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ENSAIOS SOBRE CICLOS REAIS EM ECONOMIAS EMERGENTES
ESSAYS ON BUSINESS CYCLES IN EMERGING MARKETS

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Essays on Business Cycles in Emerging Markets

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Resumo

O propósito desta tese é investigar a dinâmica dos ciclos reais em economias emergentes, com atenção especial à relação entre as condições financeiras e o comportamento das variáveis macroeconômicas em tais economias. Os ciclos de negócios nos mercados emergentes diferem-se sobremaneira relativamente aos das economias avançadas: nos primeiros, as oscilações são bastante mais pronunciadas em termos de variáveis reais, de mercados financeiros e de variáveis associadas às políticas macroeconômicas. Por exemplo, em se tratando de variáveis macroeconômicas, o produto tende a ser duas vezes mais volátil em países emergentes comparativamente aos países desenvolvidos. Outra diferença interessante relaciona-se às variáveis fiscais: enquanto o gasto do governo tende a ser anticíclico em economias avançadas, em muitos países emergentes tal variável é comumente pró-cíclica, o que tende a reforçar a volatilidade dos agregados macroeconômicos. O presente trabalho visa esclarecer o papel das instabilidades financeiras nos ciclos econômicos em países emergentes e como a pró-ciclicidade de variáveis fiscais pode ser atenuada pela introdução de regras fiscais dependentes de dívida.

O Capítulo 1 busca acessar empiricamente as implicações de fricções financeiras para os ciclos e para a dinâmica dos países emergentes. Usando um procedimento de dois estágios, o capítulo inicialmente estima índices de estresse financeiro para uma amostra de 25 economias emergentes visando construir medidas de como as condições financeiras em tais países se comportaram no período de 1994T1 até 2015T4. Em um segundo estágio, o capítulo introduz um modelo vetorial auto-regressivo (VAR) hierárquico bayesiano com efeitos limiares que usa técnicas de pooling bayesiano para estimar eficientemente os parâmetros dos VARs em cada um dos países. Os resultados são resumidos da seguinte maneira: (a) períodos de estresse financeiro ocorrem com frequência considerável nos dados (aproximadamente 30% do tempo); (b) segundos momentos de importantes variáveis macroeconômicas são regime-dependentes, com consumo e investimento sendo mais correlacionado com o produto e com maior volatilidade sob condições financeiras mais restritas; (c) o consumo é mais volátil do que o produto tanto em regimes de liquidez normais quanto em regimes de estresse financeiro; (d) a duração de um período de estresse financeiro é, em média, de 5.4 trimestres; (e) funções de resposta impulso não lineares denotam grandes efeitos de

amplificação associados ao aperto nas condições de crédito.

No Capítulo 2, um modelo em que instabilidade financeira emerge endogenamente como resultado da presença de restrições ocasionalmente ativas é utilizado para mostrar que muitas das não linearidades documentadas no Capítulo 1 podem ser entendidas como consequências de fricções financeiras. O capítulo baseia-se numa versão simplificada do modelo introduzido por Mendoza (2010), que se caracteriza pela presença de um mecanismo de deflação de dívida à la Fisher e pela presença de duas externalidades pecuniárias que amplificam a volatilidade macroeconômica caso os agentes formulem expectativas de crise no futuro. Em tal situação, a incerteza se eleva e agentes racionais elevam a poupança precaucionaria como um seguro contra crises. Como extensões, duas fontes adicionais de fricções financeiras são adicionadas ao modelo: (i) volatilidade estocástica no processo da taxa real de juros —motivada por resultados de estimações de VARs com parâmetros variantes no tempo para 9 países emergentes—; (ii) um choque financeiro que afeta a restrição de colateral da economia. Os resultados, condicionando-se num regime específico, são consistentes com aqueles do Capítulo 1. Entretanto, fontes adicionais de incerteza induzem uma queda na probabilidade de crise devido ao aumento na poupança precaucionaria. Tal resultado sugere que replicar a frequência de mudança de regime observada nos dados é uma tarefa não trivial para modelos com crises financeiras endógenas.

O Capítulo 3 estuda implicações de regras fiscais simples dependentes de dívida em pequenas economias abertas sujeitas a crises financeiras endógenas com externalidade pecuniária. A análise sugere que regras fiscais que acomodam os efeitos da acumulação de dívida sobre os preços dos ativos tendem a ser relativamente eficazes em reduzir as consequências das crises, mas podem ter impactos substanciais sobre o bem-estar caso uma crise seja suficientemente provável. Consolidações fiscais baseadas em regras ad-hoc desenhadas sobre o crescimento da dívida podem ser contraprodutivas nos momentos normais dos ciclos, e podem ter efeitos negativos significantes nos momentos de crise. Exercícios de simulação sugerem que, caso desenhadas com certo cuidado, regras fiscais baseadas em metas para o montante de dívida podem resultar em ganhos de bem-estar.

Ressalta-se que, ao resolver os modelos não lineares nos capítulos 2 e 3, a tese estende os algoritmos desenvolvidos em Maliar and Maliar (2013) e Arellano et al. (2016) do chamado Método Das Condições de Envelope para lidar com restrições ocasionalmente

ativas. Tal método, combinado a técnicas de interpolação lineares, é robusto à presença de *kinks* nas *policy functions* e capaz de acomodar equilíbrios com distorção e efeitos expectacionais.

Abstract

The purpose of this thesis is to investigate the dynamics pertaining to emerging market business cycles, with special attention to the linkage between financial conditions and the behavior of the macroeconomic variables in such economies. Business cycles in emerging economies differ in many dimensions when compared with advanced economies: the former are characterized by much larger swings in real activity, financial markets, and policy driven variables. For example, when it comes to important macroeconomic variables, output tends to be twice as volatile in emerging economies compared to their developed counterparts. Another interesting discrepancy is related to the fiscal variables: while government consumption spending tends to be counter-cyclical in advanced economies, in many emerging economies, government spending is procyclical, which tends to reinforce the volatilities of the macro aggregates. The present work tries to shed some light on the role of financial instability in the emerging market business cycles and how the procyclicality of the fiscal policy can be attenuated by the introduction of fiscal debt-targeting rules.

Chapter 1 starts by accessing the empirical implications of financial frictions for the business cycles and dynamics in emerging economies. Using a two-step procedure, the chapter first estimates unobservable financial stress indexes for 25 emerging markets to measure the evolution of the conditions of the financial markets in these countries over the period 1994Q1 to 2015Q4. With the financial indexes at hand, the chapter introduces a novel Hierarchical Bayesian Threshold VAR Model that uses Bayesian pooling to efficiently estimate the posteriors of the VAR parameters for each economy. The findings are summarized as follows: (a) stressful times occur with considerable frequency in the data ($\sim 30\%$ of the time); (b) second moments of the main macroeconomic variables are regime dependent, with consumption and investment being more correlated with GDP and with larger volatility for all variables considered under financial distress conditions; (c) consumption is more volatile than the GDP both in a regular financial condition and under a financial distress period; (d) the duration of the financial instability period is about 5.4 quarters; (e) nonlinear impulse responses show strong *amplification effects* related to the tightening of the credit conditions.

In Chapter 2, a model in which financial instability emerges endogenously as an

outcome of the presence of occasionally binding constraints is used to show that many of the nonlinearities documented in Chapter 1 can be understood as consequences of financial frictions. The chapter builds on a simplified version of the model introduced by Mendoza (2010) and features a Fisherian Debt-Deflation mechanism coupled with the presence of pecuniary externalities associated with the price of capital stock and wages. By using simulation techniques over fully nonlinear global solution methods, the channels through which financial friction affect the business cycles are disentangled. The Fisherian Debt-Deflation mechanism and the two pecuniary externalities magnify the volatility of the macro-variables whenever a crisis is expected in the future. In such a situation, uncertainty goes up and rational expectation agents increase precautionary savings to insure against the crisis. As extensions, two sources of financial frictions are added to the model: (i) a stochastic volatility in the process for the real interest rate—motivated by the results of the estimation of the time-varying parameters VAR (TVP-VAR) for 9 emerging economies—; (ii) a financial shock affecting the collateral constraint. The results, conditioned on a specific regime, are consistent with those observed in Chapter 1. However, the additional sources of exogenous uncertainty pose a reduction in the likelihood of crises occurring because of the precautionary savings. This suggest that matching the observed frequency of regime-switching is challenging for models with endogenous crises.

Chapter 3 studies the implications of simple debt-dependent rules in emerging countries subject to endogenous financial crises with pecuniary externality. The analysis suggests that debt rules that account for the effects of debt accumulation on asset prices can be relatively more efficient in reducing the likelihood of financial crises, but can have substantial impacts on welfare whenever a crisis is likely to happen. Fiscal consolidations based on ad-hoc debt growth may be counterproductive during good times while having significant negative effects on welfare during crisis episodes. Simulated exercises suggest that, when carefully designed, fiscal rules based on debt target can result in welfare gains.

Finally, it is worthwhile mentioning that, while solving the nonlinear models in Chapters 2 and 3, the thesis extends the algorithms developed in Maliar and Maliar (2013) and in Arellano et al. (2016) of the so-called Envelop Condition Method to deal with occasionally binding constraints. This method, coupled with piece-wise linear interpolation/extrapolation techniques, is robust to the presence of the kinks in the

policy function and capable of accounting for the distorted equilibrium and expectation effects.

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Chapter 1

Financial Instability and the Emerging Markets Business Cycles

One of the most striking aspects of the business cycles in emerging markets (EMs) is the pattern of the second moments of the macroeconomic data, particularly when compared to the advanced economies (AEs): emerging economies experience much larger and more frequent swings. This difference in the features of the business cycle between these groups can be illustrated by the following two stylized facts: (i) GDP is twice as volatile in the EM group as in the AE group; (ii) consumption, which is usually treated as an important measure of welfare in modern macroeconomics, has a standard deviation that tends to be greater than the standard deviation of the output in an EM, while the converse is commonly found in the data for rich countries.

Trying to understand the sources of such differences, researchers have been paying attention to the role of many distinct factors, e.g., less developed institutional environments, weaker economic policies, and greater dependence on (a few) commodities in EMs. However, as in the data almost all known episodes of substantial movements in the international financial markets coincide with large changes in the volatilities in EMs, recent studies have found a significant role played by the financial frictions in the business cycles in emerging economies (see Akinci, 2017; Chang and Fernández, 2013; García-Cicco et al., 2010). The reason is that EMs are typically more dependent on the international markets to finance its consumption and investments, making international financial instability more pronounced in such economies than in AEs—at least on average—. Consequently, the state of the financial markets naturally emerges

as a potential source that can account for at least part of the observed differences between the business cycles in EMs and AEs.¹

Accordingly, this chapter employs an empirical strategy that allows us to access the macroeconomic implications of financial frictions in EMs by using a two-step procedure. First, we estimate financial stress indexes for a set of 25 emerging economies over the period spanning from 1994Q1 to 2015Q4.² For each country, such an index is proxied by an estimated dynamic factor extracted from an extensive list of financial time series. Next, to assess the effects of financial instability in the economy, we introduce a novel two-regimes Hierarchical Bayesian Threshold VAR Model (HBT-VAR) and use it together with the estimated indicators.³ Within the HBT-VAR, the regimes are defined as two different states of nature in financial conditions: tranquil (or normal) times are situations in which the financial markets are relatively stable, while stressful times (or financial distress) are periods of high financial instability.⁴ The HBT-VAR, with the embedded estimated financial instability indicators, endogenously estimates the threshold values at which each economy in the sample switches from one regime to another. These thresholds allow us to separate the data into the two different regimes and to calculate regime-dependent impulse response functions and regime-dependent moments.

The results that emerge from the two-step analysis show that financial conditions are essential to understanding the business cycles in EMs, specially by generating strong non-linear effects. We synthesize our findings through the following stylized facts:

- (i) emerging markets are prone to frequent regime switching in their financial conditions: stressful periods occur with a considerable frequency in the data ($\sim 30\%$ of the time);⁵
- (ii) second moments of the main macroeconomic variables are regime dependent.
 - (a) Interestingly, the pattern observed in the data suggests that the channel through which financial frictions propagate to the economy is the raising of the

¹For an extensive and detailed characterization of the Business Cycle properties of the emerging markets, see Uribe and Schmitt-Grohé (2017).

²The time span varies within countries.

³A one-step analysis as implemented in Galvão and Owyang (2014) would be available, but the computational burdens make the two-step procedure preferable.

⁴Throughout the chapter, we use the terms inside and outside the parentheses interchangeably.

⁵For comparison, the so-called sudden stops events are said to be rare events, occurring in less than 4% of time (see Calvo et al., 2006; Mendoza, 2010).

credit constraint in the economy. Consumption and investment correlations with GDP tend to be higher during financial distress. This suggests that decisions become more dependent on the current income instead of the intertemporal—or permanent—income. (b) Volatility is much larger for the GDP, consumption, and investment in financial distress contexts;

- (iii) in both regimes, consumption is more volatile than the GDP;
- (iv) instabilities are persistent: the mean duration of financial distress periods is 5.4 quarters;
- (v) conforming with the facts (ii), impulse responses are strongly regime dependent for most of the countries. Under financial instability conditions, consumption and investment responses tend to be strongly amplified. These findings are consistent with the notion of the *amplification effect* of financial frictions.

We view our empirical strategy as an efficient way to deal with the problem of data availability in EMs (too short time series), while still accounting for non-linearities. First, we employ the method advocated in Koop and Korobilis (2014) to extract the information from many time series for each country in the sample to estimate our measure of financial instability. The main advantage here is that this method works with unbalanced series and with series with gaps, which are recurrent problems in EM data. Second, the HBT-VAR, as implemented in this chapter, performs Bayesian estimations of the parameters within each regime assuming exchangeable priors similar to those used in the unequational Hierarchical Linear Models (Gelman et al., 2003). As in Jarociński (2010), we adapt such a class of prior to a multiequational VAR model but apply it in the non-linear context of a Threshold VAR model. As shown in Gilhooly et al. (2012), linear VARs with such a prior can have very good small sample performance, even with only a few time series observations for each cross-sectional unit. As T-VARs are linear conditioned to a regime, the small sample properties of linear VARs with hierarchical prior schemes naturally extend to our contexts. In particular, the HBT-VAR can be used within unbalanced panels, and thus is able to extract more information from the data. Bayesian pooling is also a good feature of the method since it uses information from all countries to efficiently make the individual estimations. Since we believe that EMs share many features in terms of dynamics, the method is convenient as it exploits such similarities at the same time as the individual

heterogeneity which can also be expressed in the estimated posteriors. It is important to note that there are financial stress events that may lead to macroeconomic instability, but also moments in which financial stress tends to be isolated in financial markets. Our approach aims to identify stressful periods with implications for macro-variables.

A large body of literature has focused on business cycles in emerging markets, mainly motivated by the observed *excess volatility* of output and consumption in these economies. Many studies on this topic have used structural models in the spirit of Mendoza (1991), augmented with trend shocks in the spirit of Aguiar and Gopinath (2007) or with financial frictions, as in Neumeyer and Perri (2005), García-Cicco et al. (2010), Chang and Fernández (2013), and Mendoza (2010). This chapter is particularly related to the latter branch of literature, aiming to assess the role of financial friction in those economies. However, the chapter focuses on characterizing business cycles from a reduced-form analysis perspective coupled with a detrending technique, which is an avenue taken by Agenor et al. (2000), Lane (2003), and Calderón and Fuentes (2010). Moreover, the chapter applies a unified framework for many countries that allows us to compare the impulse responses to shocks in GDP and in the financial conditions using a Bayesian Hierarchical Panel VAR structure similar to Ciccarelli and Rebucci (2006), Canova and Pappa (2007), Jarociński (2010), Canova and Dallari (2013), and Forero (2015). The only difference is that here the model features a nonlinear regime-switching structure that comes with computational challenges.

The chapter does not try to offer any explanation for the causes of financial instability in EMs. However, it is arguably important to understand the empirical implications of financial frictions for macro-variables as well as the degree of exposure of such economies to international financial shocks, which are our main focus.

The remainder of the chapter is presented in three sections. Section 1.1 describes the methodology. Section 1.2 reports the results, and section 1.3 presents the conclusions.

1.1 Accessing Nonlinearities in the Emerging Markets Business Cycles

This section outlines the methods employed to estimate the threshold transition parameters for each country in the sample and describes how we extracted the financial stress index from the data. We begin by describing the HTB-VAR model that implicitly links the exogenous estimated financial stress index to the economic activity. Then we present the procedure and the criteria to select a variable to be part of the financial condition indicator.

1.1.1 A Panel Threshold-VAR as a Hierarchical Bayesian Model

We modeled each emerging economy as an individual threshold vector autoregressive (T-VAR) model. Although flexible, T-VAR models can suffer from high dimensionality, which is even more problematic for emerging markets because of the limited length of the time series. We overcome this problem by efficiently using the cross-sectional information within a regime. To do so, we combine the individual information with the cross-sectional information in each regime introducing a hierarchical structure setup. Importantly, the particular hierarchical structure, as represented by exchangeable priors, reflects our prior belief that countries tend to perform in a similar fashion within a certain regime, although there might be differences between regimes.

We assume that each country c , $c \in \{1, \dots, C\}$, is represented by the following non-linear vector autoregressive equation:

$$\mathbf{y}_{c,t} = \begin{cases} \sum_{l=1}^{L^1} \mathbf{B}_{c,l}^1 \mathbf{y}_{c,t-l} + \Delta_c^1 \mathbf{w}_t + \Gamma_c^1 \mathbf{z}_{c,t} + \mathbf{u}_{c,t}^1 & \text{if } y_{c,t-d} \leq y_c^* \\ \sum_{l=1}^{L^2} \mathbf{B}_{c,l}^2 \mathbf{y}_{c,t-l} + \Delta_c^2 \mathbf{w}_t + \Gamma_c^2 \mathbf{z}_{c,t} + \mathbf{u}_{c,t}^2 & \text{if } y_{c,t-d} > y_c^* \end{cases} \quad (1.1)$$

for $t = 1, \dots, T^c$, where $\mathbf{y}_{c,t}$ is a vector of $K \times 1$ endogenous variables, $\mathbf{w}_{c,t}$ is a $W \times 1$ vector of exogenous variables common to all countries, and $\mathbf{z}_t$ is a $Z^c \times 1$ vector of exogenous variables in country c . The reduced form regime-specific innovations $\mathbf{u}_{c,t}^r$, with $r = \{1, 2\}$, are assumed to be i.i.d. and to have a prior distribution $\mathbf{u}_{c,t}^r \sim N(0, \Sigma_c^r)$. The coefficient matrices in a regime r , $\mathbf{B}_{c,l}^r$ and Γ_c^r , are country-specific.

