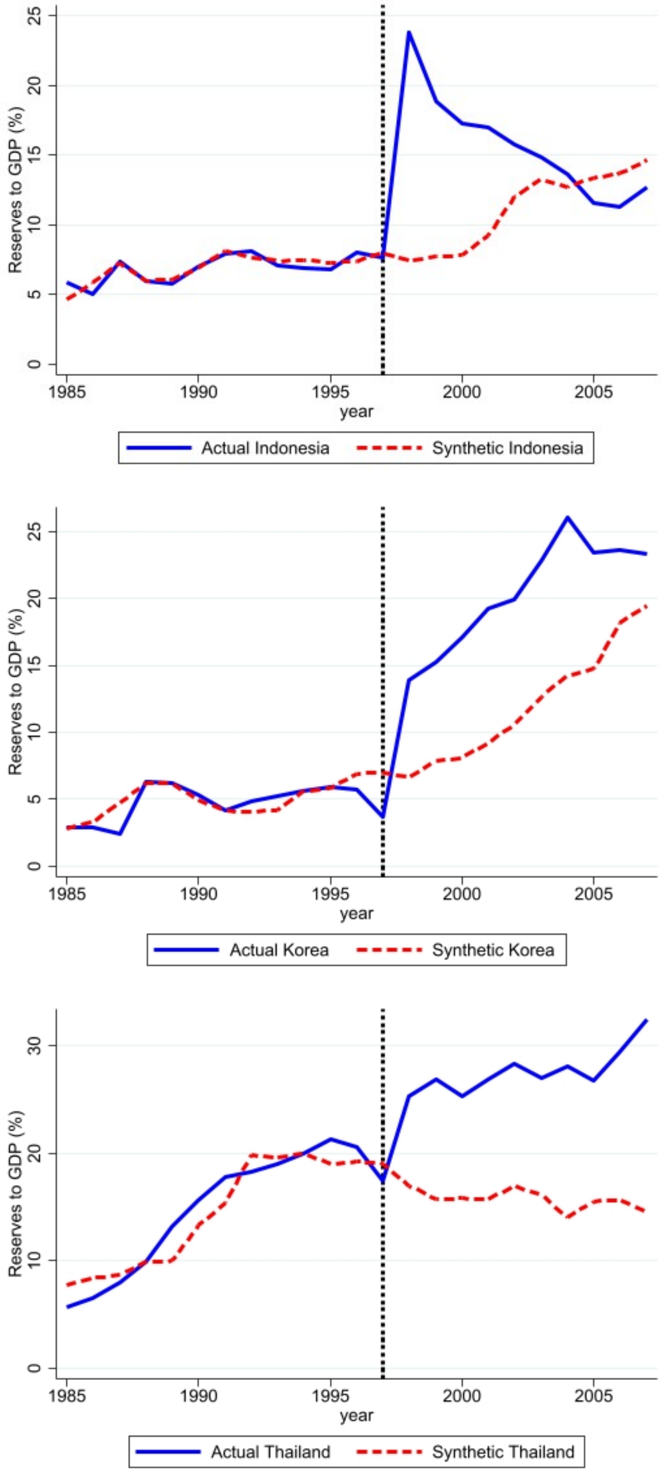
Note: $\sigma(.)$ stands for standard deviation and $corr(.)$ for correlation. “S” is international reserves, “D” is external debt, “rpre” is interest rate premium, and “TB” is trade balance.

Table 9: Shutting off output externalities or regime-switching

Country	Argentina			Jordan			Korea		
Moments	Baseline	No Ext	No Prec	Baseline	No Ext	No Prec	Baseline	No Ext	No Prec
mean(S/GDP)	6.390	6.419	15.173	29.452	41.581	37.713	7.827	43.917	6.111
mean(D/GDP)	25.160	25.524	39.592	96.384	97.886	83.178	10.444	11.289	9.558
mean(rpre)	7.278	7.348	1.023	1.940	1.631	1.824	1.740	0.130	1.726
mean(TB/GDP)	2.347	2.384	1.058	3.743	3.055	2.658	-0.045	-1.319	-0.036
σ(S/GDP)	3.307	3.323	17.287	7.921	7.434	0.247	6.949	5.082	7.041
σ(D/GDP)	8.053	8.104	21.563	27.401	22.320	0.218	3.958	8.329	3.482
σ(rpre)	7.889	7.860	0.612	0.626	0.499	0.009	0.470	0.287	0.331
σ(TB/GDP)	3.664	3.705	1.765	12.218	10.615	0.290	2.598	4.489	2.613
corr(S/GDP,D/GDP)	0.296	0.299	1.000	-0.151	-0.564	-0.222	0.402	0.959	0.408
corr(rpre,S/GDP)	0.297	0.280	0.989	-0.538	-0.312	-0.217	-0.247	0.243	-0.569
corr(rpre,D/GDP)	0.359	0.328	0.988	-0.423	-0.336	-0.265	0.648	0.413	0.465
Country	Morocco			Thailand			Turkey		
Moments	Baseline	No Ext	No Prec	Baseline	No Ext	No Prec	Baseline	No Ext	No Prec
mean(S/GDP)	12.136	11.401	14.742	20.716	13.179	23.183	6.312	0.490	-
mean(D/GDP)	33.220	33.423	38.043	37.439	39.214	37.692	27.054	32.014	-
mean(rpre)	2.176	2.237	1.479	1.829	2.558	1.675	2.957	4.842	-
mean(TB/GDP)	1.051	1.100	1.045	0.941	1.507	0.843	0.826	1.962	-
σ(S/GDP)	8.980	8.907	3.276	7.665	6.461	5.913	3.903	1.791	-
σ(D/GDP)	21.397	21.702	22.730	10.332	12.147	9.896	10.736	12.480	-
σ(rpre)	1.839	1.842	0.942	0.919	0.890	0.844	1.597	2.052	-
σ(TB/GDP)	5.238	5.259	5.037	4.693	4.729	4.546	3.035	2.826	-
corr(S/GDP,D/GDP)	-0.591	-0.588	-0.986	-0.665	-0.731	-0.964	0.482	-0.660	-
corr(rpre,S/GDP)	-0.797	-0.783	-0.986	-0.756	-0.682	-0.961	-0.271	-0.846	-
corr(rpre,D/GDP)	0.532	0.534	0.959	0.829	0.887	0.859	0.434	0.712	-