To clearly identify where an exchangeable prior will be applied, let us first rewrite the

model in the following compact form:

$$\mathbf{Y}_c = \left[\mathbf{X}_c \mathbf{B}_c^1 + \mathbf{Z}_c \mathbf{\Gamma}_c^1 + \mathbf{U}_c^1 \right] S_{c,t} + \left[\mathbf{X}_c \mathbf{B}_c^2 + \mathbf{Z}_c \mathbf{\Gamma}_c^2 + \mathbf{U}_c^2 \right] (1 - S_{c,t}), \quad (1.2)$$

where $S_{c,t} = 1 \iff y_{c,t-d} \leq y_c^*$, $\mathbf{Y}_c, \mathbf{X}_c$ and $\mathbf{Z}_c$ are, respectively, $T^c \times K$, $T^c \times M$ and $T^c \times Z^c$ matrices, where $M = Kp + W$. $\mathbf{B}_c^r$ is given by $\mathbf{B}_c^r = [\mathbf{B}_{c,1}^{r'} \cdots \mathbf{B}_{c,L^r}^{r'} \mathbf{\Delta}_c^{r'}]$ and $\mathbf{\Gamma}_c^r$ is a $(Z^c \times K)$ matrix.

Now, let $\mathbf{y}_c = \text{vec}(\mathbf{Y}_c)$, $\boldsymbol{\beta}_c^r = \text{vec}(\mathbf{B}_c^r)$, $\boldsymbol{\gamma}_c^r = \text{vec}(\mathbf{\Gamma}_c^r)$ and $\mathbf{u}_c^r = \text{vec}(\mathbf{U}_c^r)$. Then, (1.2) can be conveniently restated as

$$\mathbf{y}_c^r = (\mathbf{I}_m \otimes \mathbf{X}_c^r) \boldsymbol{\beta}_c^r - (\mathbf{I}_m \otimes \mathbf{Z}_c^r) \boldsymbol{\gamma}_c^r + \mathbf{u}_c^r, \quad r = 1, 2 \quad (1.3)$$

where $\mathbf{u}_c^r \sim N(0, \boldsymbol{\Sigma}_r \otimes \mathbf{I}_m)$. Given the normality of the error term, in order to have a normal posterior, we assume a conjugated prior that is also an exchangeable prior for each country c , given by

$$p(\boldsymbol{\beta}_c^r | \bar{\boldsymbol{\beta}}^r, \boldsymbol{\Lambda}_c^r) = N(\bar{\boldsymbol{\beta}}^r, \boldsymbol{\Lambda}_c^r) \quad (1.4)$$

where $\bar{\boldsymbol{\beta}}^r$ is the common mean within the regime r and variance $\boldsymbol{\Lambda}_c^r$ will be discussed in detail in the section below. Here, it is important to highlight that the above expression clarifies that the parameters that we are interested in are assumed to be drawn from the same data generating process. Our economic interpretation is that the underlying forces connecting variables in $\mathbf{y}_c$ are likely to be similar in our sample of emerging markets. For the remaining parameters, we assume that $p(\bar{\boldsymbol{\beta}}^r) \propto p(\boldsymbol{\gamma}_c^r) \propto 1$ and a standard diffuse prior for the regime dependent variances:

$$p(\boldsymbol{\Sigma}_c^r) \propto |\boldsymbol{\Sigma}_c^r|^{-\frac{1}{2}(N+1)}$$

The Minnesota-Style Prior and Cross-Sectional Shrinkage

For the variances Λ_c^r we follow Jarociński (2010) in specifying a Minnesota-like prior given by $\lambda^r L_c$, where:

$$L_c = \frac{\sigma_{cn}^2}{\sigma_{ck}^2}$$

The only difference from Jarociński's scheme is that we assume λ to be regime-specific. The prior for this parameter is given by:

$$p(\lambda|s, v) = IG_2 \propto \lambda^{-\frac{v+2}{2}} \exp\left(-\frac{1}{2} \frac{s}{\lambda}\right) \quad (1.5)$$

Under such a prior, Jarociński (2010) shows that the posterior for λ is given by:

$$p(\lambda_r|s, v) = IG_2 \propto \lambda_r^{-\frac{CNK+2}{2}} \exp\left(-\frac{1}{2} \frac{s + \sum_C \sum_K \sum_N [\beta_c^r(k, n) - \bar{\beta}^r(k, n)]^2 / \left(\frac{\sigma_{cn}^2}{\sigma_{ck}^2}\right)}{\lambda_r}\right)$$

Computing the Nonlinear System

Following Chen and Lee (1995), we interpret the non-linear system as a change-point problem and estimate the parameters using a Metropolis-within-Gibb sampling scheme.

Let $\Phi_c^r = \{\beta_c^r, \gamma_c^r, \bar{\beta}^r\}$ be a vector containing the VAR parameters in regime r for country c . The conditional posterior probability function of y_c^* is

$$p(y_c^* | \Phi_c^1, \Phi_c^2, \Sigma_c^1, \Sigma_c^2, d_c, \lambda^1, \lambda^2, \mathbf{Y}) \propto \prod_{j=1}^r |\Sigma_c^j|^{T_c^{(j)}/2} \times \exp\left\{-\frac{1}{2} [\mathbf{u}_c^{(j)}]' (\Sigma_c^j \otimes \mathbf{I}_{T^j}) [\mathbf{u}_c^{(j)}]\right\}$$

where $\mathbf{u}_c^{(j)} = \mathbf{y}_c - (\mathbf{I}_m \otimes \mathbf{X}_c) \beta_c^j - (\mathbf{I}_m \otimes \mathbf{Z}_c) \gamma_c^j$. The joint posterior of the parameters conditioning on a specific regime is proportional to

$$p(\beta_c^r, \gamma_c^r, \bar{\beta}^r, \Sigma_c^r, \lambda_r, y_c^*, d_c | \mathbf{Y}) \propto p(\beta_c^r, \gamma_c^r, \bar{\beta}^r, \Sigma_c^r, \lambda_r, y_c^*, d_c) \cdot p(\mathbf{Y} | \beta_c^r, \bar{\beta}^r, \Sigma_c^r, \lambda_r, y_c^*, d_c)$$

For each country c , the conditional posterior probability of d_c is a multinomial distribution with probability given by:

$$p(d_c | \Phi_c^1, \Phi_c^2, \Sigma_c^1, \Sigma_c^2, d_c, \lambda^1, \lambda^2, \mathbf{Y}) = \frac{L(\mathbf{y}_c | d_c, \Theta / d_c)}{\sum_{d_c=1}^{D_c} L(\mathbf{y}_c | d_c, \Theta / d_c)}$$

where $L(\cdot)$ denotes the likelihood function and Θ is the set of all parameters in the model,

$$\Theta = \left\{ \{\beta_c^1, \beta_c^2, \gamma_c^1, \gamma_c^2, \Sigma_c^1, \Sigma_c^2, y_c^*, d_c\}_{c=1}^C, \bar{\beta}^1, \bar{\beta}^2, \lambda^1, \lambda^2 \right\}$$

Bayesian Estimation: Metropolis-within-Gibbs Algorithm

The algorithm starts with individual OLS estimations of linear-VARs, keeping Σ_c , L_c , and β_c and the starting value $\bar{\beta} = \frac{1}{C} \sum_{c=1}^C \beta_c$. The Gibbs sampling with a Metropolis step is performed as follow:

1. Draw $p(\lambda_r | \Theta / \lambda_r, \mathbf{Y})$, for regime r , where

$$\lambda_r | \Theta / \lambda_r, \mathbf{Y} \sim IG_2 \left(s + \sum_{c=1}^C \sum_{k=1}^K \sum_{n=1}^N \left[\beta_c^r(k, n) - \bar{\beta}^r(k, n) \right]^2 \left(\frac{\sigma_{cn}^2}{\sigma_{ck}^2} \right), v + CNK \right)$$

and compute $\Lambda_c^r = \text{diag}(\text{vec}(\lambda^r L_c))$

2. Draw $p(\bar{\beta}_r | \Theta / \bar{\beta}_r, \mathbf{Y})$, where

$$\bar{\beta}_r | \Theta / \bar{\beta}_r, \mathbf{Y} \sim N(\bar{\bar{\beta}}_r, \Lambda_1^r)$$

$$\bar{\bar{\beta}}_r = \left(\sum_{c=a}^C (\Lambda_c^r)^{-1} \right)^{-1} \left(\sum_{c=a}^C (\Lambda_c^r)^{-1} \beta_c \right)$$

$$\Lambda_1^r = \left(\sum_{c=a}^C (\Lambda_c^r)^{-1} \right)^{-1}$$

3. Draw $p(\Sigma_c^r | \Theta / \Sigma_c^r, \mathbf{y}_c)$, where

$$\Sigma_c^r | \Theta / \Sigma_c^r, \mathbf{y}_c \sim IW \left((\mathbf{u}_c^r)'(\mathbf{u}_c^r), T_c^r \right)$$

4. Draw $p(\gamma_r|\Theta/\gamma_r, \mathbf{y}_c)$, where

$$\gamma_r|\Theta/\gamma_r, \mathbf{y}_c \sim N(\bar{\gamma}_c^r, \Lambda_2^r)$$

$$\bar{\gamma}_c^r = ((\Sigma_c^r)^{-1} \otimes \mathbf{Z}_c' \mathbf{Z}_c)^{-1} (\mathbf{I} \otimes \mathbf{Z}_c') ((\Sigma_c^r)^{-1} \otimes \mathbf{I}) (\mathbf{y}_c - (\mathbf{I} \otimes \mathbf{X}_c)) \beta_c^r$$

$$\Lambda_2^r = ((\Sigma_c^r)^{-1} \otimes \mathbf{Z}_c' \mathbf{Z}_c)^{-1}$$

5. Draw $p(\beta_c^r|\Theta/\beta_c^r, \mathbf{y}_c)$, and check for stability. Otherwise, discard it, where

$$\beta_c^r|\Theta/\gamma_r, \mathbf{y}_c \sim N(\bar{\beta}_c^r, \Lambda_3^r)$$

$$\bar{\beta}_c^r = ((\Sigma_c^r)^{-1} \otimes \mathbf{X}_c' \mathbf{X}_c + (\Lambda_3^r)^{-1})^{-1} (\mathbf{I} \otimes \mathbf{X}_c') ((\Sigma_c^r)^{-1} \otimes \mathbf{I}) (\mathbf{y}_c - (\mathbf{I} \otimes \mathbf{Z}_c)) \gamma_c^r + (\Lambda_c^r)^{-1} \bar{\beta}^r$$

$$\Lambda_3^r = ((\Sigma_c^r)^{-1} \otimes \mathbf{X}_c' \mathbf{X}_c + (\Lambda_c^r)^{-1})^{-1}$$

6. Draw $p(y_c^*|\Theta/y_c^*, \mathbf{y}_c)$ using an adaptive random walk Metropolis scheme. Following Alessandri and Mumtaz (2013), we set the mean of the prior as the mean value of y_c^* for each c with a value of 10 for variance.
7. Draw $p(d_c|\Theta/d_c, \mathbf{y}_c)$ from a discrete distribution, with candidates $d_c = 1, 2, 3, 4$. The algorithm is provided by Chen and Lee (1995).
8. Repeat steps 3 to 7 for $c = 1, \dots, C$.
9. Repeat steps 1 to 7 for $r = 1, 2$.

We run the sampler with 1,000,000 draws, discarding the first 50,000 to minimize the effects of the initial values. We set $s = v = 0.01$ in (1.5), resulting in a weakly informative prior so as to avoid improper posterior when $s = v = 0$.

Nonlinear Impulse Responses

To analyze the dynamic responses of the variables in this nonlinear context, we must take into account both history and the possibility of a regime switch. These requirements are at odds with traditional impulse response functions present in linear VARs since, by construction, they are symmetrical and history independent in terms of the current state of the business cycles. To better capture the nonlinear nature of the TVARs, we make use of the generalized impulse response (GIRF) proposed by Koop

et al. (1996), defined as:

$$GIRF_y(h, \varepsilon_t, \mathcal{H}_{t-1}) = E[Y_{t+h}|\varepsilon_t, \mathcal{H}_{t-1}] - E[Y_{t+h}|\mathcal{H}_{t-1}] \quad (1.6)$$

where h is the length of the simulation horizon and $\mathcal{H}_{t-1}$ is the history in period t .⁶

A concise outline of how to estimate the GIRF in a Bayesian VAR context is as follows: given a period- t shock, ε_t , and the history of what happened within the system until $t - 1$, $\mathcal{H}_{t-1}$, take the i -th draw from the Gibbs sampler of the parameters of the model, e.g. $\Theta^{(i)}$. For each draw, compute $GIRF_y(h, \varepsilon_t, \mathcal{H}_{t-1}|\Theta^{(i)})$ for a hundred of possible paths. Then, all we have to do is to integrate over $\Theta^{(i)}$. To do so, we estimate $GIRF_y$ simply by computing

$$G\hat{I}RF_y(h, \varepsilon_t, \mathcal{H}_{t-1}) = \frac{1}{D} \sum_{i=1}^D GIRF_y(h, \varepsilon_t, \mathcal{H}_{t-1}|\Theta^{(i)})$$

where D is the number of draws. As stressed by Galvão and Owyang (2014), the GIRF in a nonlinear context measures the effects of a one-standard-deviation shock to a selected variable on the endogenous variables, assuming a specific set of histories at the impact. In practice, note that we can calculate $GIRF_y(h, \varepsilon_t, \mathcal{H}_{t-1})$ for specific events in $\mathcal{H}_{t-1}$, which means that we can condition on the estimates for each regime, thus obtaining regime dependent impulse responses. Moreover, the GIRFs are defined so that the regime can change over the horizon.

Next, we discuss the method used to estimate the financial conditions for each emerging market to feed our HBT-VAR model.

1.1.2 The Financial Stress Index

A financial stress index (FSI) is intended to be a broad measure reflecting the current state of the financial markets. Such an index is constructed as a continuous variable where financial crises are at one extreme, and normal financial conditions are at the other. Usually, a FSI is based on a combination of many financial stress indicators for specific markets, with each of them constructed from many different observable variables, which enables the index to represent the whole financial system with one

⁶From now on, we use term impulse response meaning generalized impulse response functions.

single measure.

Methods for extracting from data the information that can synthesize the state of financial markets are now well-established. They are usually based on principal component methods, as in Hatzius et al. (2010), sub-index weighting schemes similar to Cardarelli et al. (2009), or the Kalman Filter coupled with advanced weighting schemes, as in Koop and Korobilis (2014). No matter what kind of method is used, the construction of a FSI faces identification problems. Moreover, one may face difficulties in choosing which sub-index should be included in the broader index, as well as in deciding what variable can best represent a particular sub-index.

When constructing such a FSI for many countries, a common practice in the literature is to limit the number of variables composing a sub-index—instead of using as many as possible—. This is done for two main reasons: (i) data availability, which may be scarce when dealing with emerging markets, and (ii) comparability.

Concerning (i), one can take advantage of the existence of common factors driving the financial markets, so that even a few variables may contain the most relevant information about the common components. Thus, the marginal gain of information is a decreasing function of the number of variables. When it comes to (ii), comparability is desired when one aims to analyze the effects of global shocks and spillover effects on countries, as in Cardarelli et al. (2009) for advanced economies and as in Balakrishnan et al. (2011) for emerging markets. In the present case, we need a comparable proxy so that the central distribution of the common coefficients is unaffected by the index.

Our measure of financial stress in emerging markets closely follows that proposed by Balakrishnan et al. (2011) for emerging economies. The authors argue that an emerging market is likely to be influenced by financial stresses coming from international markets—in particular, from advanced economies and other emerging economies. Changes in factors such as global GDP growth and prices such as interest rates can have a substantial impact on the financial conditions within an emerging market. On the other hand, a country-specific factor expressed by the degree of financial and trade linkages and macroeconomic vulnerabilities can make a country more exposed to a financial stress period.

However, while we follow Balakrishnan et al. (2011) in constructing and selecting the variables to be included in our measure of financial conditions, we extract the

information from the data employing the methods proposed by Koop and Korobilis (2014). Such methods have many advantages compared to the pure principal component methods widely used in the literature. First, they account for an unbalanced set of financial variables, a recurrent problem when it comes to emerging economies—in which data is frequently scarce prior to 2000. Second, the methods take into account that an ideal financial stress index should only express shocks on the financial system, as emphasized by Hatzius et al. (2010). This can be done by estimating a system of equations containing not only financial variables but also macroeconomic variables expressing the macroeconomic environment so that the macroeconomic information is purged from the estimated index. Third, the weights are calculated from the data, so that the researchers can stay agnostic from each of the financial variables that should be included at a specific moment of time.⁷ The appendix is devoted to presenting the method used in more detail.

We construct a Financial Stress Index for all countries for which we have sufficient data. Following the suggestions by Balakrishnan (2011), our measure includes the following sub-indexes:

Banking Sector Stress - FCI.1

- (i) **Banking Sector- β** - This measure, given by the ratio of bank share prices to total share prices, aims to isolate the stress of the banking sector in terms of the whole economy. It is our first choice sub-index to measure banking sector stress and is given by:

$$\beta_{c,t} = \frac{cov(r_{c,t}^m, r_{c,t}^b)}{var(m)},$$

where r^b and r^m are the returns to the banking sector stock index and the overall stock index. A value $\beta > 1$ means that the banks are relatively riskier compared the average volatility of the other markets. We estimate β using monthly data from DataStream based on a twelve-months rolling window, assigning a value of 1 when $\beta > 1$ and 0 otherwise. The overall return is proxied by the return of the

⁷Moreover, although the computations are much more complex compared to a pure principal component method, the method proposed by the authors is quite fast under certain setups. Combined with the high flexibility, computation cost is another reason why we choose not to include the financial stress measure as another layer in our TVAR. For example, the methods proposed by Lopes and West (2004) could be employed as additional equations in the Gibbs sampler, but the computational burden would be increased.

S&P500.

- (ii) **Bank Spreads** For countries with unavailable data to compute $\beta_{c,t}$, we measure the stress in the banking sector using the spread in the loan versus deposit rates using data from the IFS.

Foreign Market Pressure - FCI.2 To capture instabilities in the exchange markets, we use the exchange market pressure Index (EMPI) proposed by Eichengreen et al. (2004), which is defined as

$$EMPI_{c,t} = \left(\frac{\Delta e_{c,t} - \mu_{c,\Delta e}}{\sigma_{c,\Delta e}} \right) - \left(\frac{\Delta R_{c,t} - \mu_{c,\Delta R}}{\sigma_{i,\Delta R}} \right)$$

where Δ is the monthly variation, μ is the mean value, σ is the standard deviation, e is the nominal exchange rate of local currency per dollar, and R stands for the reserves.

Equity Market Volatility - FCI.3 and - FCI.4 For the Equity Market, we use two sub-indexes.

- (i) **FCI.3** Following Balakrishnan et al. (2011), we proxied the stress surrounding the security markets by the negative of the annual variation of the overall index in country c , given by $\Delta^{12}y_c = y_{c,t} - y_{c,t-12}$, where y_c is the overall index in country c in period t .
- (ii) **FCI.4** The second sub-index attempts to capture the effects of expected loss, risk, or uncertainty about firms' future profits. An increase is expected in this variable when the likelihood of a financial stress period increases. To construct this measure, we estimate simple GARCH(1,1) models for each of the emerging economies in our sample using the following process:

$$\sigma_{c,t}^2 = \omega + \phi_{c,1}\epsilon_{c,t-1}^2 + \phi_{c,2}\sigma_{c,t-1}^2$$

where σ_t^2 is the variance of a regression of an AR(1) regression for the overall equity price index.