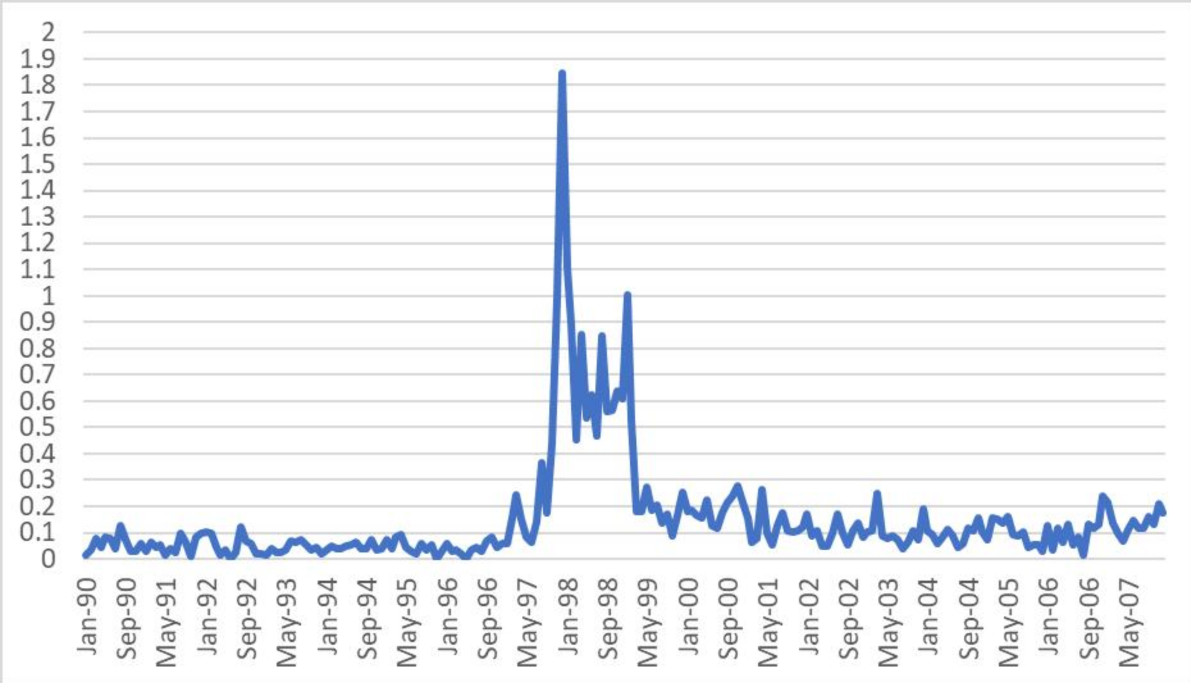
Note: See Table 8 for the definitions.

Figure 1: Actual and counterfactual (synthetic) paths of international reserves



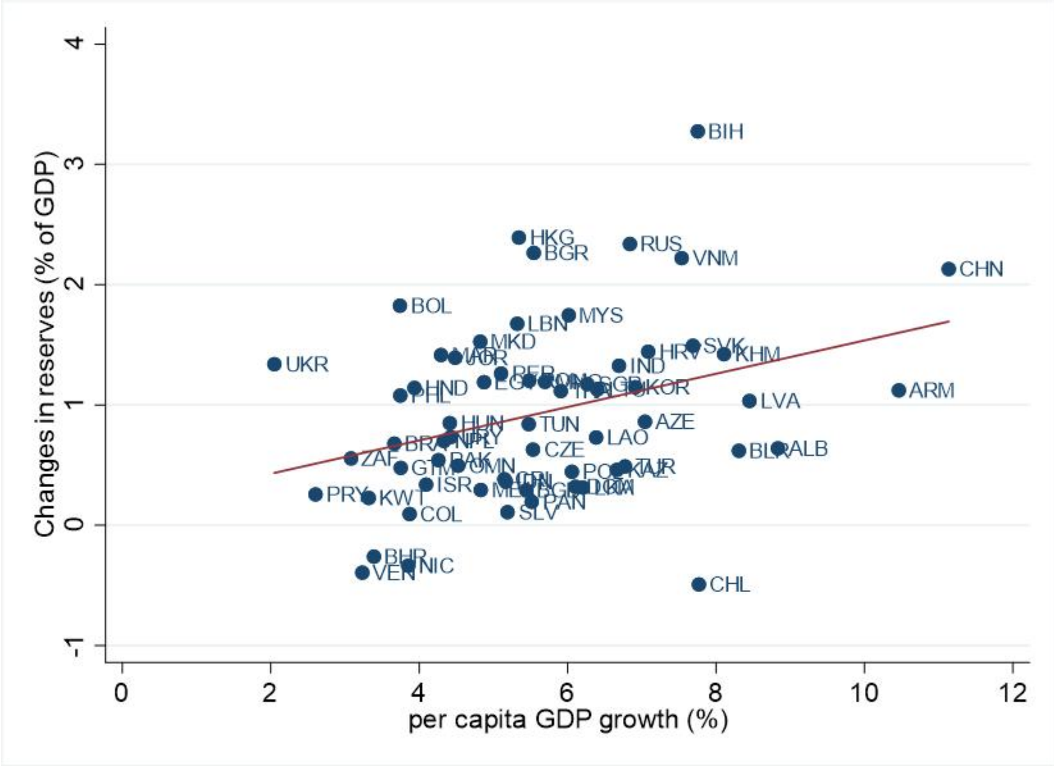
Note: The treatment is the AFC and the treatment year is 1997. It is indicated by the (black) vertical dotted line.