Sovereign Debt Stress - FCI.5

- (i) **EMBI+** The EMBI+, as calculated by J.P.Morgan, is our preferred measure of stress related to sovereign debts.
- (ii) **Sovereign Spread 1** For countries where EMBI+ is unavailable or too short, we use the spread between the interest rate on sovereign debt in country c and 3-month USA bonds.
- (iii) **Sovereign Spread 2** Alternatively, we use the spread between security markets in country c compared to the USA.
- (iv) **Sovereign Spread 3** Finally, for countries with gaps in EMBI+, we fill the missing data using credit default swaps (CDS) data.

1.2 Estimations and Empirical Findings

The datasets used in this chapter are presented in Tables A.2 and A.3. They encompass financial as well macroeconomic data from a set of 25 emerging economies. The only criterion for a country to be selected is data availability. For the FSI, we use monthly data to construct the sub-indexes described in the previous section and take the quarterly average after ensuring that the series are stationary and free of seasonality effects. For the GDP, consumption, and investment, we use the logarithm of the real values and compute deviations from a trend (HP-Filter). As the data come from many different sources and are of different time spans, we refer the reader to the aforementioned tables to access detailed information.

Let us start presenting the results for the FSIs. As suggested by Figure 1.1, the frequency of financial stress periods in EMs seem quite high. Importantly, there are clearly two distinct pictures. Prior to 2004, financial instability appeared to be governed by both international and idiosyncratic forces. From 2004 onwards, the international markets' condition seems to be the most important determinant of financial stability. For our econometric strategy, this is important because it suggests that such economies may be highly dependent on each other and might suffer from spillover effects stemming from the financial markets condition. However, a comprehensive study of the determinants of the FSI in EMs is out of the scope of this chapter. For the interested reader, we refer to Balakrishnan et al. (2011) and Park and Mercado (2014). Plots of the individual series can be found in Figure A.13 in the appendix.

Figure 1.1: Estimated FSI for all countries in the sample

To analyze the implications of financial instability and how it dynamically affects an emerging economy, we estimate our HBT-VAR. We setup each VAR equation as follows:

$$\mathbf{y}_{c,t} = \begin{bmatrix} y_{c,t} \\ c_{c,t} \\ i_{c,t} \\ fsi_{c,t} \end{bmatrix}$$

where $y_{c,t}$ is GDP, $c_{c,t}$ is consumption, $i_{c,t}$ is investment and $fsi_{c,t}$ is the financial stress index. Because of the limited time span, we restricted the maximum lag to 3. Fortunately, the data seem to favor an HBT-VAR with one lag. Using the priors described in section 1.1.1, settled under a fairly loose scheme, we ran the Bayesian algorithm to search for endogenous regime-switching in the sample. The results are expressed in Figures A.1 to A.5 in the appendix and are summarized in Table 1.1.

Table 1.1: Crises in EMs: Properties

	SAMPLE MEAN
Frequency of bad regimes in the data	31%
Duration (mean # of quarters in a bad regime)	5.4

From the HBT-VAR estimates, EMs are economies prone to frequent financial instabilities that may have consequences for macroeconomic variables. In our sample, a typical emerging economy switches from one regime to another about 30% of the time. Moreover, when a crisis begins, it takes about one and a half years for the economy to return to a stable financial condition.

Turning to the analyses of the empirical implications of financial distress, we use the estimated unobservable threshold parameters for each EM in the sample to separate each time series into periods of financial instability and periods of tranquility. Then,

using the separated time series, we compute the regime-dependent moments —i.e., business cycle moments within regimes—and compare them between regimes. The results are expressed in Table 1.2.

Table 1.2: Emerging Markets Business Cycles			
CORRELATIONS			
Within regimes	Value	Relative	Value
$\rho_1(c, y)$	0.628	$\frac{\rho_1(c, y)}{\rho_1(i, y)}$	0.964
$\rho_1(i, y)$	0.630	$\frac{\rho_2(c, y)}{\rho_1(i, y)}$	0.838
$\rho_2(c, y)$	0.651	$\frac{\rho_2(i, y)}{\rho_2(c, y)}$	
$\rho_2(i, y)$	0.751		
STANDARD DEVIATIONS			
Within regimes	Value	Relative	Value
$\sigma_1(y)$	0.020	$\frac{\sigma_1(y)}{\sigma_1(c)}$	0.722
$\sigma_1(c)$	0.025	$\frac{\sigma_2(y)}{\sigma_1(c)}$	0.690
$\sigma_1(i)$	0.086	$\frac{\sigma_2(c)}{\sigma_1(i)}$	0.571
$\sigma_2(y)$	0.027	$\frac{\sigma_2(i)}{\sigma_2(y)}$	
$\sigma_2(c)$	0.036		
$\sigma_2(i)$	0.151		
STANDARD DEVIATIONS RELATIVE TO GDP			
Regime 1	Value	Regime 2	Value
$\frac{\sigma_1(c)}{\sigma_1(y)}$	1.267	$\frac{\sigma_2(c)}{\sigma_2(y)}$	1.327
$\frac{\sigma_1(i)}{\sigma_1(y)}$	4.415	$\frac{\sigma_2(i)}{\sigma_2(y)}$	5.581

Financial frictions have serious implications for EMs, affecting the business cycles in a nonlinear fashion. For moments, there are two major consequences: first, correlations of consumption and investment with the GDP tend to be higher in financial instability regimes relative to tranquil times. The relative correlation between regimes for consumption is 0.964 and is 0.838 for investment. Although the result for consumption may be an artifact of the small sample, the difference for investment is substantial. The volatility implications are less subtle. As one can expect, the volatility in a financial distress regime is much more pronounced than in a normal regime. While the GDP tends to show an average increase of about 38% in volatility in times of stress, consumption volatility magnifies by about 44% and investment by about 75%, on average.

We also investigate whether the standard deviations of consumption and investment

change between regimes relative to the standard deviation of the GDP. This analysis is of interest since it can shed some light on how intertemporal decisions are affected by tighter credit constraints. The results, presented at the bottom of Table 1.2, show that as financial conditions deteriorate, consumption and investment become even more volatile than the GDP. This means that households and firms may face more difficulty in anticipating future income to buy consumption and investment goods. These results echo those of the literature on the phenomenon called *excess volatility*. Here, under financial distress, the *excess volatility* worsens.

To better understand how financial frictions translate to the dynamics of macro-variables, we now simulate shocks on the GDP and FSI and compute the GIRFs. The GIRFs are computed within a regime but allow for the possibility of a regime-switch. Starting with the histories in one regime for a certain country, we simulate the evolution of the VAR system for 40 quarters with and without the shock of interest, compute the differences between the simulated paths, and take the average responses. In such a context, the GIRF measures the responses of the endogenous variables to a shocked variable at some horizon h within a specific regime r . The confidence band is calculated from the draws of the VAR coefficients from the last 1,000 draws in the Metropolis-within-Gibbs-sampler.

Let us first analyze the effects of a positive shock of one standard deviation on the GDP gap. The results are expressed in Figures A.6 to A.10. The first and most interesting point to note is that, for almost all of the cases, the non-linear effects previously identified in business cycle moments are also expressed in the GIRFs.⁸ Second, there are clearly heterogeneous responses both within regimes as well as between regimes.

To be specific about the nonlinear effects found in the data, the responses in the financial distress regime are much larger than in the normal regime. Since accounting for these differences by looking at such a large number of plots can be cumbersome, we calculate a measure of the mean amplification effects in the sample caused by the presence of financial friction. We do so by taking the mean difference between the responses in regimes 2 (stressful times) and 1 (normal times). A positive sign means that the response in regime 2 is more pronounced than in regime 1, assuming that both have the same sign. We compute the differences both *at impact*—meaning the impact in

⁸As the impulses are calculated from different histories and coefficients, the superposition of confidence interval is for illustration purposes, only.

the first period—and on the cumulated impact, calculated from the cumulative impulse responses. The results are shown in Table 1.3 expressed via the mean differences in the sample. At impact, the responses of the GDP tend to be almost 89.8% higher in regime 2. For the consumption, the difference is somewhat lower compared to the case of the GDP but still quite pronounced: approximately 79.4% higher in regime 2. For investment, the difference between the regimes rises dramatically, reaching 134.4%. When the effects are cumulatively summed over all of the simulated horizon, we see that the differences continue to increase. Our result suggests a large *amplification effect* due to the presence of financial frictions, which is in line with the financial accelerator literature (see, for example, Bernanke et al., 1999; Kiyotaki and Moore, 1997).

Table 1.3: Amplification: Mean Difference Between Regimes

AT IMPACT	SIGN	MEAN DIFFERENCE
GDP	+	89.89%
Consumption	+	79.42%
Investment	+	134.48%
CUMULATED	SIGN	MEAN DIFFERENCE
GDP	+	188.18%
Consumption	+	146.40%
Investment	+	394.95%

Note: At impact and cumulated mean difference between regimes after a GDP shock.

We repeat the previous exercise, but now for a positive one standard deviation shock on the financial instability proxy. This shock is interpreted as worsening the financial conditions in a specific regime. For brevity, the results are expressed for only four countries in Figure A.11. As the GIRFs make clear, poor financial conditions are pervasive to EMs. As the credit conditions worsen, independently of the regime, GDP, consumption, and investment fall. Specifically, the effects in regime 2 are more pronounced than in regime 1, with some countries experiencing severe impacts, as in Malaysia and Romania in the figure.⁹ Complementing these findings, table 1.4 shows the mean differences in the responses both at impact and cumulated for the simulated horizon. For the sample as a whole, tightening financial conditions—captured by a positive shock to the Financial Stress Index—reduces the GDP, consumption, and investment in both regimes. The negative effects are again more intense in the financial distress regime.

⁹Table A.1 in the appendix summarizes the mean impacts for the whole sample.

Table 1.4: Difference in Responses Between Regimes

AT IMPACT	SIGN	MEAN DIFFERENCE
GDP	+	30.76%
Consumption	+	64.70%
Investment	+	200.48%
CUMULATED	SIGN	MEAN DIFFERENCE
GDP	+	13.55%
Consumption	+	39.62%
Investment	+	70.69%

Note: At impact and cumulated mean difference between regimes after a financial shock.

Therefore, not only do the financial conditions imply regime switches with remarkable frequency in the emerging economies, but also adverse financial shocks are propagated in a very nonlinear and asymmetrical fashion in these economies.

1.3 Conclusion

This chapter provides an empirical characterization of the dynamics imposed by financial frictions to the emerging markets' business cycles. In a first step, we estimated a Financial Stress Index (FSI) by employing dynamic factor methods and showed that financial markets in emerging economies frequently feature events of financial instability. Then, in a second step, where we introduced a Hierarchical Bayesian Threshold VAR (HBT-VAR) model, we fed the HBT-VAR with the FSI estimated for each country in the sample (25 emerging economies) to estimate a transition variable indicator that indicates whether the economy is under a normal financial stability or under a financial distress period.

We show that financial instability may affect both the correlations and the volatilities of important macro-aggregates—GDP, consumption, and investment—and can also generate enormous asymmetries between regimes. In summary, when economies experience tranquil times and good conditions in financial markets, their business cycle properties are remarkably different from those in a financial distress period. During such events, EMs tend to be much more volatile, and such behavior has implications not only for the second moments of the data but also for the dynamics of the macro-variables. Moreover, shocks are propagated in a regime-dependent fashion:

in a financial instability regime, shocks to GDP have a larger (much larger, in some cases) effect on real variables such as output, consumption, and investment. Thus, we interpreted our results as suggesting that financial frictions play a very important role in the business cycles in emerging markets. Within different channels, the amplification effects seem to be crucial.

Chapter 2

Endogenous Financial Crises in a Quantitative Model For a Small-Open Economy

In this chapter, we show that a framework based on workhorse models for a Small-Open Economy extended with an endogenous financial crises scheme can account for some of the stylized facts of the strong non-linearities pertaining to the emerging markets (EM) business cycles. Among those facts are: (i) financial instability can affect the correlations of consumption and investment with GDP and has substantial effects on volatilities; (ii) consumption is more volatile than GDP; (iii) financial instability is persistent; (iv) there is an amplification effect resulting from the tightening of financial conditions.

We begin by discussing that Threshold VAR models, especially when augmented with financial condition indicators—in the spirit of the empirical model used in Chapter 1—can be interpreted as an empirical counterpart of a structural Dynamic Stochastic General Equilibrium (DSGE) model with a time-varying credit constraint.

Motivated by this fact and by the empirical results obtained in Chapter 1, we build a simplified version of the model developed by Mendoza (2010), in which financial instability is an outcome of a endogenous, occasionally binding constraints. In the model, agents can borrow from the international financial market to the extent to which they can meet a collateral constraint. Depending on the state of nature, highly leveraged agents may face a binding constraint. The collateral constraint is itself endogenous

and based on the value of the capital stock in the economy. When the constraint marginally binds, credit goes down causing a restriction on the intertemporal decisions of households and firms. As a result, both consumption and investment drop. Because atomistic agents cannot internalize the effects of their decisions on prices, fire sales start making the credit restriction even worse. Thus, the endogenous crisis is reinforced in a spiral fashion as a result of a Fisherian Debt-Deflation mechanism. However, in regions away from the binding constraint, the economy experiences periods with smoother business cycles. Therefore, in this class of model, there is an endogenous regime-switching mechanism that changes according to the financial conditions of the economy. Periods of typical business cycles are nestled within periods of severe instability caused by the financial markets.

We use the model to disentangle the channels through which endogenous financial constraints can affect variables' responses and moments within and between regimes. We do so by employing a battery of simulation procedures conditioned on situations in which the economy stays in a particular regime, then computing the regime-dependent impulse response functions and moments predicted by the model. The results show that a model in this class can produce synthetic data with statistical properties similar to the stylized facts we provided in Chapter 1.

The model is also used to analyze how the endogenous uncertainty is affected by the presence of endogenous financial instability. Rational expectation models feature endogenous uncertainty because agents make predictions about the future state of the economy. In linearized models, these predictions are mostly driven by the exogenous shock. However, in models with endogenous regime switching, agents make forecasts also taking into account the possibility of a future binding constraint. Since a binding constraint is an uncertain event, regions with a high probability of crisis have more uncertainty than regions with a low likelihood of crisis. This channel is important because it suggests that high volatility in an EM can also be explained by the risk of future crises. To measure the uncertainty surrounding the macroeconomic variables, we follow Plante et al. (2015) by computing the expected volatility of the forecast error of future GDP. We find that uncertainty is higher when crises are in place, but also when crises are expected to be in place in the future —i.e., when the probability of crises in the future is high enough.

Although the model can have relative success in replicating some facts found in the

data, it has the known weakness that, in the long run, financial crises occur with very low probability (see, for example, Arellano and Mendoza, 2002; Mendoza, 2010), even when calibrated for emerging economies. When looking at the data, we find that the likelihood of financial stress periods is about 30%. Trying to match this fact, we then extend the model by adding two additional frictions. First, following Fernández-Villaverde et al. (2011), we allow the interest rate to follow a stochastic volatility process that can be interpreted as representing risk shocks. The introduction of such stochastic volatility is motivated by the strong evidence of time-varying volatility in the real interest rate for the EMs that we provided. This channel affects the cost of borrowing and introduces a risk to consumption and labor. Going further, following Jermann and Quadrini (2012), we assume that the collateral constraint has a stochastic AR(1) process that can be understood as a source of financial shocks coming from the international markets. Permeating all the shocks to compete, or treating each of them as separate additional shocks, our results are that more exogenous uncertainty makes endogenous crises even rarer because rational expectation agents increase the precautionary savings in the face of greater risk and uncertainty. Thus, we conclude that matching the frequency of financial instability is challenging for models with endogenous financial crises. However, the regime-dependent impulse responses for both shocks show large nonlinear effects for both volatility and financial shocks. For the latter, impulse responses are similar to the pattern found in the data.

The central feature of the models of the class used in this chapter is that credit constraints are connected to the market-determined prices, which creates systemic risk. The literature considers two classes of model adapted to emerging markets. The first, where the collateral is based on stocks, has been successfully employed to explain rare sudden stops events. Using data from Mexico, Mendoza (2006, 2010) shows that the model replicates many of the unconditional (long-run) business cycles moments of that economy. He also implemented analysis around the event of crisis and showed that the model can account for the behavior that we see in the data for GDP, private consumption, investment, Tobin's Q , and net exports–GDP ratio. The model was extended in Akinci and Chahrour (2015) with predictable but imperfectly forecastable changes in future productivity that can replicate the stylized fact that periods of bust are preceded by periods in which output, consumption, and investment are above the trends. Both papers, however, find a low probability of crisis ($\sim 2.5 - 3.5\%$ chance).

The second branch of literature introduces a Debt-Deflation mechanism associated with the relative price of nontradable goods (Bianchi, 2011; Mendoza, 2002a). The findings from this strand of literature are that the quantitative effects of systemic credit externality are significant. The pecuniary externality raises the probability of crisis from 0.4 to 5.5% and introduces strong nonlinear effects. Note, however, that this probability is still far from the financial distress frequency that we find in the data.

The chapter is organized as follows: section 2.1 discusses how the results from Chapter 1 can be rationalized in a model with an occasionally binding constraint. Section 2.2 presents the model. In section 2.3, the results of the benchmark model are presented while section 2.4 shows the results from the extensions to the model. In section 2.5, the analysis of the endogenous uncertainty is described, and then 2.6 presents the conclusions.

2.1 Connecting Data and Theory: Nonlinearities and the State of Financial Markets

A large body of theoretical and quantitative models (e.g., Aiyagari and Gertler (1999), Kiyotaki and Moore (1997), Bernanke et al. (1999), Christiano et al. (2010), Mendoza (2010)) has emphasized the importance of the state of the credit markets and initial conditions to the real activity, notably relating to the aftermath of the recent global financial crisis and the worldwide recession. For the EM literature, the state of the financial markets has long been regarded an important source of fluctuation and uncertainty (see Mendoza, 2002a, for a brief review of the literature), a vision that has been supported by empirical studies (see, for example, Calvo et al., 2006).

Confronting this class of model with data is not a straightforward task because of the implied nonlinearities coming from the theory. To see this point, let us consider a simple example similar to Aiyagari and Gertler (1999) and inspired by Schmid (2013). Suppose that the maximum amount of leverage at which the market is willing to lend to an agent is given by:

$$\kappa \geq -b_{t+1}/q_t k_{t+1}$$

where κ is the leverage coefficient, b_{t+1} is the holdings of debt, q_t is the asset price,

and k_{t+1} is the amount of capital. Clearly, if the leverage ratio, $-b_{t+1}/q_t k_{t+1}$, is closer to κ , a sudden fall in the market value of assets, $q_t k_{t+1}$, induces a borrowing limit to b_{t+1} . Since b_{t+1} is a variable used by the consumer to smooth consumption, a limit to b_{t+1} will generate a fall in consumption as a result of the corner solution. Thus, the economy behaves differently whether the constraint is binding or not. In this sense, a model with occasionally binding constraints can be understood as a model with thresholds effects.

Threshold VAR (TVAR) can be interpreted as a reduced form, empirical counterpart of such theoretical models in the following sense. Recall from Chapter 1 that when the proxy of the financial instability in period t , fsi_t , exceeds a certain threshold value, $fsi_t > fsi^*$, we say that the economy is entering the financial distress regime. Now suppose that the Lagrange multiplier for the above occasionally binding constraint is λ_t . Then, we have the following relations:

$$\begin{aligned} \text{If } fsi_t \leq fsi^* &\Rightarrow \lambda_t = 0 \quad \text{and} \quad b_{t+1} > -\kappa q_t k_{t+1}, && \text{no threshold effects} \\ \text{If } fsi_t > fsi^* &\Rightarrow \lambda_t > 0 \quad \text{and} \quad b_{t+1} \leq -\kappa q_t k_{t+1}, && \text{threshold effects} \end{aligned}$$

Note that the TVAR is in the class of the regime-switching models but with an endogenous regime-switching mechanism. Thus, in a TVAR with a financial indicator as the threshold variable, threshold effects are interpreted as episodes in which the collateral constraint is endogenously binding.

2.2 A General Equilibrium Model with Endogenous Regime Switching

The model resembles the standard RBC models for small open economies with incomplete markets (Correia et al., 1995; Mendoza, 1991) embedded with a collateral constraint similar to Mendoza (2010). Such collateral constraint is based on the value of the asset, and it introduces a Debt-Deflation mechanism that, in turn, implies spiral effects that strengthens the results of the endogenous financial crises. It also encompasses a working capital requirement in which firms must borrow from the international market to pay wages in advance in the spirit of Uribe and Yue (2006) and Neumeyer and Perri (2005). The benchmark model is subject to standard technology and real

interest rate shocks and is used to disentangle the channels by which financial frictions affects the dynamics in the economy. In a next section, we introduce two other sources of shocks into the model. To account for the time-varying volatility of the interest rate¹, we assume that interest rates evolve featuring a stochastic volatility component in the spirit of Fernández-Villaverde et al. (2011). Moreover, similar to Jermann and Quadrini (2012), we introduce an autoregressive collateral limit that can be interpreted as a financial shock.

2.2.1 Households

The Small Open Economy (SOE) is populated by a large set of identical, infinitely-lived households. Following Mendoza (2010), these agents are assumed to derive utility from a composite good, c_t , and labor, h_t , through a Stationary Cardinal Utility (SCU) *à la* Epstein (1983). The SCU has the convenient property of having an endogenous rate of time preference that supports a unique, invariant limiting distribution of foreign assets under incomplete markets, which is used to avoid explosive dynamics. It is given by:

$$E_0 \left[\sum_{t=0}^{\infty} \exp \left\{ - \sum_{\tau=0}^{t-1} \nu(c_{\tau} - G(h_{\tau})) \right\} u(c_t - G(h_t)) \right] \quad (2.1)$$

where $u(\cdot)$ is a standard twice-continuously-differentiable and concave utility function satisfying Inada conditions, and $\nu(\cdot)$ is a time preference function, which is assumed to be increasing, concave, and twice-continuously-differentiable.

As in Greenwood et al. (1988), utility is defined in terms of excess of consumption relative to the disutility of labor, where $G(\cdot)$ is a twice-continuously differentiable convex function. Under these assumptions, the wealth effect on labor supply is eliminated since the marginal rate of substitution between consumption and labor becomes independent of consumption, preventing a counterfactual increase in labor supply during crises. Moreover, the GHH preferences seem a suitable choice to replicate the second moments of data for EM (Correia et al., 1995; Fernández-Villaverde et al., 2011).

¹In the appendix, we documented strong time-varying volatility in real interest rates in the data for some emerging markets economies.

Each household owns a firm that combines capital, k_t , and labor to produce a final good through the technology $y_t = z_t F(k_t, h_t)$, where $F(\cdot)$ is a twice-continuously-differentiable, concave production function and z_t is the productivity shock that has compact support and a Markov representation. Capital is subject to an adjustment cost, $\Phi(\frac{i_t}{k_t})k_t$ where i_t is investment and $\Phi(\cdot)$ has the following properties: $\Phi'(\cdot) > 0$, $\Phi''(\cdot) \geq 0$, $\Phi(\delta) = 0$ and $\Phi'(\delta) = 0$, where δ is the depreciation rate. Working capital loans pay a fraction χ of labor in advance, where lenders charge the gross interest rate, R_t .

The representative agent chooses sequences of consumption, labor, investment, and holds of bonds to maximize (2.1) subject to the following standard budget:

$$c_t + i_t = z_t F(k_t, h_t) - k_t \Phi\left(\frac{i_t}{k_t}\right) - \chi(R_t - 1)w_t h_t - \frac{b_{t+1}}{R_t} + b_t \quad (2.2)$$

where w_t is the wage rate and b_t denotes holdings of a one-period bond that is negotiated in an incomplete international market. Such a market structure reflects the limited ability of the EMs to issue bonds at long horizons (see Alfaro and Kanczuk, 2009). In accessing such a market, the agent faces a collateral constraint that has to be met at any period: The global credit market requires that the total debt, given by the sum of intertemporal debt and working capital loans, not to exceed a fraction κ of the holdings of next-period capital:

$$\kappa q_t k_{t+1} \geq -\frac{b_{t+1}}{R_t} + \chi R_t w_t h_t \quad (2.3)$$

where q_t is the price of the domestic capital. Two features of this type of collateral constraint are worth discussing. The first is that when (2.3) binds, there will be an endogenous premium over the global interest rate (Mendoza and Smith, 2006). The second is that, as discussed by Bianchi (2011), such a collateral constraint introduces two pecuniary externalities due to the presence of the prices q_t and w_t .

It is worth mentioning that Mendoza and Smith (2006) and Mendoza (2006, 2010) argue that the quantitative relevance of such externalities is rather small, and solve the models using methods that ignore them. However, such small effects may be a byproduct of the low probability of crises, implying minor impacts to the unconditional moments. Instead, since we are interested in the dynamics within regimes—i.e., conditionally on a certain regime—as well as in the behavior of uncertainty, we employed a fully

nonlinear solution method that accounts for all potential distortions in our setup.²

The central source of uncertainty coming from the occasionally binding constraint (2.3) is the following: Since agents are acting competitively, they do not internalize the effects of their actions on prices. As a consequence, they will maintain a suboptimal low level of pecuniary savings, in turn, being, more exposed to financial crises compared to an equilibrium in which a planner internalizes the effects of debt accumulation on prices. In this case, regions in the state space with high a probability of binding constraints will have higher uncertainty compared to regions with lower probability of crises there will be mass of probability of a regime switching.

2.2.2 Competitive Equilibrium

Rewriting the problem of the SOE in the standard notation of the dynamic programming literature, we look for a Markov Equilibrium that is a solution to the following dynamic problem:

$$V(b, k, \varepsilon) = \max_{c, h, i, b', k'} \left\{ u(c, h) + \beta(c, h) \mathbb{E}[V(b', k', \varepsilon')] \right\} \quad (2.4)$$

subject to

$$\begin{aligned} b' &= R \left(b + zF(k, h) - c - i - k\Phi\left(\frac{i}{k}\right) - \chi(R - 1)wh \right) \\ k' &= k(1 - \delta) + i \\ b' &\geq R(\chi Rwh - \kappa qk') \end{aligned}$$

where $\mathbb{E}$ is the expectation operator. In this setup, agents take as given the price of installed capital, q , the real wage, w , and the price of bond, R . The Markov Equilibrium is then characterized by the stochastic sequences $[c_t, h_t, i_t, b_{t+1}, k_{t+1}]_{t=0}^{\infty}$ and $[q_t, w_t]_{t=0}^{\infty}$ that: (i) satisfy the first order conditions (derived in the appendix); (ii) satisfy the market clearing conditions and; (iii) the resource constraint.

²Moreover, the solution method employed in this chapter accounts for the expectation effects by adjusting the decision rules to whatever expected state of nature, while the methods usually employed by the literature forces the decision rules to be fixed on a few points in the grid. See the appendix for details.

2.3 Calibration and Results

The five functions that characterize lifetime utility, the resource constraint, and the constant return to scale production adopt the following forms:

$$G(h) = \theta \frac{h^\omega}{\omega}, \quad \omega > 0 \quad (2.5a)$$

$$u(c - G(h)) = \frac{[c - G(h)]^{1-\sigma} - 1}{1-\sigma}, \quad \sigma > 1 \quad (2.5b)$$

$$v(c - G(h)) = \psi \left[\ln(\bar{\psi} + c - G(h)) \right], \quad 0 < \psi \leq \sigma \quad (2.5c)$$

$$F(k, h) = k^\alpha h^{1-\alpha}, \quad \alpha \in (0, 1) \quad (2.5d)$$

$$\Phi\left(\frac{i}{k}\right) = \frac{\phi}{2} \left(\frac{i}{k} - \delta\right)^2 \quad (2.5e)$$

Much of the calibration follows Mendoza (2010), except for the parameters related to (2.5c) and (2.5a). For the latter, θ is set so the mean hour in the steady-state equals one. ϕ is set to match the second moments of investment. Regarding the endogenous discount function, following Uribe and Schmitt-Grohé (2017), we introduce the parameter $\bar{\psi}$ to give more flexibility to match the moments with the data. A low (high) discount factor is associated with more impatience (patience), and less (more) willingness to postpone consumption. The standard value is $\bar{\psi} = 1$, but we set $\bar{\psi} = 1.1$, resulting in a slightly higher impatience. ψ is calculated from the steady state values of c and h .

The remaining parameters follow Mendoza (2010). $\sigma = 2$ is the standard value for the risk aversion. $\delta = 0.08$ is the value used in literature for EM. The Frisch elasticity of labor is such that $\omega = 1.855$. Capital share α is equal to 0.32. The share of working capital is $\chi = 0.258$. Table 2.1 summarizes the selected values for the parameters.

Regarding the stochastic components, we assume that the productivity follows an AR(1) process given by:

$$z' = (1 - \rho^z)\bar{z} + \rho^z z + \varepsilon'_z \quad (2.6)$$

where $\bar{z}$ is the average productivity level, with $\varepsilon_z \sim i.i.d.N(0, \sigma_z^2)$. For the interest rate, the benchmark model assumes that it evolves by the rule:

$$R' = (1 - \rho^R)\bar{R} + \rho^R R + \varepsilon'_R \quad (2.7)$$

where $\bar{R}$ is the average interest rate, and $\varepsilon_R \sim i.i.d.N(0, \sigma_R^2)$.

Table 2.1: Model Calibration

PARAMETER	CONCEPT	VALUE
<i>Technology</i>		
α	Capital Share	0.320
$\bar{z}$	Long Run Technology	1.000
δ	Capital Depreciation Rate	0.080
ϕ	Capital Adjustment Coef.	0.025
<i>Financial Markets</i>		
$\bar{R}$	Long Run Interest Rate	1.070
χ	Share of Working Capital	0.258
<i>Preferences</i>		
ψ	Elasticity Of Rate Time Preference	0.013
θ	Labor Parameter	0.929
ω	Labor Elasticity	1.855
σ	Risk Aversion	2.000
<i>Stochastic Process</i>		
ρ^z	Technology Persistence	0.750
ρ^R	Interest Rate Persistence	0.571
σ_z	S.D. of TFP Shock	0.011
σ_R	S.D. of Interest Rate shock	0.015

As previously discussed, solving the above system requires global methods to cope with the non-linearities implied by the presence of the collateral constraint. The appendix B.1 is devoted to explaining the solution method employed in the chapter.

2.3.1 Policy Functions: Benchmark Model

Let us start by presenting the implied policy functions from the equilibrium conditions. Figure 2.1 depicts policy functions for consumption, investment, capital, next period

Figure 2.1: Policy functions for Consumption, Investment, Capital, Bonds, Tobin's Q and Labor for a low technology realization and mean interest rate.

bonds, Tobin's Q, and labor in a situation in which the technology is two standard deviations below its mean and interest rate on its long-run value. There are three different regions in this part of the state space. For values of bonds higher than about -0.2 , the effects of the collateral constraint are very small. For values lower than -0.4 , the amounts of consumption, investment, Tobin's Q, and, consequently, capital deteriorate too fast because of the limit on debt. The intermediate region is a risky region in which the pecuniary externality is higher and is the region in the state space where the fire sales occur.³ Because the pecuniary externality varies along the state-space, the curvature of policy functions is state-dependent. Figure B.2 presents

³Note: the policy function for labor is flat in the region where the constraint is slack due to the GHH preferences.

the policy functions for combinations of pairs (b, k) .

To analyze the impact of those nonlinearities on the dynamic the economy, we now turn to the simulation procedures. We define crises as periods in which the constraint binds and current account exceed one standard deviation from its mean value. We generate simulations of 1,000,000 years and compute statistics. Table 2.2 presents the results for Regime-Dependent Moments, defined as the moments within a certain regime. Similar to the pattern of the data, the model predicts that the correlation between both consumption and investment with GDP tends to be slightly higher for the former and considerably higher for the latter when the economy is in financial distress. Moreover, the standard deviations are also greater within a financial crisis, as expected. These findings confirm our interpretations that financial instability can affect not only the volatilities but also the correlations for both consumption and investment. In a corner solution, current income plays a central role for consumption and investment since agents face difficulties in smoothing intertemporal consumption and investment.

Table 2.2: Business Cycles Properties Between and Within Regimes

REGIME DEPENDENT BUSINESS CYCLES MOMENTS			
<i>Correlations</i>		<i>Standard Deviations</i>	
$\rho_1(y, c)$	0.914	$\sigma_1^2(c) / \sigma_2(c)$	0.887
$\rho_2(y, c)$	0.991	$\sigma_1^2(i) / \sigma_2(i)$	0.740
$\rho_1(y, i)$	0.674		
$\rho_2(y, i)$	0.910		
$\rho_1(y, c) / \rho_2(y, c)$	0.922		
$\rho_1(y, i) / \rho_2(y, i)$	0.740		

To further investigate this channel, Figure 2.2 presents the Generalized Impulse Responses of a shock to productivity for GDP, consumption, capital, labor hours, and investment. Since capital is predetermined, the model cannot reproduce the “at impact” effect, so we focus on the accumulated functions. The GIRFs are simulated departing from a situation in which the economy is at normal times (blue line) and one in which the economy is under financial distress (orange line). The results are consistent with our empirical results in Chapter 1. GDP, consumption, and investment are much more responsive in the financial distress regime. This suggests strong amplification effects coming from the financial frictions. To see why, Figure 2.3 shows the standard responses of Bonds in each of regimes. In a normal time, a positive TFP shock produces

a reduction of the Bond position (Bonds are negative in the ergodic distribution). Thus, a large part of the extra income is precautionarily saved. On the other hand, under a binding constraint, since the constraint is relaxed, agents react by consuming and investing more until they reach the steady state equilibrium, then they start to save.

Figure 2.2: Accumulated GIRFs to a TFP shock. “normal regime” (R1) vs. “financial distress regime” (R2). Computed based on 10,000 simulated paths.

Figure 2.3: GIRFs to a TFP shock. “normal regime” (R1) vs. “financial distress regime” (R2). Computed based on 10,000 simulated paths.

Therefore, when it comes to moments within regimes and impulse responses, the model does well in replicating the pattern in the data. Next, we evaluate the accuracy of the model regarding generating crises with frequency and duration consistent with the data. The results are based on a simulated series used to compute the moments previously reported. Confirming the findings of the literature, we find that crisis

events occur with low probability: even with agents being more impatient since we assume $\bar{\psi} = 1.1$, the frequency of crises in our simulation procedure is 5.5%. Increasing impatience may lead to more crises, but the other results become unreasonable. After entering in a bad regime, the economy spends about 2.15 years experiencing binding constraints. Since in our sample the average quarters in crises is about 5.4, our findings here suggest that the model produces crises slightly more persistent than in the data.

Table 2.3: Average Duration and Frequency of Crises

IMPLIED CRISES AND THEIR PROPERTIES	Mean
Frequency of crises	5.52 %
Duration (# of years in a bad regime)	2.15

Thus, the setup as we defined until now can do a good job explaining moments and dynamics within regimes but lacks the ability to generate crises with the frequency that we see in the data. We next investigate the effects of adding external shocks that may lead to financial crises.

2.4 Extensions

2.4.1 Risk Shocks as Volatility Shocks

Until now, we have treated the price of bonds with a constant volatility. However, one important feature of the business cycles in emerging markets is that real interest rates present time-varying volatility. To support this claim, this section begins providing evidence from stochastic volatility models for nine emerging economies. The estimations are based on a bivariate TVP-VAR following Primiceri (2005). The system is composed of GDP growth and country spreads. The latter is calculated following Uribe and Yue (2006) and Aguiar and Gopinath (2007), gathered from the EMBI+ spread and a proxy for the world interest rate. Details are presented in appendix B.3. Complementing the findings of Gruss and Mertens (2009) and Fernández-Villaverde et al. (2011), our results, also in appendix B.3, show a significant variation in the behavior of real interest rate for our sample of emerging economies.

Motivated by these evidences, we introduce stochastic volatility into the data generating

process for the interest rate, assuming the following law of motions:

$$R_{t+1}^{SV} = (1 - \rho^R)\bar{R} + \rho^R R_t^{SV} + \sigma_t^{SV} \varepsilon_{R,t+1}^{SV} \quad (2.8a)$$

$$\sigma_{t+1}^{SV} = (1 - \rho^\sigma)\bar{\sigma} + \rho^\sigma \sigma_t^{SV} + \varepsilon_{\sigma,t+1}^{SV} \quad (2.8b)$$

The parameters $\bar{R}$ and ρ^R follow the previous calibration. $\varepsilon_{R,t}^{SV}$ is assumed to be $\varepsilon_{R,t}^{SV} \sim N(0, 1)$. The other parameters are inferred from our empirical estimations. $\bar{\sigma}$ is set to -6.5, ρ^σ is equal to 0.9, and the standard deviation of $\varepsilon_{\sigma,t}^{SV}$ equals 0.058.

By embedding a stochastic volatility into our model, we are assuming that crises may be results from both domestic, endogenous credit conditions and by external, exogenous sources of financial instability. Frictions coming from the interest rate may have consequences for employment through the working capital constraint and to credit, through the price of bonds. The impacts on credit markets are complicated by the fact that interest rates affect the collateral constraint. Thus, increasing the uncertainty coming from stochastic components may also increase the endogenous uncertainty associated with a binding constraint. In a similar exercise in a model without occasionally binding constraints, Fernández-Villaverde et al. (2011) report that the ergodic distributions of bonds, labor, investment, and consumption change after the addition of stochastic volatility into the model because rational expectation agents optimally adjust their precautionary savings to avoid an excess of volatility of consumption. In our model, such implications are also present, but they come with implications for the likelihood of crises. The reduction in the ergodic mean of consumption coupled with an increase in the ergodic mean of bonds makes the frequency of crises decrease to 2.5%. The reason is that when the volatility of interest rates rises, taking debt becomes riskier as the economy becomes more prone to larger shocks to interest rates. To reduce the exposure of the marginal utility to such shocks, agents cut consumption to lessen their amount of debt.