Figure 2: A monthly index of the press coverage on international reserves in Korea



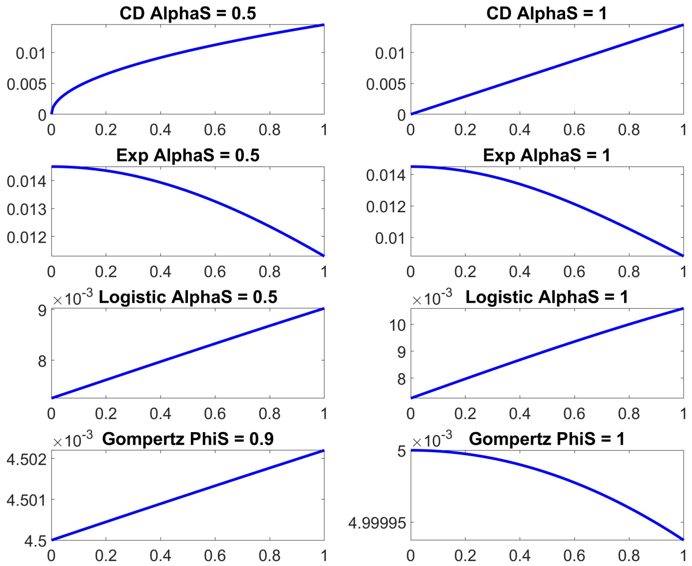
Note: This monthly index is produced by first taking the ratio of the number of newspaper articles on international reserves to the number of total newspaper articles per newspaper, which is multiplied by 100 to give the percentage interpretation, and then averaging across newspapers. We use four major newspapers in Korea: Chosun Ilbo, Hankook Ilbo, Hankyoreh, and Kyunghyang Shinmun.

Figure 3: The correlation between per capita output growth and reserve accumulation



Note: The figure plots the average annual per capita GDP growth (in %) against the average annual reserve accumulation (as % of GDP) for 62 emerging market and developing countries between 1990 and 2007.

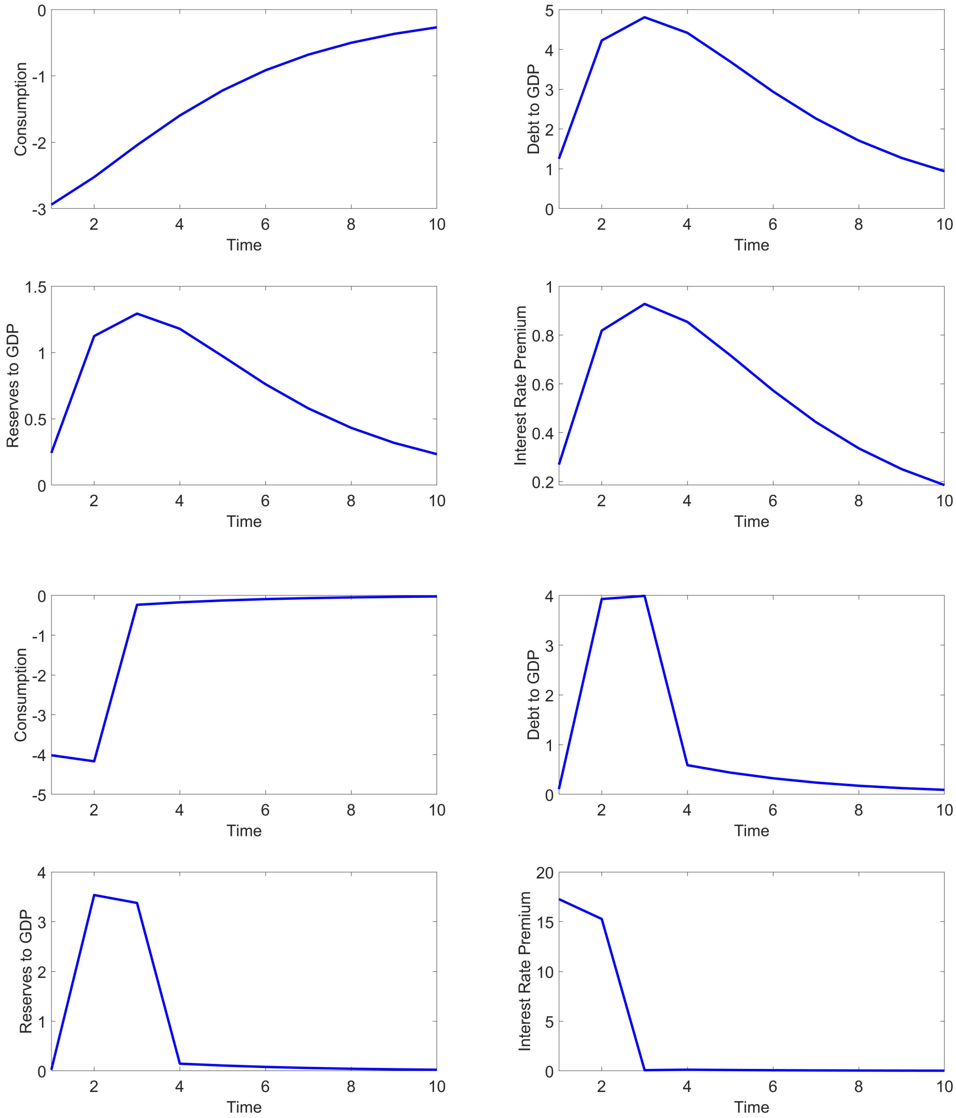
Figure 4: Shapes of output externalities