However, in the model with occasionally binding constraints, the increase in the precautionary saving has a regime-dependent property. To see this dynamically, Figures 2.4 and 2.5 compare the dynamics of a positive shock in volatility of the interest rate within both regimes. In a normal regime, the effects are similar to what Fernández-Villaverde et al. (2011) find: since debt becomes a worse hedge to negative

productivity shocks, consumption and investment drop. Hours worked is reduced by two sources: a lower marginal productivity of labor associated with a fall in the output and a lower demand for labor due to the working capital constraint. On the other hand, in a financial distress regime, such a precautionary behavior is constrained by the lower values of consumption and investment (corner solutions). As a result, the impacts are much less pronounced compared to the normal regime.

Figure 2.4: GIRFs to a shock on interest rate volatility: “normal regime” (R1) vs. “financial distress regime” (R2). Computed based on 10,000 simulated paths. Variables in % dev.

2.4.2 Financial Shocks as Stochastic Collateral Constraint

This section extends the model by adding financial shocks in the spirit of Jermann and Quadrini (2012). To do so, we rewrite the collateral constraint as

$$b_{t+1} \geq R_t \left(\chi R_t w_t h_t - \kappa_t^{fs} q_t k_{t+1} \right)$$

where

$$\kappa_{t+1}^{fs} = (1 - \rho^{fs}) \kappa + \rho^{fs} \kappa_t^{fs} + \varepsilon_{t+1}^{fs} \quad (2.9)$$

To calibrate the parameters, given our interpretation of TVAR models as counterparts of reduced-form models with occasionally binding constraints, we modeled the FSI

Figure 2.5: GIRFs to a shock on interest rate volatility: “normal regime” (R1) vs. “financial distress regime” (R2). Computed based on 10,000 simulated paths. Variables in % dev.

estimated in Chapter 1 for the Mexican economy as an AR(1) process and assume that the financial FSI has the same dynamic properties of κ_t^{fs} . This produces $\rho^{fs} = 0.83$ and $\sigma_{\varepsilon^{fs}} = 0.145$.⁴

To see how financial shocks dynamically affect an economy with endogenous financial crises, we simulate a negative shock on (2.9). The GIRFs are plotted in Figure 2.6. The results resemble the responses of GDP, consumption, and investment in our sample for emerging economies in Chapter 1: under a financial distress regime, the impact of the “financial shock” is much larger than in the normal regime. The reason is that there will be two different effects with very different implications. The first is an increase in the precautionary savings and the other is the binding effects in a corner solution fashion. The intuitions are as follows: in normal times, increasing the collateral requirements will result in a reduction in GDP, consumption, and investment especially due to the increase in pecuniary savings. As the constraint is very unlikely to bind in such regimes and agents have access to financial markets, savings rise as a consequence of the increase in the risk of a binding constraint; In financial distress, consumption and investments are just limited by the constraint. In this case, tightening the constraints induce even lower consumption and investment. GDP also drops because firms will face more difficulty in financing working capital, lowering the demand for labor.

⁴For a comparison, Jermann and Quadrini calibrate their model to USA, assuming that the constraint is always binding, and computing κ_{t+1} as a residual.

While the dynamics for a financial shock have a pattern similar to what we found in the data, the introduction of another channel makes crises even more rare, a consequence similar to what we found in the previous subsection. The effects on borrowing imply an increase in the bond positions in the ergodic distribution. As a result, the likelihood of a crisis reduces to about 2%. Solving the model with both volatility and financial shocks makes the reduction even stronger: the likelihood of a financial distress regimes falls to 0.35% in one million of years.

We conclude that replicating the observed frequency of crises in a model with endogenous collateral constraint and Debt-Deflation mechanism is a challenging task that requires looking for other channels, for example, impatient effects, different utility forms, and rigidities in wages and prices.

Figure 2.6: GIRFs to a shock on the collateral constraint: “normal regime” (R1) vs. “financial distress regime” (R2). Computed based on 10,000 simulated paths. Variables in % dev.

2.5 Endogenous Uncertainty in Business Cycle Models for Emerging Markets

As we discussed in the introduction, in models with occasionally binding constraints, in addition to the uncertainty coming from the exogenous variables, there will be also an endogenous uncertainty. To see this point, one can use the implied Euler Equations⁵ for the problem and derive the following expression (see Mendoza and Oviedo, 2006a):

$$q_t = E_t \left[\sum_{j=0}^{\infty} \left(\prod_{i=0}^j \left(\frac{1}{\bar{R}_{t+i+1}^t} \right) \right) d_{t+j+1} \right], \quad (2.10)$$

where $\bar{R}_{t+1}^t \equiv \frac{\lambda_t - \kappa \mu_t}{\lambda_{t+1}}$ and d_t is the dividends in period t . This equation makes clear that there is a premium associated with the occasionally binding constraint. However, since λ_{t+1} is uncertain, agents will make forecast about it to infer q_t .

Thus, if agents place probability mass on both regimes, there will also be a probability that the economy goes from one regime to another. Abstracting the case where agents have dogmatic expectations of never leaving the actual state of economy —e.g., the good state—, if a rise in the likelihood of an occasionally binding constraint in the future is internalized by the agents, they will review their choices of consumption and investment paths in order to accommodate the possible binding constraint, causing an increase in the volatility of macroeconomic variables even before the regime change. Understanding how this channel works could help to understand why volatility increases so significantly in times of financial distress.

2.5.1 Accessing Endogenous Uncertainty

Thanks to the solution methods and techniques used to compute expectations, we can assess how uncertainty about future variables endogenously responds to the current state of the economy. We also focus on the paths of the endogenous variables (specifically GDP) whenever the likelihood of a binding constraint is high, so we can compare the uncertainty between the regimes as well as when there is a possible regime switching.

⁵See appendix.

We quantify the degree of endogenous uncertainty by the following methods described in Plante et al. (2015). The idea is to simulate paths of future GDP and compute the forecast errors. Let g_{t+1}^y be the growth rate of GDP in $t + 1$. The measure of endogenous uncertainty surrounding GDP is defined as:

$$\sigma_{g^y,t} \equiv \sqrt{E_t \left[(g_{t+1}^y - E_t g_{t+1}^y)^2 \right]} \quad (2.11)$$

Note that $E_t g_{t+1}^y$ intrinsically takes into account the possibility of change in the state.⁶ To compute $\sigma_{g^y,t}$, we simulate 10,000 series of length 50 starting from two different situations. Then, we compare such cases to the case of normal financial conditions.

The reported computations are based on the benchmark model, but similar results were found for the other models, although with higher differences. Figure 2.7 shows the situation in which a crisis occurred in period t . At t , the endogenous uncertainty about $t + 1$ is almost three times as high ($0.0155/0.0053 \sim 2.93$ times) as in the benchmark situation of no crisis, on average. Interestingly, uncertainty continues to be high until period $t + 3$. This happens because crises are persistent and even if the economy escapes from the constrained region, the risk of a new binding constraint is still quite high. Repeating the exercise now for a situation of no crisis at t but with 50% of chances crisis in $t + 1$ confirms that endogenous uncertainty is increasing in the probability of crises. The relative error of forecasting of GDP growth for $t + 1$ is about 2.2 times as large as in the benchmark case. The analysis in this section is suggestive in that the possibility of a binding constraint in the future has substantial implications for uncertainty in emerging economies, which partially helps to explain the differences in volatility between such economies and Advanced Economies.

⁶We described in the appendix the methods employed to integrate the expectation variables.

Figure 2.7: GIRFs to a TFP shock. Blue line: “normal regime” (R1). Red line: “financial distress regime” (R2). Computed based on 10,000 simulated paths. Variables in % dev.

2.6 Conclusions

This chapter examines the implications of financial instability on business cycles in the emerging markets. It does so by using an equilibrium business cycle model in which a financial crisis is endogenous due to the presence of a Fisherian Debt-Deflation mechanism and pecuniary externalities related to asset prices and wages. When the collateral constraint binds, credit in the economy drops making intertemporal decisions

(consumption and investment) less dependent on the permanent income and more dependent on current income. Since the GDP also falls, consumption and investment drop. However, the presence of Fisherian Debt-Deflation magnifies the drops for the following reason: atomistic rational expectation agents fire sell capital, which turns out to reinforce the binding constraint and gives rise to spiral effects. Thus, a crisis in such an economy can have substantial impacts that come from the financial market conditions.

The existence of endogenous crises gives rise to a transition mechanism due to the credit conditions that is consistent with what we found in the data. In light of this fact, we use the model to disentangle the effects of financial crises coming from both endogenous and exogenous shocks and evaluate the accuracy of the model to generate synthetic data similar to real data. We view this endogenous mechanism as important since financial crises in emerging markets result from both international, exogenous market conditions and also domestic, endogenous conditions related to leverage.

Since these features imply large nonlinearities, we apply a full global solution method coupled with an accurate method to compute the continuous future variables to have access to expectation effects. We compute moments and regime dependent impulse responses. Our findings are: (i) financial instability has serious implications for the second moments of the macro-variables (more correlation with the GDP, much more volatility, more *excess volatility* of consumption relative to the GDP); (ii) financial distress is a rare event with a considerable persistence that causes huge increases in the endogenous uncertainty; (iii) credit tightening implies large amplification effects. Most of these results are consistent with the evidence from emerging market economies.

However, the model fails to generate the frequency of financial distress periods found in the data. The reason is that rational expectation agents make precautionary savings to avoid the large welfare impacts of crises. Embedding more shocks in the model that may lead to financial crises results in an increase of precautionary savings and, in turn, in a reduction of the likelihood of crisis. This suggests that matching the high frequency of crises is challenging for this class of model.

Chapter 3

Debt-Dependent Fiscal Rules in a Small Open-Economy with Endogenous Financial Crises

3.1 Introduction

The pervasive effects of debt and financial crises in the 80s and 90s stressed the requirement of fiscal discipline in emerging markets. Due to the extreme consequences of those episodes, a series of reforms in fiscal institutions were introduced in these countries, expressing the concerns of the policymakers and authorities over the connections between the path of the fiscal variables and the behavior of financial markets. One such reforms was the adoption of fiscal rules. According to the dataset compiled by the IMF staff (see Schaechter et al., 2012), the number of emerging economies following fiscal rules grew rapidly since the mid 90s. While in 1995 very few emerging economies were running some kind of fiscal rule, by 2010 the number reached 33 countries. Often, such rules are based on revenue, expenditure, budget balance or debt, and are motivated by a better macroeconomic stability, reduction of solvency problems, reduction in the likelihood of financial stress periods, and stability of the fiscal size.

However, yet another convincing argument for the adoption of fiscal rules in emerging markets is the role of fiscal policy in macroeconomic volatility. Until recently, many emerging economies have experienced great procyclicality of the fiscal policy—a

remarkable difference when compared to the advanced economies. This behavior of fiscal variables is arguably explained by problems like (i) a limited government access to credit markets, reinforced during financial crises (Gavin and Perotti, 1997; Mendoza and Oviedo, 2006b; Riascos and Vegh, 2003); (ii) rent-seeking problems (Ilzetzki, 2011); and (iii) political economy incentives (Alesina et al., 2008; Tornell and Lane, 1999). As procyclicality tends to exacerbate the volatility of the macroeconomic variables, policymakers may wish to exogenously introduce fiscal rules to discipline spending and revenue to alleviate the effects of government variables on uncertainty.

Notwithstanding, we provide evidence that fiscal rules can be a vehicle to deal with the procyclicality problem. Table 3.1 presents both individual and mean statistics for nine emerging economies that engaged in some fiscal discipline induced by fiscal rules. Data is quarterly HP-filtered time series of government spending and GDP from 1996Q1 to 2012Q4. Comparing the correlations of the whole sample with the period after 2002—coinciding with the period where most countries adopted fiscal rules—, excepting Brazil, Bulgaria, and Hungary, the relationship between government spending and GDP in emerging countries seems now to be much less pro-cyclical. Polling the data, we see that emerging markets have turned to be slightly countercyclical or acyclical at most. Of course, it is hard to establish any causal effect by just comparing correlations. However, as we can see in Table 3.2, expanding the database to countries with no fiscal rule, the reduction in the procyclicality is substantially attenuated, suggesting that the change was much more pronounced in countries following fiscal rules. Moreover, the results are robust to different filtering methods.¹

Although the arguments favoring the adoption of debt rules seems plausible, despite the pieces of evidence, there are many open questions: First, how should the policy-makers define the rule? Second, what are the welfare implications of the selected rule? Third, because emerging markets are likely to suffer from international financial crises,

Table 3.1: Government Spending and GDP Correlations: HP-Filtered series.

TIME SPAN	BGR	BRA	CHI	COL	ECU	HUN	MEX	MYS	PER	POOLED STAT.
1996Q1/2012Q4	0.26	0.16	-0.45	0.11	0.36	0.12	-0.09	0.25	-0.08	0.16
2002Q1/2012Q4	0.32	0.37	-0.64	-0.02	-0.11	0.11	-0.27	-0.17	-0.39	-0.06

¹Frankel et al. (2013) finds that stronger institutions can also be a way to escape from the procyclicality trap. Note that fiscal rules can be interpreted as an institutional policy.

Table 3.2: Comparison of Spending Correlations in emerging markets

SPENDING CORRELATIONS IN EMERGING MARKETS				
	QUADRATIC FILTER		ANNUAL GROWTH	
	1996/2012	2002/2012	1996/2012	2002/2012
Countries Following Rules (#9)	0.182	-0.012	0.325	0.098
All Countries (#14)	0.320	0.257	0.340	0.269

what is the dynamic response of the macroeconomic variables under the chosen rule in turbulent and normal times?

Trying to shed some light on these questions, in this chapter, we developed a dynamic stochastic general equilibrium (DSGE) model for a production Small Open-Economy (SOE) in which both private and public sectors have limited access to financial markets. In our setup, a benevolent government that takes revenue as given can optimally choose between public goods and bonds whenever it can access financial resources. At the same time, the private sector faces a collateral constraint that limits its capacity to borrow from the rest of the world. The financial friction in the private sector is in the spirit of the literature that studies fire sales and financial accelerators (see, for example, Kiyotaki and Moore (1997) and Jermann and Quadrini (2012)) but reinforced by a pecuniary externality that emerges because atomistic private agents do not internalize the amplification effects arising from the connections between debt accumulation and market prices. Thus, the economy features the endogenous financial crises scheme with a Fisherian Debt-Deflation mechanism that has been used to explain many important stylized facts pertaining to the business cycles in emerging markets (Mendoza, 2010).

Using calibration for a typical Emerging Economy, the simulated paths show that, even though the economy is subject to endogenous financial crises and incomplete markets in sovereign debt, a forward-looking government chooses spending in a slightly countercyclical fashion in the model, as we see in the recent data.² The reason is that the fiscal authority saves precautionarily in good times so as to compensate, in welfare terms, private agents in bad times.

We then use the model to analyze both the dynamic and welfare implications of debt-dependent fiscal rules for a typical Emerging Market. We argue that when the

²This result contrasts the ones obtained by Riascos and Vegh (2003) and Mendoza and Oviedo (2006a), where government spending is pro-cyclical in the presence of incomplete markets.

economy is subject to a pecuniary externality, a “good” debt depending rule may take care of the incentives of private agents to accumulate debt. One such rule is the one that tries to mimic the tax implied by a regulator that can internalize the effects of private debt accumulation on prices. In this case, the fiscal rule may depend on private debt. Using rules of this type, we show that welfare can be improved due to the reduction of occurrence of a financial crisis and the lower consumption volatility. On the other hand, rules targeting only government debt also have potential in reducing the probability of crises—although it does not explicitly account for the pecuniary externality—, but can have counterproductive effects in some unlikely states of nature. However, under such rules, the government can partially offset the adverse effects by compensating households in bad states of nature using the extra revenue.

Our work is related to a recent literature that studies the quantitative effects of fiscal rules in SOEs subject to financial frictions. However, the literature follows the tradition of the sovereign default framework à la Eaton and Gersovitz (1981). In this vein, Alfaro and Kanczuk (2016) analyzed an emerging economy in which the government is present biased. They showed that both optimal fiscal rule and even simple fiscal rules can result in substantial welfare gains compared to the case with no rule. Hatchondo et al. (2015) find that limiting the sovereign debt premium might be the best choice for a sovereign authority. As an exception, Bi (2010) use the standard DSGE framework for real small open economy to study optimal debt-targeting in an economy with a debt-elastic sovereign risk premium.

The present study is also related to the literature that analyzes debt-dependent fiscal effects when the fiscal rule follows debt depending rules, as in Richter and Throckmorton (2015) and Bi et al. (2016). Finally, it is related to the literature that studies optimal tax in economies subject to Fisherian Debt-Deflation (Bianchi and Mendoza, 2010, 2015; Jeanne and Korinek, 2013).

The chapter is organized as follows: Section 3.2 presents the benchmark model. Section 3.3 discuss the policy analysis. In section 3.4 the quantitative results are presented. Section 3.5 presents the welfare implications of some selected rules. Finally, section 3.6 concludes.

3.2 The Benchmark Model

We consider an infinite horizon small open economy populated by two agents: a “firm-household”, which we refer to as the private sector, and the government (or the public sector). Financial markets are incomplete and time is discrete.

3.2.1 The Private Sector

Following Mendoza (2010), we assume a representative firm-household that makes production and consumption decisions. These agents maximize their discounted utility given the preferences:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t, g_t^*) \quad (3.1)$$

where β is the subjective discount factor, c_t is the consumption of private goods, l_t is labor supply, and g_t^* is the public good taken as given by the households. Here, $u(\cdot)$ is assumed to be a concave, twice-continuously differentiable function and E_0 is the expectations operator.

The representative agent combines a fixed physical asset (land), k_t , and labor to produce a final good using a concave, twice-continuously differentiable production function, $F(\cdot)$, subject to a productivity shock, z_t . Thus, the GDP is given by $y = F(z_t, k_t, l_t)$. The private agent has access to a foreign risky-less bond market where they can borrow at the world risk-free interest rate, R_t , facing the following budget constraint:

$$c_t + q_t k_{t+1} + \frac{b_{t+1}}{R_t} = (1 - \tau_t) F(z_t, k_t, l_t) + b_t + q_t k_t \quad (3.2)$$

where q_t is the market price of the land, b_t is a one-period non-state-contingent foreign bond, and τ_t is the government taxes on rents. Following Fornaro (2015) and Bianchi and Mendoza (2015), we normalize the supply of the fixed factor at $k_t = 1$. Technology evolves through a simple AR(1) process given by:

$$z_{t+1} = (1 - \rho_z)z + \rho_z z_t + \varepsilon_{z,t+1} \quad (3.3)$$

The private sector takes the government choices as given. Similar to Mendoza (2010), the firm-household faces a collateral constraint in the spirit of Kiyotaki and Moore

(1997) given by:

$$\frac{b_{t+1}}{R} \geq -\phi_p q_t k_{t+1} \quad (3.4)$$

Thus, the private sector is potentially subject to a pecuniary externality associated with a Fisherian Debt Deflation (Jeanne and Korinek, 2010; Korinek and Mendoza, 2014; Mendoza, 2010).