Note: See the text for the parametrization.

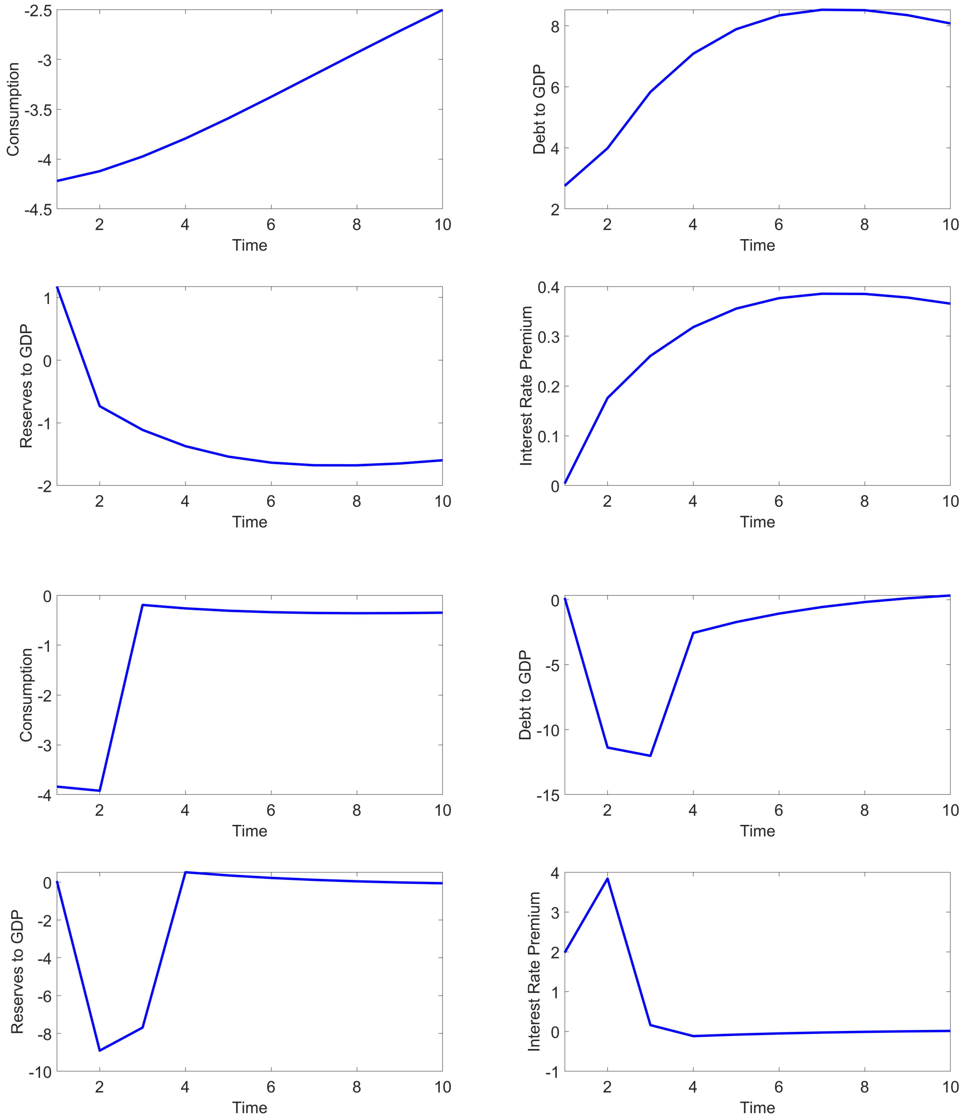
Figure 5: Impulse response functions

5.1 Argentina



Note: Continued on the next page.