3.2.2 The Government

As in Cuadra et al. (2010), in our benchmark setup, we assume a benevolent government that chooses sequences of expenditure, g_t , and debt public, d_t , trying to maximize the utility of the households. Government finances its expenditures by borrowing or lending from abroad and by taxing households on rents. Its decisions are subject to the following budget constraint:

$$g_t + \frac{d_{t+1}}{R} = d_t + \tau_t F(z_t, k_t, l_t) \quad (3.5)$$

As usual, the government spending is assumed to be non-negative, $g_t \geq 0$. The benchmark model will be used as a basis for studying different fiscal rules followed by the government, which will be described later in details (see section 3.3). Our primary focus is not to find an optimal taxation in a Ramsey problem, so we follow Mendoza and Oviedo (2006a) and assume that taxes are exogenous. In the basic setup, taxes evolve by a simple AR(1) process given by:

$$\tau_{t+1} = (1 - \rho_\tau)\tau + \rho_\tau \tau_t + \varepsilon_{\tau,t+1} \quad (3.6)$$

where τ is assumed a stationary process and ε^τ is interpreted as an unpredictable discretionary shock.

For simplicity, we abstract from introducing the option to default into the sovereign problem, assuming instead that the government has limited access to financial markets by means of a natural debt limit in the spirit of Aiyagari (1994):

$$d_{t+1} \geq -\phi_g \quad (3.7)$$

This kind of constraint can be justified as a reduced form of a limited enforcement

setup (see Bianchi and Mendoza, 2015). Under this ceiling effects, agents can make decisions taking into account a limited capacity of the government to supply insurance in turbulent times.

It is important to note that the interest rate is constant and is the same for the two assets, making the international investor indifferent between which asset to hold. Finally, we close the SOE by assuming $\beta R < 1$, with the same discount factor for both private and public sectors.

3.2.3 Competitive Equilibrium

In what follows, we use the standard notation for recursive problems where a variable without a superscript denotes a current value, while variables with a prime denote future values. Let $\varepsilon' = (z', \tau')$ the vector of shocked variables, and λ and μ the Lagrange multipliers on (3.2) and (3.4), respectively. The dynamic programming problem of the private sector can be expressed as follows:

$$V(d, b, k, \varepsilon) = \max_{c, l, d', k'} \left\{ u(c, l, g^*) + \beta \mathbb{E}[V(d', b', k', \varepsilon')] \right\} \quad (3.8)$$

subject to

$$\begin{aligned} b' &= R(b - c + (1 - \tau)F(z, k, l)) \\ b' &\geq -R\phi_p q k' \end{aligned}$$

Using the implied first order conditions combined with the envelope conditions, we get:

$$u_c - \mu = \beta R \mathbb{E}[u_c'] \quad (3.9a)$$

$$q(u_c - \mu\phi_p) = \beta \mathbb{E}[u_c'((1 - \tau')F_k(z', k', l') + q')] \quad (3.9b)$$

$$-u_l = (1 - \tau)F_l(z, k, l)u_c \quad (3.9c)$$

where $\mathbb{E}$ is the expectation operator.

From (3.9) we see that private choices are potentially distorted by two distinct sources. The first is associated with taxes, and it will be always in place in our calibrated experiments. Current taxes, τ , distort the intratemporal decisions by af-

fecting labor. Expected taxes, $\mathbb{E}[\tau']$, affect consumption and labor decisions through $\mathbb{E}[u_c'] = \mathbb{E}[V'_{b'}(d', b', k', z', \tau')]$ term, where $V'_{b'}$ is the derivative of the value function with respect to b' , because the expected future taxes are taken into account, as (3.8) makes clear. Under plausible calibrations, an expected increase in taxes tends to increase the expected marginal utility of consumption. Accordingly, $\mathbb{E}[F_k(k', l')]$ will be updated after an expected change in future taxes. As the price of land is a function of these expected variables as well as its own future expected value, its current value will also be changed after a revision a future expected tax. Taking these channels into account, this set of equations is essential in our analysis, because it opens the door for the fiscal policy to affect prices and private decisions to take on debt, possibly affecting borrowing decisions.

The second source of distortion, $\mu_t \geq 0$, is due to the occasionally binding collateral constraint. As equations (3.9a) and (3.9b) make clear, in the event of a crisis, current marginal consumption is higher and prices are higher. Consequently, consumption falls.

To better understand how fiscal policy can influence private debt position, let us first analyze how fiscal policy, collateral constraint, and asset prices interact within the model. Following Mendoza and Smith (2006) and Bianchi and Mendoza (2010), we can use (3.9b) to compute the following forward solution for the land prices:

$$q_t = \mathbb{E} \left[\sum_{j=0}^{\infty} \left(\prod_{i=0}^j m_{t+i+1} \right) (1 - \tau_{t+j+1}) F_k(z_{t+j+1}, k_{t+j+1}, l_{t+j+1}) \right],$$

where $m_{t+i+1} = \frac{\beta u_{c,t+i+1}}{u_{c,t+i} - \mu_{t+i} \phi_p}$. This expression makes clear that both expected borrowing restrictions and expected taxes affect today's prices. To get more intuition, let the expected asset return net of taxes be defined as $R_{t+1}^q \equiv \frac{(1 - \tau_{t+1}) F_k(z_{t+1}, k_{t+1}, l_{t+1}) + q_{t+1}}{q_t}$. Working on the Euler equations, it is easy to see that the expected excess return on land relative to bond is given by the condition:

$$\mathbb{E}[R_{t+1}^q - R] = \frac{\mu_t(1 - \phi_p)}{u_{c,t+i} - \mu_{t+i} \phi_p \mathbb{E}[m_{t+1}]} - \frac{\text{cov}(m_{t+1}, R_{t+1}^q)}{\mathbb{E}[m_{t+1}]}$$

Thus, when $\mu > 0$, there will be an a premium. Moreover, compared to the economy without government taxes, the expected excess return on land relative to bond should

be more volatile, because the uncertainty surrounding taxes introduces more volatility on $\mathbb{E}[R_{t+1}^q]$.

Turning to the government's problem, similar to Cuadra et al. (2010), we assume that the government takes optimal choices from the private sector and prices as given, but is aware of the effects of its decisions on the private sector. Given the set of optimality conditions for the private sector, its problem can be represented as:

$$V(d, b, k, \varepsilon) = \max_{g, d'} \left\{ u(c^*, l^*, g) + \beta \mathbb{E} \left[V(d', b'^*, k'^*, \varepsilon') \right] \right\} \quad (3.10)$$

subject to

$$\begin{aligned} d' &= R(d + \tau F(z, k, l) - g) \\ b'^* &= R(b - c^* + (1 - \tau)F(z, k, l^*)) \\ l^* &= l(\tau) \\ d' &\geq -\phi_g \end{aligned}$$

We show in the appendix that the Euler equation for the government is given by

$$u_g \left(1 + \frac{\partial b'}{\partial d'} + R \frac{\partial c}{\partial d'} \right) \geq R\beta \mathbb{E}[u_g'] \quad (3.11)$$

where the inequality reflects the fact that the government collateral constraint may be binding occasionally. The term $\frac{\partial b'}{\partial d'}$ is the marginal effect of an increase in government indebtedness on private debt, whereas $\frac{\partial c}{\partial d'}$ is its analogue to private consumption. These terms reflect the fact that the government takes into account the effect of issuing more bonds on the economy, specifically on private debt and private consumption.

We restrict our attention to an equilibrium in which both private and public sectors are net debtors. In a nutshell, we look for a competitive equilibrium characterized by stochastic sequences of allocations sequentially chosen by the agents—both in private and public sectors—such that: (i) $\{g_t, d_t\}_{t=0}^{\infty}$ solves the government's problem; (ii) $\{c_t, b_t, d_t\}_{t=0}^{\infty}$ solves the household's problem; (iii) the Lagrange multipliers associated with the resource constraint and collateral constraints on private and public sectors, as well as sequences of prices $\{q_t, w_t\}_{t=0}^{\infty}$ satisfies the set of equations just described given the economy debt position $\{d_t, b_t\}$; initial conditions, stochastic process for

productivity, and taxes, are such that the economy-wide resource constraint is satisfied.

We begin by discussing the a simple discretionary policy. Then we analyze an optimal situation in which a planner—also called “regulator” —can internalize the effects of debt accumulation on prices. This case is important since it can serve us as a benchmark to compare welfare and dynamics implications of the fiscal rules. Importantly, this optimal rule is used to give us insights into the design of the fiscal rules.³ Finally, we compare the proposed fiscal rules with some alternatives.

3.3 Policy Analysis

3.3.1 Discretionary Policies: No Rule

Discretionary Policies in our context are simple policies based on equation (3.6). A positive (negative) shock is interpreted as a contractionary (expansionary) shock. The government reacts to the changes in revenue by optimally saving or dissaving, depending on the state of nature. The main difference from our setup to a setup with no financial crises is that the effects of discretionary policies will be state-dependent. When the economy is under a good financial condition, the private sector has full access to the international financial markets to readjust consumption decisions. On the other hand, if the collateral constraint is binding, this readjustment will be limited.

3.3.2 Social Planner: A Pigouvian Tax

With the aftermath of the recent financial crises, a large body of literature have devoted efforts to understand the interaction between debt accumulation and asset prices, especially concerning policy. For emerging markets, the workhorse models are those for open economies subject to pecuniary externalities induced by the presence of collateral constraints (Mendoza, 2002b, 2010).

In sum, there are two branches of literature: in the first, the literature studies the effectiveness of a debt tax to reduce crises probability in a setting where the borrowing capacity is limited by a particular linkage between the relative price of nontradable to

³Additionally, we will use the private debt position under the regulator to calibrate some parameters of our fiscal rules.

tradable goods and the streams of endowments of tradable and nontradable goods. Broadly speaking, such taxes are effective in reducing the likelihood of crises. Examples of ex-ante policies in this class of models are Bianchi (2011) and Schmitt-Grohe and Uribe (2016), and Benigno et al. (2013) for ex-post analysis.

This chapter follows the approach of the second branch of literature, in which the collateral constraint is based on stocks and the pecuniary externality relates to the asset prices, as in Jeanne and Korinek (2010), Bianchi and Mendoza (2010) and Bianchi and Mendoza (2015). These papers focus on equilibrium in which a planner can offset the distortion implied by the collateral constraint by introducing a Pigouvian tax on debt to reduce the incentives for the private sector to take debt compared to the decentralized case. We illustrate how this works as follows:⁴ suppose the planner can internalize the effects of private debt accumulation on prices. Then, the relevant borrowing constraint for the planner is $b' \geq -\phi_p q(b, \cdot) k' R$, and its problem would be to maximize the agent's utility subject to the economy budget constraint under this reformulated inequality. The implied equilibrium under the planner's choice can be attained by introducing a Pigouvian state-contingent tax so that the price of bonds becomes $\frac{1}{R(1+\tau^{sp})}$. The tax-revenue from this tax is rebated back to the economy as lump sum transfers. The modified budget constraint for the private sector becomes:

$$c + g = b + (1 - \tau)F(z, k, l) - \frac{b'}{R(1 + \tau^{sp})} + T \quad (3.12)$$

where τ^{sp} is the social planner tax and T is the lump sum transfer. This so-called macroprudential tax is usually interpreted as a contractionary policy since it makes more expensive to borrowers to take on debt (Jeanne and Korinek, 2013; Stein, 2012). Under this rule, the bonds Euler equation becomes:

$$u_c = \beta R E \left[u'_c (1 + \tau^{sp}) \right] + \mu^{sp},$$

thus, inducing a wedge in the debt demand. To replicate the constrained social optimum, the social planner sets:

$$\tau^{sp} = -E \left[\frac{\xi' u'_{cc} q'}{u'_c} \right] \geq 0$$

⁴The full set of optimal conditions for the planner's problem is presented in appendix C.2

where $\zeta' = \mathbb{E} \left[\frac{\phi_p \mu'}{u'_c - \phi_p \mu'} \right]$, u'_{cc} is the derivative of u_c with respect to c .

The problem with this kind of tax is that it is entirely based on forward-looking variables, which makes it of limited use in practice. In the next section, we discuss simple fiscal rules with more practical appeal.

3.3.3 Debt-Dependent Fiscal Rules

A debt-dependent fiscal rule is a particular kind of fiscal rule that aims to discipline government's decisions by a predetermined adjustment of tax or spending due to realizations of debt. Such a rule can be defined in terms of a fixed debt target—usually as share of GDP—or in terms of debt growth. Our setup suggests three possibilities to build up debt-dependent rules. The tax may depend on d , on b , or on the overall SOE debt $b + d$, which is an intermediate case. By construction, the simplicity of the financial sector in the model implies that most of the potential welfare gains come from private debt. This follows from the presence of the pecuniary externality due to the collateral constraint, as discussed in the previous section. When the government changes τ , it affects dividends as well as asset prices. By internalizing that the choice of b' can affect prices q in some states of nature $\left(\frac{\partial q(b', \cdot)}{\partial b'} \neq 0 \right)$, the debt rule on τ could be set in a particular way such that the likelihood of financial crises could be smaller. Therefore, in the present model, the fiscal authority might be targeting the private debt. Clearly, this seems at odd with the debt rules commonly advocated in the literature, but the message here is the following: in economies subject to debt deflation, when constructing debt-dependent fiscal rules, policymakers should care about the effects leverage on prices.

To make this point clear, let us now explore a connection between debt-dependent fiscal rules and the so-called macro-prudential policy. To do so, we first solve a problem similar to the planner's problem but setting $T = 0$ so there will be no instantaneous rebate. Instead, the revenue from the extra tax will be incorporated into the government's budget constraint so that the government may decide whether to save or to provide public goods. Solving the regulator problem, which in turn requires

assuming that $q(b, \cdot)$, would give the following Euler equations:

$$u_c - \mu^* = \beta R \mathbb{E} \left[u_c' \left(1 + \phi_p \mu' \frac{\partial q'}{\partial b'} \right) \right] \quad (3.13a)$$

$$q(u_c - \mu^* \phi_p) = \beta \mathbb{E} [u_c' ((1 - \tau') F_k(z', k', l') + q')] \quad (3.13b)$$

Plugging (3.13a) into (3.13b) and rearranging, results in:

$$\mathbb{E}(1 - \tau') = \mathbb{E} \left[\frac{q \left(\beta R u_c' (1 + \phi_p \mu' \frac{\partial q'}{\partial b'}) + \mu (1 - \phi_p) \right)}{\beta u_c' F_k(z', k', l')} \right] - \mathbb{E} \left[\frac{q'}{F_k(z', k', l')} \right] \quad (3.14)$$

Comparing this expression to the similar expression obtained from the decentralized equilibrium,

$$\mathbb{E}(1 - \tau') = \mathbb{E} \left[\frac{q (\beta R u_c' + \mu (1 - \phi_p))}{\beta u_c' F_k(z', k', l')} \right] - \mathbb{E} \left[\frac{q'}{F_k(z', k', l')} \right],$$

it is easy to see that a regulator could introduce the following tax to force the private sector allocations to coincide with the planners' allocations:

$$\tau_b(b') = \phi_p q \mathbb{E} \left[\frac{u_c' \mu'}{F_k(z', k', l')} \frac{\partial q'}{\partial b'} \right] \quad (3.15)$$

which equals zero when the collateral constraint is expected to be slack.⁵ Thus,

$$\mathbb{E}(1 - \tau'_R) = \mathbb{E}(1 - \tau' - \tau_b(b')) = \mathbb{E} \left[\frac{q (\beta R u_c' + \mu (1 - \phi_p))}{\beta u_c' F_k(z', k', l')} \right] - \mathbb{E} \left[\frac{q'}{F_k(z', k', l')} \right]$$

where $\tau'_R \equiv \tau'_R(\tau', \tau_b(b')) = \tau' + \tau_b(b')$. Combining (3.6) with $\tau_b(b')$ we can find an autoregressive expression for τ'_R that suggests that if the fiscal authority is willing to optimally perceive a debt-dependent tax schedule, such a tax would be in a sense related to a kind of capital control tax rule.

Having this comparative analysis in mind, in the next section we present a set of simple fiscal rules based on the current choice of the private debt position. The comparative analysis in this section is suggestive in that a “good” fiscal rule should mimic the behavior of the optimal capital control tax. Thus, we make use of the results obtained from the Macro-prudential Pigouvian Tax to calibrate the parameters in the rules and

⁵The abuse of notation is to reinforce the dependence of τ'_b on b' .

evaluate in relative terms its potential effects on welfare and the dynamics in crisis events. The next subsection describes the selected rules.

3.3.3.1 Tax Rules Depending on Private Debt

We consider three different rules, namely:

Rule 1: Nonlinear isoelastic

$$\tau'_{R_1} = (1 - \rho_\tau)\tau + \rho_\tau\tau_{R_1} + \gamma_{R_1} \left[\max \left(0, \left(\frac{b'}{b^T} \right)^{\phi_1} + \phi_2 \right) \right] + \varepsilon'_\tau \quad (3.16)$$

Rule 2: Nonlinear deviation

$$\tau'_{R_2} = (1 - \rho_\tau)\tau + \rho_\tau\tau_{R_2} + \gamma_{R_2} \left[\max \left(0, \frac{b'}{b^T} - \phi_3 \right)^2 \right] + \varepsilon'_\tau \quad (3.17)$$

Rule 3: Simple debt growth

$$\tau'_{R_3} = (1 - \rho_\tau)\tau + \rho_\tau\tau_{R_3} + \gamma_{R_3} \left[\left(\frac{b'}{b} - 1 \right)^2 \right] + \varepsilon'_\tau \quad (3.18)$$

where γ_b , ϕ_1 , ϕ_2 and b^T are parameters. γ_R controls for the responsiveness of τ to changes in the underlying debt-to-target ratio. ϕ_1 is the elasticity of the rule to deviations from the target, b^T , and ϕ_2 is the amplitude of the rule. R_1 and R_2 will be in place only when the collateral constraint is binding, whereas the R_3 will be always active. As discussed in the previous sections, except for the R_3 , the parameters are calibrated trying to match the results obtained when we solve the model using the planner's choices. For example, b^T , the debt target, is the minimum debt position obtained from the planner's problem in every state of nature.

3.3.3.2 Tax Rules Depending on Government Debt

For the cases in which the rules are based on government debt, we consider the following two rules:

Rule 4: Government debt growth

$$\tau'_{R_4} = (1 - \rho_\tau)\tau + \rho_\tau\tau_{R_4} + \gamma_{R_4} \left[\left(\frac{d'}{d} - 1 \right)^2 \right] + \varepsilon'_\tau \quad (3.19)$$

Rule 5: Government debt target

$$\tau'_{R_5} = (1 - \rho_\tau)\tau + \rho_\tau\tau_{R_5} + \gamma_{R_5} \left[\left(\frac{d'}{d^T} - 1 \right)^2 \right] + \varepsilon'_\tau \quad (3.20)$$

were the γ_R are similar to the above cases and d^T is the parameter relating the rule with the debt target.