5.2 Morocco



Note: The variables appear as either percentage change (consumption) or percentage point change (the rest) from their steady state values. The upper panel gives responses to one standard deviation negative output shock and the lower panel to the regime shock that pushes the economy into a crisis that lasts for two periods.

Appendix

A Additional details on the model properties

In Section 3.1, we explain that the determinacy of our model critically depends on the relative sizes of φ_D and φ_S. In addition to the determinacy issue, these parameters also govern the quantitative aspect of the comovement between debt and international reserves in the model. In what follows, we analyze these properties in detail. Because uncertainty and output externalities are not essential for examining these issues, we mainly consider a simpler model without these features here for expositional convenience.

Under a perfect foresight equilibrium, the Euler equations are

$$C_t^{-\gamma} = \beta \left(1 + r^* - \varphi_0 + (1 + \frac{D_{t+1}}{Y_{t+1}} \varphi_D) \varphi_0 e^{\varphi_D (\frac{D_{t+1}}{Y_{t+1}} - \bar{d}) - \varphi_S (\frac{S_{t+1}}{Y_{t+1}} - \bar{s})} \right) C_{t+1}^{-\gamma}$$

$$C_t^{-\gamma} = \beta \left(1 + r^* + \frac{D_{t+1}}{Y_{t+1}} \varphi_0 \varphi_S e^{\varphi_D (\frac{D_{t+1}}{Y_{t+1}} - \bar{d}) - \varphi_S (\frac{S_{t+1}}{Y_{t+1}} - \bar{s})} \right) C_{t+1}^{-\gamma}.$$

These imply the restriction

$$(1 + (\varphi_D - \varphi_S) \frac{D_{t+1}}{Y_{t+1}}) e^{\varphi_D (\frac{D_{t+1}}{Y_{t+1}} - \bar{d}) - \varphi_S (\frac{S_{t+1}}{Y_{t+1}} - \bar{s})} = 1$$

that needs to be satisfied at all times. Taking the total differential of this gives

$$(\varphi_D + (\varphi_D - \varphi_S)(1 + \varphi_D \frac{D_{t+1}}{Y_{t+1}})) dD_{t+1} = \varphi_S (1 + (\varphi_D - \varphi_S) \frac{D_{t+1}}{Y_{t+1}}) dS_{t+1}$$

which leads to the derivative

$$\frac{dS_{t+1}}{dD_{t+1}} = \frac{\varphi_D + \varphi_D (\varphi_D - \varphi_S) \frac{D_{t+1}}{Y_{t+1}} + (\varphi_D - \varphi_S)}{\varphi_S + \varphi_S (\varphi_D - \varphi_S) \frac{D_{t+1}}{Y_{t+1}}}.$$

The derivative depends only on debt which is not surprising because the interest premium applies only to debt. Recall that $\varphi_D, \varphi_S > 0$. It follows that

$$\frac{dS_{t+1}}{dD_{t+1}} \begin{cases} > 1 & \text{if } \varphi_D > \varphi_S \\ = 1 & \text{if } \varphi_D = \varphi_S \\ < 1 & \text{if } \varphi_D < \varphi_S \end{cases} .$$

Intuitively, the more effective international reserves are in lowering the premium, the lesser is the increase. In the second case ($\varphi_D = \varphi_S$), it is clear that only $D_{t+1} - S_{t+1}$ (i.e., net debt-reserve portfolio) is determinate. The second derivative is

$$\frac{d^2 S_{t+1}}{dD_{t+1}^2} = -\frac{\frac{\varphi_S(\varphi_D - \varphi_S)^2}{Y_{t+1}}}{(\varphi_S + \varphi_S(\varphi_D - \varphi_S)\frac{D_{t+1}}{Y_{t+1}})^2} \leq 0 \text{ because } \varphi_S > 0.$$

The magnitude depends on φ_D and φ_S (and D_{t+1}), being equal to zero when $\varphi_D = \varphi_S$ as expected. So, the rate at which international reserves increase is (weakly) decreasing in the debt level. This suggests that incentive to over-accumulate international reserves is limited as discussed in Section 3.1.

Now, we analyze the (local) determinacy property of the simpler model. For expositional convenience, we set $Y_t = Y$ for all t. The system to be solved consists of

$$C_t^{-\gamma} = \beta \left(1 + r^* + \frac{D_{t+1}}{Y} \varphi_0 \varphi_S e^{\varphi_D(\frac{D_{t+1}}{Y} - \bar{d}) - \varphi_S(\frac{S_{t+1}}{Y} - \bar{s})}\right) C_{t+1}^{-\gamma}$$

$$(1 + (\varphi_D - \varphi_S)\frac{D_{t+1}}{Y})e^{\varphi_D(\frac{D_{t+1}}{Y} - \bar{d}) - \varphi_S(\frac{S_{t+1}}{Y} - \bar{s})} = 1$$

$$Y + (D_{t+1} - S_{t+1}) = C_t + (1 + r^*)(D_t - S_t) + \varphi_0 \left(e^{\varphi_D(\frac{D_t}{Y} - \bar{d}) - \varphi_S(\frac{S_t}{Y} - \bar{s})} - 1\right) D_t.$$

The linear approximation of these equations around the steady state (after appropriate substitutions) gives

$$(1 + \varphi_D \frac{D}{Y})(1 - \beta(1 + r^*))\hat{D}_{t+1} - \varphi_S \frac{S}{Y}(1 - \beta(1 + r^*))\hat{S}_{t+1} - \gamma \hat{C}_{t+1} = -\gamma \hat{C}_t$$

$$D(\varphi_D + (\varphi_D - \varphi_S)(1 + \varphi_D \frac{D}{Y}))\hat{D}_{t+1} - S\varphi_S(1 + (\varphi_D - \varphi_S)\frac{D}{Y})\hat{S}_{t+1} = 0$$

$$D\hat{D}_{t+1} - S\hat{S}_{t+1} = \frac{D}{\beta}\hat{D}_t - \frac{S}{\beta}\hat{S}_t + C\hat{C}_t$$

which in the state space form is

$$\underbrace{\begin{bmatrix} (1+\varphi_D\frac{D}{Y})(1-\beta(1+r^*)) & -\varphi_S\frac{S}{Y}(1-\beta(1+r^*)) & -\gamma \\ D(\varphi_D+(\varphi_D-\varphi_S)(1+\varphi_D\frac{D}{Y})) & -S\varphi_S(1+(\varphi_D-\varphi_S)\frac{D}{Y}) & 0 \\ D & -S & 0 \end{bmatrix}}_{A} \begin{bmatrix} \hat{D}_{t+1} \\ \hat{S}_{t+1} \\ \hat{C}_{t+1} \end{bmatrix} =$$

$$\underbrace{\begin{bmatrix} 0 & 0 & -\gamma \\ 0 & 0 & 0 \\ \frac{D}{\beta} & -\frac{S}{\beta} & C \end{bmatrix}}_{B} \begin{bmatrix} \hat{D}_t \\ \hat{S}_t \\ \hat{C}_t \end{bmatrix}.$$

As usual, the hat notation refers to percentage deviation from steady state. Pre-multiplying each side by

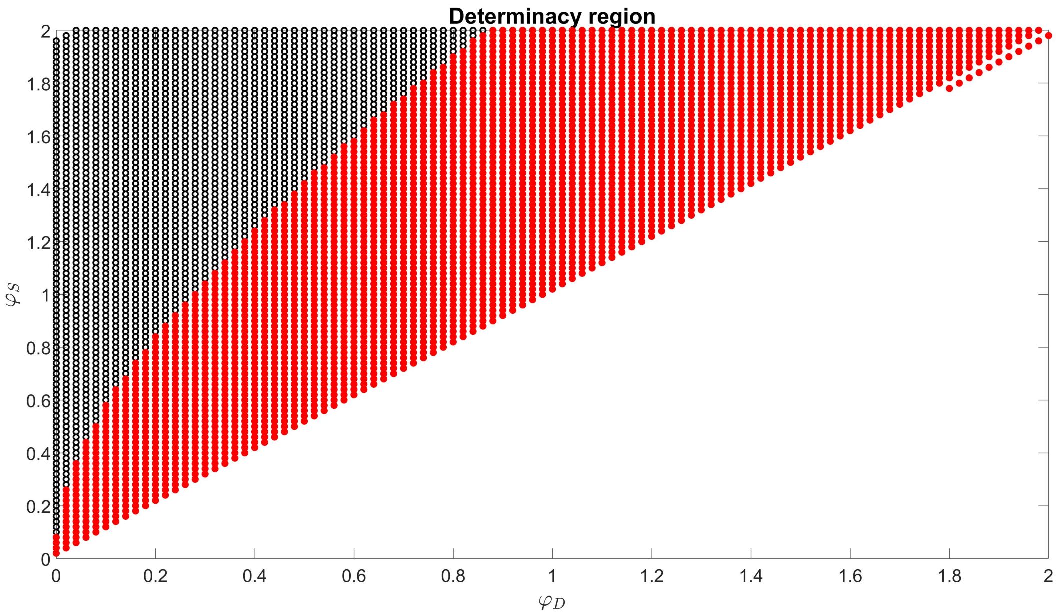
$$A^{-1} = \begin{bmatrix} 0 & \frac{1}{D(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} & -\frac{\varphi_S(1+(\varphi_D-\varphi_S)\frac{D}{Y})}{D(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} \\ 0 & \frac{1}{S(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} & -\frac{(\varphi_D+(\varphi_D-\varphi_S)(1+\varphi_D\frac{D}{Y}))}{S(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} \\ -\frac{1}{\gamma} & \frac{(1-\beta(1+r^*))(1+(\varphi_D-\varphi_S)\frac{D}{Y})}{\gamma D(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} & -\frac{\varphi_S(1-\beta(1+r^*))}{\gamma D(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} \end{bmatrix}$$

leads to the reduced-form system

$$\begin{bmatrix} \hat{D}_{t+1} \\ \hat{S}_{t+1} \\ \hat{C}_{t+1} \end{bmatrix} =$$