3.4 Quantitative Analysis

3.4.1 Functional Forms and Calibration

We assume the following functional forms:

$$u(c, l, g) = (1 - \pi) \frac{(c - \theta \frac{l^\omega}{\omega})^{1-\sigma}}{1 - \sigma} + \pi \frac{g^{1-\sigma}}{1 - \sigma} \quad (3.21)$$

$$F(z, k, l) = zk^{\alpha_k}l^{\alpha_l}, \quad \alpha_k, \alpha_l \geq 0, \quad \alpha_k + \alpha_l < 1 \quad (3.22)$$

where π is the weight used to sum a standard GHH utility and the utility derived from the public good. σ is set to the standard parameter in DSGE literature for both government and the private sector. θ is an inessential parameter set so as the mean hours equals 1 in equilibrium. The parameter in ω in the Frisch elasticity of labor supply is set to 1.855 following Mendoza (2010). The discount factor parameter, β , is set so as to have about 4% of a crisis in the steady-state for most versions of the model. The parameters related to the production function are calibrated following Fornaro (2015), who calibrated a similar model for small European economies. We set $\alpha_l = 0.64$ and $\alpha_k = 0.05$. Note that because we assume a fixed factor normalized to 1, the production function presents decreasing returns to scale.

For the financial markets, we set $R = 1.05$ which is a value closer to a typical Emerging Economy. The ad-hoc government debt parameter, ϕ_g , is set arbitrarily to 0.9, while the parameter in the collateral constraint for the private sector is set to be consistent

with the mean private debt in the steady-state. The debt-to-GDP ratios are set following Riascos and Vegh (2003). $\bar{\tau}$ is a value closed to the mean tax estimated for emerging economies, while ϕ is taken from Cuadra et al. (2010). The stochastic process are estimated from a VAR using HP-filtered series from GDP and tax revenue in Mexico from 1985 to 2015.

Table 3.3: Calibrated Parameters

PARAMETER	CONCEPT	VALUE	SOURCE/TARGET
<i>Technology</i>			
α_l	Share of labor	0.6400	Fornaro (2015)
α_k	Share of land	0.0500	Bianchi and Mendoza (2010)
k	Land	1.0000	Normalization
<i>Preferences</i>			
σ	Risk Aversion	2.0000	Literature
β	Discount Factor	0.9100	About 4% of crisis
θ	Labor Parameter	0.5632	Set so that $l = 1$
ω	Labor Elasticity	1.8550	Mendoza (2010)
<i>Financial Markets</i>			
ϕ_p	Collateral coefficient	0.5500	Implied by the S.S.
ϕ_g	Ad-hoc debt limit	0.9000	More than $2 \times d$ in the S.S.
R	Interest Rate	1.0500	A typical emerging market
b/y	Private Debt-to-GDP ratio	0.3500	Riascos and Vegh (2003)
d/y	Public Debt-to-GDP ratio	0.4000	Riascos and Vegh (2003)
<i>Government Sector</i>			
$\bar{\tau}$	Mean tax	0.1375	Mean tax in Mexico (1985-2015)
π	Gov.-to-Consumption ratio	0.3000	Cuadra et al. (2010)
<i>Stochastic Process</i>			
ρ_z	TFP AR coefficient	0.6900	VAR estimates
σ_z	TFP std. deviation	0.0125	
ρ_τ	τ AR coefficient	0.7500	
σ_τ	τ std. deviation	0.0115	

3.4.2 Policy Functions - A Comparison of Implied Equilibria

Let us analyze the quantitative implications of the model, starting by exploring the effects of debt rules on agents decisions. Because the model cannot be solved analytically, we employ a global solution method to solve it. To do so, we extend the Envelope

Table 3.4: Calibrated Parameters in Rules 1 to 5

PARAMETER	VALUE
γ_{R1}	0,05000
γ_{R2}	0,03000
γ_{R3}	0,05000
γ_{R4}	0,00125
γ_{R5}	0,00125
ϕ_1	0,70000
ϕ_2	-0,80000
ϕ_3	2,00000
b^T	-0,31000
d^T	-0,40000

Condition Method described in Arellano et al. (2016) to deal with occasionally binding constraints. The solution method is described in appendix C.3.

3.4.2.1 Private Decisions Under Rules Depending on Private Debt

We start by analyzing the effects of debt rules tracking private debt. Figure 3.1 compares the bond decision of private agents under different tax schemes. The V-Shape of the policy functions for bonds is a consequence of the presence of the debt deflation mechanism. In the figure, the “Regulator Rule” is the implied policy function when a regulator introduces the macro-prudential tax described in section 3.3.2. “No Debt Rule” is the case in which tax evolves following (3.6) and “R1” is the Rule 1 given by (3.16). We concentrate on “R1” for brevity. Clearly, under the regulator case, private agents take much less debt. This comes from the fact that the regulator takes into account the pecuniary externality and induces agents to get the highest welfare in the presence of financial instability, which in turn requires a lower amount of credit to avoid situations in which leverage is closed to the maximum level that economy can support. On the other hand, with no rule, agents accumulate the highest level of debt, implying a higher leverage as well as a greater risk of a binding constraint. As a result, the economy becomes more exposed to bad states of nature.

Figure 3.1: Private debt dynamics under different regimes. Figure depicts a situation of bad technological shock and a low tax.

The introduction of Rule 1 induces the agents to an intermediate case in which the leverage is not as high as in decentralized equilibrium, but not as low as in the pure regulator case. To see this point, Figure 3.2 depicts the leverage and debt position under the situations with No Rule and Rule 1. Clearly, the constrained area, the situation in which the collateral constraint is binding, is higher when agents choose debt without any anchor. As a result, the absence of any control induces the economy to a higher probability of crises.

The effects of the introduction of the debt targeting R1 on consumption and prices can be accessed by looking at Figure 3.4. The additional tax reduces debt, but also consumption. That is the main channel for this debt rule, with consumption getting closer to the amount of consumption in the regulator case in regions away from the binding area. However, prices are only slightly lesser than the decentralized version, which means that the leverage under the regulator would be quite different.

The set of policy functions for a combination of pairs (b, d) is presented in Figure C.1 in the appendix.

Figure 3.2: Leverage and private debt dynamics under different regimes. Figure depicts a situation of bad technological shock and a low tax.

Figure 3.3: Consumption and land prices dynamics. Figure depicts a situation of bad technological shock and a low tax.

3.4.2.2 Private Decisions Under Rules Depending on Government Debt

We now turn to the case where the fiscal rule follows the government debt. The main difference here is that the pecuniary externality is not accounted. For brevity, we present the results for Rule 5 focusing on a situation in which the target d^T is the long-run government debt. Figure 3.4 shows the implied decision rules in an unlikely situation in which the public debt is too low so that that next period tax will be increased. Because government debt is in another dimension in our setup, it is fixed at every point of the private debt grid. Therefore, graphical representation here excludes plots the tax increment.⁶ The first point to note is that the differences

⁶See Figure C.2 in the appendix for a 3-dimensional representation.

in policy functions when the economy is in the decentralized case (No Rule) or in Rule 6 depends on the current amount of private debt. Forward-looking agents, anticipating the extra tax in situations where the government debt is away from the target, reduce consumption and increase savings. As a consequence, both land prices and debt are higher than in the decentralized case. However, because a greater price implies a higher value of the collateral, the leverage decrease alleviates the constraint. Consequently, the economy faces a constrained area under Rule 5 slightly smaller than in the decentralized equilibrium.

Figure 3.4: Consumption and Land Prices Dynamics. Figure depicts a situation of bad technological shock and a low tax.

To see this point, Figure 3.5 plots leverage and decision rule for bonds when the economy is following Rule 5 and a situation with any rule. As in the case of Rule 1, the constrained area is smaller than in the decentralized equilibrium. However, there are clear differences in dynamics away from the region where the constraint marginally binds. We stress this differences in Figure 3.6. It plots the bonds decision rules under decentralized equilibrium, Rules 1 and 5. As soon as the probability of a binding constraint reduces, agents starts to save more under Rule 5. They do so as an optimal response to an expected increase in the wedge. This means that, under

Rule 5, borrowing decisions are affected in a strong non-linear fashion whenever the government is running out of the debt target. When agents face a binding constraint, a higher tax would worsen the effects of the crises. However, in tranquil times, an expected increase in tax would induce agents to increase the precautionary savings.

Figure 3.5: Leverage and Private debt dynamics under different regimes. Figure depicts a situation of bad technological shock and a low tax.

Although the results illustrated in the figures suggest substantial effects in economy, the situations analyzed here could be the results of very infrequent events in the state-space of the model. Thus, to investigate the potential of the debt rules in affecting the long-run properties of the economy, we now turn to some simulations exercises. We start by presenting the Business Cycle Properties of the selected rules. Next, we analyze the dynamics within crisis, and then how the debt rules can affect the business cycles. Finally, we analyze the welfare implications.

3.4.3 Business Cycle Properties

As the only source of friction in the private sector is the collateral constrained coupled with the Fisherian debt-deflation, we are not expecting a good power for the model in replicating the moments in the data. However, it is important to analyze the business cycles to have an idea on how government is affecting the business cycles. Table 3.5

Figure 3.6: Private debt dynamics under selected rules.

presents the unconditional second moments for the decentralized economy as well as for the economy under Rules 1 to 5.

Table 3.5: Implied Second Moments Under Different Rules

CORRELATION WITH GDP						
	No Rule	R1	R2	R3	R4	R5
Consumption	0.7708	0.7706	0.7737	0.7784	0.7754	0.7919
Employment	0.8890	0.8908	0.8925	0.8932	0.8952	0.8925
Land Price	0.7986	0.7098	0.7990	0.7980	0.7898	0.7907
Spending	-0.0855	-0.0576	-0.0875	-0.0842	-0.07842	-0.0502
STANDARD DEVIATIONS						
	No Rule	R1	R2	R3	R4	R5
Consumption	0.0394	0.0361	0.0396	0.0397	0.0392	0.0322
Employment	0.0219	0.0202	0.0217	0.0218	0.0220	0.0205
Land Price	0.0299	0.0307	0.0301	0.0302	0.0306	0.0251
Spending	0.0145	0.0185	0.0212	0.0154	0.0210	0.0283
GDP	0.0284	0.0271	0.0290	0.0285	0.0289	0.0281

Two aspects of Table 3.5 are worthwhile to discuss. First is that government spending is slightly countercyclical. Interestingly, when revenue is based on Rules 1 and 5, the absolute value of the correlation coefficient becomes smaller, closer to zero, and similar to the data presented in the introduction of the chapter for some emerging economies that are following some kind of fiscal rule. Moreover, under these two rules, consumption and employment are less volatile, suggesting that some fiscal rules could be a good vehicle to stabilize the economy by reducing the frequency of crises. To have

more in-depth analyses, we next study the dynamics under the selected rules.

3.4.4 Event Analysis

In this section, we try to shed some light on how fiscal rules can affect the dynamic behavior of the economy during crises. To do so, following the strategy of Bianchi and Mendoza (2010) and Mendoza (2010), we simulate the economy for 100,000 periods—dropping the first 1,000 as burn-in—and collect all episodes in which the collateral constraint binds and the current account-to-GDP ratio exceeds one standard deviation. With the episodes marked as “crisis” at hand, we start by computing the probability of crises and the average losses in consumption, land prices, and credit under the selected rules. Table 3.6 presents the results.

The benchmark case is the decentralized economy, labeled as “No Rule.” The long-run likelihood of crises for this case is 4.15%, with consumption dropping about 9.66%, prices by 12.40%, and credit by 10.22%. The most effective rule in terms of reducing the drop is Rule 1. This is because it is the only rule that aims to account for the pecuniary externality, albeit in an arbitrary manner. Under this rule, consumption drops 7.54%, which is 2.1 percentage points lower than the fall in decentralized case. Both prices and credit also have lesser reductions under this rule. In contrast, Rules 3 and 4 seem to perform similarly to the decentralized case. The reason is that such rules do not take into account the non-linear relationship between credit and the state of the economy. Rule 2 has complex implications because it gives the same weight for regions above and below the target. This results in loss of efficiency because the tax is raised in times of crises. Therefore, the potential gains are offset by the rising in the wedge. Finally, Rule 5 seems to suffer from a trade-off. While it is the most efficient rule in reducing the likelihood of crises from 4.15% to 1.15%, in turbulent times, it makes the drop on consumption more pronounced. To see this dynamically, we constructed a five year window centered around the crisis event and analyze the dynamic behavior of some selected variables at years $t - 2$, $t - 1$, the year of crisis episode, t , $t + 1$, and $t + 2$. The results are expressed in Figure 3.7

Table 3.6: Crises Properties Under Different Rules

RULE	CRISIS PROBABILITY	AVERAGE LOSS		
		c	q	CREDIT
No Rule	4.15%	-9.66%	-12.40%	-10.22%
R1	2.80%	-7.54%	-9.25%	-7.43%
R2	4.07%	-9.71%	-12.39%	-10.20%
R3	4.25%	-9.76%	-12.54%	-10.35%
R4	4.15%	-9.95%	-12.84%	-10.65%
R5	1.15%	-10.67%	-12.89%	-10.68%

Figure 3.7: Event Analysis for different regimes

3.5 Welfare Implications

To analyze the welfare effects, we compute the welfare costs as compensating consumption variations for each state of nature so that agents are indifferent between the allocations from the decentralized equilibrium (DE) and the equilibrium implied by the rules. The welfare cost is the value γ_{Rule}^ω such that the following condition holds:

$$E_t \sum_t \beta^t u(c_t^{DE}(1 + \gamma_{Rule}^\omega), l_t^{DE}, g_t^{DE}) = E_t \sum_t \beta^t u(c_t^{Rule}, l_t^{Rule}, g_t^{Rule})$$

where *Rule* stands for the values associated with the planner's problem or to Rules 1 to 3. Because there is no closed form for γ_{Rule}^ω under the assumed utility form, we need resort to numerical methods to calculate it. As these computations introduce a large computation cost, we focus on Rules 1 and 5.

The potential gains from the fiscal rules compared to the DE comes from two sources, namely (i) the reduction consumption variability due to a lower probability of crises, and (ii) the response of the government in crises events compensating agents from the loss in welfare derived from consumption. However, there might be an amplification of the wedge in situations where tax is increased, which can potentially decrease welfare. Figure 3.8 plots the welfare costs as a function of b for a low-productive and low-tax scenario. In the two cases, the gains of switching from the decentralized equilibrium to a debt targeting rule are more pronounced in the region of high externality. Importantly, in both cases, the gain is positive for most of the state space. However, for some extremely infrequent situations, the gains under Rule 5 could be harmful. Using the simulated shocks to calculate the unconditional average welfare cost over the ergodic distribution in the decentralized equilibrium, we find $E[\gamma_1^\omega] = 0.026$ and $E[\gamma_5^\omega] = 0.018$. Therefore, similar to Bianchi and Mendoza (2010), the welfare losses from consumption fluctuation are quite small—which is a feature shared by models with CRRA utility, trend-stationary income, and no idiosyncratic uncertainty. However, for reasonable regions in the state space, debt-dependent rules can be welfare improving.

Figure 3.8: Welfare Gains for Rules 1 and 5

3.6 Conclusion Remarks

Many emerging economies that have recently engaged in some type of fiscal rule are now experiencing a decline in the positive correlation between government spending and GDP. For such countries, fiscal rules can be a vehicle to overcome difficulties to discipline fiscal variables and therefore stabilize macro variables.

This chapter provides a simple quantitative dynamic stochastic general equilibrium model for Small Open Economies that feature incomplete markets and endogenous financial crises. In the model, government spending and borrowing decisions are limited by an ad-hoc debt limit. At the same time, private sector faces a collateral constraint with a debt-deflation mechanism that introduces a pecuniary externality.

We use this framework to analyze different fiscal rules based on debt targeting. The presence of the pecuniary externality suggests that rules that can account, to some extent, for the effects of debt accumulation on prices can have more positive effects on welfare. Accordingly, calibrating the model to a typical emerging economy, we find that debt rules with such a feature can improve welfare by reducing the consumption and labor volatilities.

Thus, for emerging economies that suffer from problems related to financial markets, the channels explored in our model suggest that debt rules can be welfare improving if carefully designed.

Appendix A

Appendix to Chapter 1

A.1 TVAR Estimates

Figure A.1: Regime-switching in some countries in the sample

Figure A.2: Regime-switching in some countries in the sample

Figure A.3: Regime-switching in some countries in the sample

Figure A.4: Regime-switching in some countries in the sample

Figure A.5: Regime-switching in some countries in the sample

A.2 GIRFs for a positive shock on GDP

Figure A.6: GIRFs: shock to GDP. Blue line: normal regime. Red line: financial distress. Confidence interval for financial distress periods omitted for simplicity.

Figure A.7: GIRFs: shock to GDP. Blue line: normal regime. Red line: financial distress. Confidence interval for financial distress periods omitted for simplicity.

Figure A.8: GIRFs: shock to GDP. Blue line: normal regime. Red line: financial distress. Confidence interval for financial distress periods omitted for simplicity.

Figure A.9: GIRFs: shock to GDP. Blue line: normal regime. Red line: financial distress. Confidence interval for financial distress periods omitted for simplicity.

Figure A.10: GIRFs: shock to GDP. Blue line: normal regime. Red line: financial distress. Confidence interval for financial distress periods omitted for simplicity.

A.3 GIRFs for a positive shock on FSI

Figure A.11: GIRFs: Financial Shock in selected countries. Blue line: normal regime. Red line: financial distress. C.I.: Confidence Interval for the normal regime.

Table A.1: Impulse Responses for a Financial Shock

	At impact		Cumulated	
	R1	R2	R1	R2
GDP	-0.0026	-0.0034	-0.059	-0.067
Consumption	-0.0017	-0.0028	-0.053	-0.074
Investment	-0.0069	-0.0207	-0.215	-0.367

Notes: R1 stands for Tranquil Times Regime. R2 stands for Financial Instability Regime

A.4 Posterior Distribution of Prior Hyper-Parameters in Each Regime

The posterior distribution of the parameter λ_r is the tightness of the prior distribution of the VAR coefficients for a regime r . Following Gelman (2006), we use a fairly loose prior to allow the data speak. As suggested by Figure A.12, the degree of cross-sectional shrinkage is similar and well identified in the two regimes.

Figure A.12: λ_i : Cross-sectional shrinkage similarities between regimes.