$$\underbrace{\begin{bmatrix} -\frac{\varphi_S(1+(\varphi_D-\varphi_S)\frac{D}{Y})}{\beta(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} & \frac{S}{D}\frac{\varphi_S(1+(\varphi_D-\varphi_S)\frac{D}{Y})}{\beta(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} & -\frac{C}{D}\frac{\varphi_S(1+(\varphi_D-\varphi_S)\frac{D}{Y})}{(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} \\ -\frac{D}{S}\frac{(\varphi_D+(\varphi_D-\varphi_S)(1+\varphi_D\frac{D}{Y}))}{\beta(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} & \frac{(\varphi_D+(\varphi_D-\varphi_S)(1+\varphi_D\frac{D}{Y}))}{\beta(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} & -\frac{C}{S}\frac{(\varphi_D+(\varphi_D-\varphi_S)(1+\varphi_D\frac{D}{Y}))}{(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} \\ -\frac{\varphi_S(1-\beta(1+r^*))}{\gamma\beta(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} & \frac{S}{D}\frac{\varphi_S(1-\beta(1+r^*))}{\gamma\beta(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} & 1-\frac{C}{D}\frac{\varphi_S(1-\beta(1+r^*))}{\gamma(\varphi_D-\varphi_S)(2+(\varphi_D-\varphi_S)\frac{D}{Y})} \end{bmatrix}}_{\tilde{A}=A^{-1}B} \begin{bmatrix} \hat{D}_t \\ \hat{S}_t \\ \hat{C}_t \end{bmatrix}.$$

In the model, C_t is a jump variable and D_t and S_t are predetermined variables. Therefore, only one eigenvalue of $\tilde{A}$ should have a modulus greater than one for the model to be determinate. As discussed above, the model is not determinate when $\varphi_D = \varphi_S$ which can be seen from the fact that the elements of $\tilde{A}$ become infinitely large in magnitude in this case. To graphically illustrate the determinacy property, we set $Y = 1$, $\gamma = 2$, $r^* = 0.025$, $\bar{d} = 0.7$, $\bar{s} = 0.49$, and $D = 0.48$, which are taken from the parametrization for the model with the exponential specification in Section 3.4, and vary the values of φ_D and φ_S. The determinacy region is plotted with dots in the figure below. For this specific parametrization, the model requires the value of φ_S to be not so smaller than or not so substantially greater than that of φ_D for it to be determinate. This is not surprising as the elements of $\tilde{A}$ depend not only on φ_D and φ_S individually but also on their difference. Imposing additional conditions, for instance non-negativity constraints on steady state international reserves and consumption, can further reduce the set of admissible values for φ_D and φ_S, which is indicated by (red) filled dots in the same figure. We impose similar constraints in estimating our full models in Section 4.3.



The results above demonstrate that the relative sizes of φ_D and φ_S determine the key properties of the model under the perfect foresight equilibrium, an insight that carries over to our full models. Because the full models feature uncertainty (including sudden stops) and output externalities additionally, the properties documented above are modified accordingly. For instance, with output externalities from reserve accumulation $v_t = f(S_t)$ also in the model, the restriction derived from the two Euler equations becomes

$$(1 + (\varphi_D - \varphi_S)\frac{D_{t+1}}{Y_{t+1}})\varphi_0 e^{\varphi_D(\frac{D_{t+1}}{Y_{t+1}} - \bar{d}) - \varphi_S(\frac{S_{t+1}}{Y_{t+1}} - \bar{s})} = \varphi_0 + f'(S_{t+1}).$$

This in turn implies the first derivative

$$\frac{dS_{t+1}}{dD_{t+1}} = \frac{\frac{\varphi_D + \varphi_D(\varphi_D - \varphi_S)\frac{D_{t+1}}{Y_{t+1}} + (\varphi_D - \varphi_S)}{Y_{t+1}}\varphi_0 e^{\varphi_D(\frac{D_{t+1}}{Y_{t+1}} - \bar{d}) - \varphi_S(\frac{S_{t+1}}{Y_{t+1}} - \bar{s})}}{f''(S_{t+1}) + \frac{\varphi_S + \varphi_S(\varphi_D - \varphi_S)\frac{D_{t+1}}{Y_{t+1}}}{Y_{t+1}}\varphi_0 e^{\varphi_D(\frac{D_{t+1}}{Y_{t+1}} - \bar{d}) - \varphi_S(\frac{S_{t+1}}{Y_{t+1}} - \bar{s})}}$$

whose value depends not only on φ_D, φ_S, and D_{t+1} but also on S_{t+1} and the curvature of output externalities $f^{''}(S_{t+1})$. When $f^{''}(S_{t+1}) = 0$ (no output externalities or linear output externalities), the derivative reduces to that for the simpler model above.

Taking stock, the exposition here establishes that our premium function is not only tractable but also flexible enough to accommodate a variety of relationships between debt and international reserves, which is further corroborated by the empirical results in Section 5.

B Simulated moments under different values of the elasticity of intertemporal substitution

Here, we study how the model behavior changes as the EIS increases from the estimated value in Table 7 while keeping other parameters at their originally estimated values in the same table. To be able to do so without also changing the RRA, we consider Epstein and Zin's (1989) recursive utility function

$$U_t = \left\{(1-\beta)C_t^{1-\psi} + \beta[E_t(V_{t+1}^{1-\gamma})]^{\frac{1-\psi}{1-\gamma}}\right\}^{\frac{1}{1-\psi}}$$

where ψ is the reciprocal of the EIS and γ is the RRA. Setting $\psi = \gamma$ takes us back to the CRRA utility function in equation (6). This makes our exercise well-defined, with the reciprocal of γ in Table 7 serving as our benchmark EIS. We do not carry out the exercise where γ is varied instead because its estimated values across our sample countries already belong to a sensible range (Section 5.1). Note that this is not an exercise where our model is reestimated under the Epstein-Zin utility function. Because the Epstein-Zin utility function introduces an additional parameter to the SMM estimation procedure that is just-identified (as discussed in Section 4.3), that exercise is not feasible without also introducing at least one more target moment. Because this can be too demanding of our simple model whose performance under the CRRA utility function is already reasonable, we choose not to go down this road.

We examine a subset of countries considered in Section 5.4 whose output externalities from international reserve accumulation follow the exponential specification in equation (11) because it turns out that this specification is more numerically stable for this particular exercise. The table below provides the results. As explained above, a decrease in ψ corresponds to an increase in the EIS. For Argentina, Morocco, and Thailand whose RRA parameter γ is estimated to be not too low, the range of values entertained for ψ is consistent with that from the existing literature (Gruber, 2013; Havránek, 2015; Thimme, 2017). The first column is for the baseline parametrization given in Table 7 and the subsequent columns for our exercise.

The table shows that the increase in the EIS can lead to a variety of changes in the model behavior, for instance an increase in the reserve accumulation for Argentina and Turkey and a decrease for Morocco on average. However, the change is not always monotonic as shown by the reserve accumulation and the interest rate premium for Thailand.

Country	Argentina					Morocco				
Moments	$\psi = 3.664$	$\psi = 2$	$\psi = 1.75$	$\psi = 1.5$	$\psi = 0.5$	$\psi = 2.894$	$\psi = 2$	$\psi = 1.75$	$\psi = 1.5$	$\psi = 0.5$
mean(S/GDP)	6.390	6.477	6.535	6.614	7.364	12.136	11.782	11.690	11.605	11.411
mean(D/GDP)	25.160	25.913	26.069	26.244	27.288	33.220	35.791	36.555	37.343	40.866
mean(rpre)	7.278	7.405	7.417	7.425	7.377	2.176	2.258	2.281	2.303	2.384
mean(TB/GDP)	2.347	2.374	2.378	2.384	2.407	1.051	1.146	1.182	1.224	1.488
σ(S/GDP)	3.307	2.537	2.404	2.263	1.572	8.980	7.692	7.249	6.757	3.992
σ(D/GDP)	8.053	6.227	5.879	5.509	4.028	21.397	18.329	17.323	16.235	10.778
σ(rpre)	7.889	7.597	7.535	7.464	6.998	1.839	1.643	1.578	1.506	1.125
σ(TB/GDP)	3.664	3.379	3.350	3.335	3.863	5.238	4.591	4.362	4.102	2.575
corr(S/GDP,D/GDP)	0.296	0.330	0.327	0.318	0.010	-0.591	-0.553	-0.533	-0.506	-0.210
corr(rpre,S/GDP)	0.297	0.400	0.422	0.447	0.621	-0.797	-0.790	-0.787	-0.785	-0.788
corr(rpre,D/GDP)	0.359	0.234	0.196	0.146	-0.377	0.532	0.443	0.406	0.361	0.011
Country	Thailand					Turkey				
Moments	$\psi = 3.326$	$\psi = 2$	$\psi = 1.75$	$\psi = 1.5$	$\psi = 0.5$	$\psi = 0.118$	$\psi = 0.1$	$\psi = 0.075$	$\psi = 0.05$	$\psi = 0.025$
mean(S/GDP)	20.716	23.003	22.918	22.830	22.405	6.312	6.642	7.205	7.913	8.828
mean(D/GDP)	37.439	40.737	40.883	41.032	41.684	27.054	27.391	27.949	28.625	29.473
mean(rpre)	1.829	1.734	1.743	1.753	1.799	2.957	2.933	2.893	2.844	2.784
mean(TB/GDP)	0.941	0.967	0.979	0.993	1.089	0.826	0.938	1.109	1.300	1.520
σ(S/GDP)	7.665	6.792	6.474	6.118	4.016	3.903	4.553	5.906	7.802	10.409
σ(D/GDP)	10.332	9.816	9.457	9.060	6.818	10.736	11.069	11.815	12.992	14.817
σ(rpre)	0.919	0.779	0.741	0.699	0.447	1.597	1.508	1.417	1.386	1.434
σ(TB/GDP)	4.693	4.274	4.147	3.998	2.934	3.035	2.457	1.641	1.292	2.247
corr(S/GDP,D/GDP)	-0.665	-0.421	-0.398	-0.369	-0.071	0.482	0.604	0.741	0.846	0.925
corr(rpre,S/GDP)	-0.756	-0.840	-0.838	-0.835	-0.803	-0.271	-0.178	-0.102	-0.078	-0.087
corr(rpre,D/GDP)	0.829	0.529	0.507	0.479	0.198	0.434	0.399	0.320	0.208	0.078

Note: See Table 8 for the definitions.

References

1. Gruber, J. (2013). A Tax-Based Estimate of the Elasticity of Intertemporal Substitution. *Quarterly Journal of Finance* 3(1), 1350001.

2. Havránek, T. (2015). Measuring Intertemporal Substitution: The Importance of Method Choices and Selective Reporting. *Journal of the European Economic Association* 13(6), 1180-1204.

3. Thimme, J. (2017). Intertemporal Substitution In Consumption: A Literature Review. *Journal of Economic Surveys* 31(1), 226-257.