A.5 Data Appendix

Table A.2: Financial Variables

Variables	EMPI: NEER, Reserves			Sovereign Spreads			Bank Stress			Stock Market		
	Country	Source	Time Span	Measure	Source	Time Span	Measure	Source	Time Span	Source	Time Span	Time Span
Argentina		GEM	1994Q1	2015Q4	Embi	GEM	1994Q3	2015Q4	Beta	DataStream	1994Q1	2015Q4
Brazil		GEM	1994Q1	2015Q4	Embi	GEM	1994Q3	2015Q4	Beta	DataStream	1994Q1	2015Q4
Bulgaria		GEM	1994Q2	2015Q4	Embi	GEM	1994Q2	2014Q1	Beta	DataStream	1994Q1	2015Q4
Chile		GEM	1994Q1	2015Q4	Embi	GEM	1999Q3	2015Q4	Beta	DataStream	1994Q1	2015Q4
Colombia		GEM	1994Q1	2015Q4	Embi	GEM	1997Q2	2015Q4	B.Spread	DataStream	1994Q1	2015Q4
Croatia		GEM	1994Q1	2015Q4	Embi	GEM	1997Q2	2015Q4	B.Spread	DataStream	1994Q1	2015Q4
Czech Rep.		GEM	1994Q1	2015Q4	S.Spread	IFS	1997Q1	2015Q4	Beta	DataStream	1994Q1	2015Q4
Ecuador		GEM	1994Q1	2015Q4	Embi	GEM	1995Q2	2015Q4	B.Spread	DataStream	1994Q1	2015Q4
Hungary		GEM	1994Q1	2015Q4	Embi	GEM	1999Q1	2014Q1	B.Spread	DataStream	1994Q1	2015Q4
India		GEM	1994Q1	2015Q4	Se.Spread	IFS	1994Q2	2015Q4	Beta	DataStream	1994Q1	2015Q4
Indonesia		GEM	1994Q1	2015Q4	Embi	GEM	2004Q3	2015Q4	B.Spread	DataStream	1994Q1	2015Q4
Korea		GEM	1994Q1	2015Q4	Embi	GEM	1994Q3	2014Q1	Beta	DataStream	1994Q1	2015Q4
Malaysia		GEM	1994Q1	2015Q4	Embi	GEM	1996a4	2015Q4	Beta	DataStream	1994Q1	2015Q4
Mexico		GEM	1994Q1	2015Q4	Embi	GEM	1998Q1	2015Q4	Beta	DataStream	1994Q1	2015Q4
Peru		GEM	1994Q1	2015Q4	Embi	GEM	1997Q2	2015Q4	Beta	DataStream	1994Q1	2015Q4
Philippines		GEM	1994Q1	2015Q4	Embi	GEM	1998Q1	2015Q4	Beta	DataStream	1994Q1	2015Q4
Poland		GEM	1994Q1	2015Q4	Embi	GEM	1995Q4	2014Q1	Beta	DataStream	1994Q1	2015Q4
Romania		GEM	1994Q1	2015Q4	S.Spread	IFS	1994Q1	2013Q3	Beta	DataStream	1994Q1	2015Q4
Russian F.		GEM	1994Q1	2015Q4	Embi	GEM	1998Q1	2015Q4	Beta	DataStream	1994Q1	2015Q4
Slovak Rep.		GEM	1994Q1	2015Q4	Se.Spread	IFS	1998Q3	2015Q4	B.Spread*	IFS/Eurostat	1994Q1	2015Q4
Slovenia		GEM	1994Q1	2015Q4	S.Spread	IFS	1996Q1	2007Q2	B.Spread*	IFS/Eurostat	1994Q1	2015Q4
South Africa		GEM	1994Q1	2015Q4	Embi	GEM	1995Q1	2015Q4	Beta	DataStream	1994Q1	2015Q4
Taiwan		NST	1994Q1	2015Q4	S.Spread	N.Stats.	1994Q1	2015Q4	Beta	DataStream	1994Q1	2015Q4
Thailand		GEM	1994Q1	2015Q4	Se.Spread	IFS	1994Q1	2015Q4	Beta	DataStream	1994Q1	2015Q4
Turkey		GEM	1994Q1	2015Q4	Embi	GEM	1996Q3	2015Q4	Beta	DataStream	1994Q1	2015Q4

Notes: NST stands for National Statistics of Taiwan. B.Spread is the spread between lending and deposit rate. S.Spread is the spread between treasury rate provided by IFS and US Treasury Bill rates, from FRED. Se.Spread is the spread between government securities and US Treasury Bill.

Table A.3: National Accounts and Macroeconomic Variables

Country	Var.	Source	Time Span	Var.	Source	Time Span	Var.	Source	Time Span	Var.	Source	Time Span
Argentina	y	GEM	1994Q1	y (c.p.)	GEM	1994Q1	c, i	IFS	1994Q1	Deflator	GEM	1994Q1
Brazil	y	IBGE	1994Q1	y (c.p.)	IBGE	1994Q1	c, i	IFS	1994Q1	Inflation	GEM	1994Q1
Bulgaria	y	GEM	1995Q1	y (c.p.)	GEM	1995Q1	c, i	IFS	1995Q1	Deflator	GEM	1995Q1
Chile	y	IFS	1996Q1	y (c.p.)	GEM	1996Q1	c, i	IFS	1996Q1	Deflator	GEM	1996Q1
Colombia	y	DANE	1994Q1	y (c.p.)	GEM	1994Q1	c, i	DANE	1994Q1	Deflator	GEM	1994Q1
Croatia	y	IFS	1997Q1	y (c.p.)	IFS	1997Q1	c, i	IFS	1997Q1	Deflator	GEM	1997Q1
Ecuador	y	IFS	1994Q1	y (c.p.)	GEM	1994Q1	c, i	IFS	1994Q1	Inflation	GEM	1994Q1
Hungary	y	GEM	1995Q1	y (c.p.)	GEM	1995Q1	c, i	IFS	1995Q1	Inflation	GEM	1995Q1
India	y	GEM	1996Q2	y (c.p.)	GEM	1996Q2	c, i	OECD	1996Q2	Inflation	GEM	1996Q2
Indonesia	y	GEM	1994Q1	y (c.p.)	GEM	1994Q1	c, i	IFS	1994Q1	Inflation	GEM	1994Q1
Czech Rep.	y	GEM	1996Q1	y (c.p.)	GEM	1996Q1	c, i	OECD	1996Q1	Inflation	GEM	1996Q1
Korea, Rep.	y	GEM	1994Q1	y (c.p.)	GEM	1994Q1	c, i	IFS	1994Q1	Inflation	GEM	1994Q1
Malaysia	y	IFS	1994Q1	y (c.p.)	IFS	1994Q1	c, i	IFS	1994Q1	Inflation	GEM	1994Q1
Mexico	y	GEM	1994Q1	y (c.p.)	GEM	1994Q1	c, i	OECD	1994Q1	Inflation	GEM	1994Q1
Peru	y	BCRP	1994Q1	y (c.p.)	BCRP	1994Q1	c, i	IFS	1994Q1	Inflation	GEM	1994Q1
Philippines	y	GEM	1994Q1	y (c.p.)	GEM	1994Q1	c, i	IFS	1994Q1	Inflation	GEM	1994Q1
Poland	y	GEM	1995Q2	y (c.p.)	GEM	1995Q2	c, i	IFS	1995Q2	Inflation	GEM	1995Q2
Romania	y	GEM	1995Q1	y (c.p.)	GEM	1995Q1	c, i	IFS	1995Q1	Inflation	GEM	1995Q1
Russian F.	y	GEM	1995Q1	y (c.p.)	GEM	1995Q1	c, i	IFS	1995Q1	Inflation	GEM	1995Q1
Slovenia	y	GEM	1995Q1	y (c.p.)	GEM	1995Q1	c, i	OECD	1995Q1	Inflation	GEM	1995Q1
Slovak Rep.	y	GEM	1997Q1	y (c.p.)	GEM	1997Q1	c, i	OECD	1997Q1	Inflation	GEM	1997Q1
South Africa	y	OECD	1994Q1	y (c.p.)	OECD	1994Q1	c, i	OECD	1994Q1	Inflation	GEM	1994Q1
Taiwan	y	GEM	1994Q1	y (c.p.)	GEM	1994Q1	c, i	N.Stat.	1994Q1	Inflation	GEM	1994Q1
Thailand	y	GEM	1994Q1	y (c.p.)	GEM	1994Q1	c, i	IFS	1994Q1	Inflation	GEM	1994Q1
Turkey	y	IFS	1994Q1	y (c.p.)	IFS	1994Q1	c, i	IFS	1994Q1	Inflation	GEM	1994Q1

Notes: GEM: Global Economic Monitor; IBGE: Instituto Brasileiro de Geografia e Estatística; IFS: IMF eLibrary Data; DANE: Departamento Administrativo Nacional de Estadística; BCRP: Banco Central de Reserva del Perú; OECD: OECD Statistics; N.Stat.: National Statistics Republic of China (Taiwan).

A.6 Estimation of the Financial Stress Index

This section briefly describes how we estimate the FSI. We construct all sub-index using monthly data from various sources prior to converting them to a quarterly basis and taking the average values in a quarter, as described in Table A.2.

Let $x_{c,t}$ be a vector of length $n_c \times 1$, where $t = 1, \dots, T^c$, containing financial sub-indexes composing an overall financial index and $h_{c,t} = (g_{c,t}, m_{c,t}, \pi_{c,t})'$, where g_t is the GDP growth in country c , m_t is the growth of M1, and π_t is the inflation rate. We assume a TVP-FAVAR with the following form:

$$\begin{aligned} x_{c,t} &= \lambda_{c,t}^y h_{c,t} + \lambda_{c,t}^f f_{c,t} + u_{c,t} \\ \begin{bmatrix} h_{c,t} \\ f_{c,t} \end{bmatrix} &= c_{c,t} + B_{c,t}^1 \begin{bmatrix} h_{c,t-1} \\ f_{c,t-1} \end{bmatrix} + \dots + B_{c,t}^p \begin{bmatrix} h_{c,t-p} \\ f_{c,t-p} \end{bmatrix} + \varepsilon_{c,t} \end{aligned} \quad (\text{A.1})$$

where p is the VAR order, $\lambda_{c,t}^y$ and $\lambda_{c,t}^f$ are, respectively, the regression coefficients and factors loading possibility time variant, $f_{c,t}$ is the unobservable factor interpreted as the financial condition index, $c_{c,t}$ in the intercept and $(B_{c,t}^1, \dots, B_{c,t}^p)$ are regression coefficients. We assume that $u_{c,t} \sim N(0, V_{c,t})$ and $\varepsilon_{c,t} \sim N(0, Q_{c,t})$, where V_t e Q_t are time varying. The identification is based on the commonly used hypothesis that V_t is a diagonal matrix, such that u_t is a vector of idiosyncratic shocks, and $f_{c,t}$ has all relevant information pertaining to financial variables. For each country, we also assume that the time-varying parameters evolve as random walks of the form:

$$\begin{aligned} \lambda_t &= \lambda_{t-1} + v_t \\ \beta_t &= \beta_{t-1} + \eta_t \end{aligned} \quad (\text{A.2})$$

where $\lambda = ((\lambda_t^y)', (\lambda_t^f)')'$, $\beta_t = (c_t', \text{vec}(B_t^1)', \dots, \text{vec}(B_t^p)')'$, $v_t \sim N(0, W_t)$ and $\eta_t \sim N(0, R_t)$, e v_t , η_t , u_t and ε_t are uncorrelated both in time as well as between equations. We use the same hyperparameter scheme as in Koop and Korobilis (2014).

A.7 Individual FSI

Figure A.13: Individual Estimated FSI for all countries in the sample

Appendix B

Appendix to Chapter 2

B.1 Numerical Solution Method

Our solution method is a variant of the algorithms for the Envelope Condition Method described in Arellano et al. (2016), extended to deal with the occasionally binding constraint. It is similar to the Euler-equation class of methods (see Judd, 1998; Santos, 1999), but instead of updating policy functions, we update the derivatives of the value function. The main advantage here is that we need to update only two variables—this number is determined by the number of envelope conditions—given the expected state of nature to compute the new guesses, which makes a significant difference in a very large problem such as discussed in the present chapter.¹ Additionally, except for the interpolation/extrapolation scheme, calculations are entirely based on matrix forms. Moreover, no rootfinding is needed.

Using the envelope conditions, the equilibrium conditions must satisfy the following non-linear system of equations:

$$u_c = R\beta V'_{B'} + \mu \quad (\text{B.1a})$$

$$-\frac{u_h}{u_c} = zF_h(k, h) - \chi(R - 1)w - \frac{\mu}{\lambda}\chi R w \quad (\text{B.1b})$$

$$q = \frac{\beta V'_{k'}}{(\lambda - \kappa\mu)} \quad (\text{B.1c})$$

¹Note that because of the assumed utility function, we also need to update the level of the value function.

where $V'_{b'}$ and $V'_{k'}$ are the expected discounted values of the derivatives of $\mathbb{E}[V(b', k', \epsilon')]$ with respect to b' and k' , respectively. The current values of the derivatives of the value function are given by:

$$\frac{\partial V}{\partial b} \equiv V_b = \lambda \quad (\text{B.1d})$$

$$\frac{\partial V}{\partial k} \equiv V_k = \left[zF_k(k, h) + q(1 - \delta) - \Phi\left(\frac{i}{k}\right) - k\Phi'\left(\frac{i}{k}\right) \right] \lambda \quad (\text{B.1e})$$

We will illustrate the algorithm for the version of the model with four shocks. It works as follows:

1. Form a meshgrid from the tensor product $\mathcal{G}^{b,k,z,R,\sigma,\kappa} = \mathcal{G}^b \otimes \mathcal{G}^k \otimes \mathcal{G}^z \otimes \mathcal{G}^R \otimes \mathcal{G}^\sigma \otimes \mathcal{G}^\kappa$. We set 100 gridpoints for b , 40 for k , and 7 for each shocked variable (resulting in a state space with 9,604,000 grid points).

2. Guess $\tilde{c}(\mathbf{s})$, $\tilde{i}(\mathbf{s})$ and $\tilde{\mu}(\mathbf{s})$.

- (a) At the iteration j , using $\tilde{i}(\mathbf{s})^{j-1}$ compute $k'^j = k(1 - \delta) + \tilde{i}(\mathbf{s})^{j-1}$, the capital adjustment, and $q(\tilde{i}(\mathbf{s})^{j-1})$ from the first order condition for Tobin's Q. Using $\tilde{\mu}(\mathbf{s})^{j-1}$, compute h^j from (C.4b) and use it to compute wage and the working capital. Finally, use $\tilde{c}(\mathbf{s})^{j-1}$ to compute b' from

$$b'^j = \max \left\{ R \left(b + zF(k, h)^j - i^{j-1} - c^{j-1} - k\Phi\left(\frac{i^{j-1}}{k}\right) - \chi R w^j h^j \right), \right. \\ \left. R(\kappa q^j k'^j - \chi R w^j h^j) \right\}$$

- (b) Compute (C.4e) and (C.4f). Use the sextet $\mathbf{s}' = (b'^j, k'^j, z', R', \sigma', \kappa')$ to update $\tilde{V}_b^j(\mathbf{s})$ and $\tilde{V}_k^j(\mathbf{s})$ and calculate $V_{b'}^j(\mathbf{s}')$ and $V_{k'}^j(\mathbf{s}')$. We use a 6-dimensional piecewise linear interpolation/extrapolation whenever the points are off the grid. To numerically integrate the expected variables, we use the monomial rule M2 as described in Judd (1998) and Judd et al. (2011).
- (c) Compute $c(c^{j-1}, i^{j-1}, \mu^{j-1})$ using (C.4a) and use it to calculate (C.4e). Then, compute $i(c^{j-1}, i^{j-1}, \mu^{j-1})$. Update $\mu(c^{j-1}, i^{j-1}, \mu^{j-1})$ using (C.4a) and (C.4e).
- (d) Use damping parameters to compute c^j , i^j and μ^j as weighted averages of the current and last guesses.

- (e) Iterate over the policy functions until a desired tolerance criterion is met (1e-10).

B.2 Simulating Nonlinear Responses in a DSGE Model

Because of the forward-looking nature of the agent's behavior and the endogenous possibility of a change in the regime, simulating paths in a nonlinear DSGE model with an occasionally binding constraint is not a straightforward task. It requires intense use of numerical methods. Due to these difficulties, it is worth mentioning some technical questions.

We first consider the impulse response functions keeping in mind the stylized facts synthesized in Chapter 1. We compute the nonlinear responses as in Gavin et al. (2013), by adapting the Generalized Impulse Responses (GIRF) described in Koop et al. (1996) to the context of a nonlinear DSGE model. The advantage of this method is that it is consistent with the agent's expectations that the stochastic process will mean reverting when the model has initiated away from its stochastic steady state, a feature that is not shared by the standard impulse response function calculated in each regime. We do so by applying the following steps:

1. Find the state vector for each regime:
 - Normal Regime: simulate the model until it converges to its stochastic steady state, $\mathbf{x}_0^{ss}$.
 - Financial Distress Regime: simulate 500,000 quarters using random draws from the technological process and find the shock that induces the economy to a binding constraint, on average. Simulate the model until it converges conditioning on the calculated state for the technological process. The initial state vector is the average state vector conditional on the binding constraint, $\mathbf{x}_0^{obc}$.
2. Draw random shocks, $\{\varepsilon_{z,t}, \varepsilon_{R,t}\}$, from independent normal distributions. In each regime, simulate D different draws of the sequence of shocks of length N starting from its corresponding initial vectors, $\mathbf{x}_0^{ss}$ and $\mathbf{x}_0^{obc}$, which will generate D equilibrium paths for each case, $\{x_t^j(\mathbf{x}_0^{ss})\}_{t=0}^N$ and $\{x_t^j(\mathbf{x}_0^{obc})\}_{t=0}^N$, where $j \in$

$1, \dots, N$. We set $N = 40$ and $D = 10,000$.

3. Using the D draws from step 2, replace the technology shock in period $t = 1$ with a 1% shock, re-estimating the model to obtain the new R shocked equilibrium paths, $\{x_t^j(\mathbf{x}_0^{ss}, \varepsilon_{z,1})\}_{t=0}^N$ and $\{x_t^j(\mathbf{x}_0^{obc}, \varepsilon_{z,1})\}_{t=0}^N$.
4. Average across R simulated paths from steps 2 and 3:

$$\bar{\mathbf{x}}_t^{ss}(\mathbf{x}_0^{ss}) = \frac{1}{D} \sum_{j=1}^D x_t^j(\mathbf{x}_0^{ss}), \quad \bar{\mathbf{x}}_t^{ss}(\mathbf{x}_0^{ss}, \varepsilon_{z,1}) = \frac{1}{D} \sum_{j=1}^D x_t^j(\mathbf{x}_0^{ss}, \varepsilon_{z,1}),$$

$$\bar{\mathbf{x}}_t^{obc}(\mathbf{x}_0^{obc}) = \frac{1}{D} \sum_{j=1}^D x_t^j(\mathbf{x}_0^{obc}), \quad \bar{\mathbf{x}}_t^{obc}(\mathbf{x}_0^{obc}, \varepsilon_{z,1}) = \frac{1}{D} \sum_{j=1}^D x_t^j(\mathbf{x}_0^{obc}, \varepsilon_{z,1}),$$

5. The GIRF is just the difference between the two average paths for each regime.

B.3 Measuring Uncertainty Through a TVP-VAR

In this section, we provide evidence for strongly time-varying volatilities in GDP growth and the real interest rate for a set of emerging economies (ARG, BRA, CHL, CHI, ECU, MEX, PER, TUR, and RUS). Data include the semi-annual GDP growth rates (proxied by the semi-annual industrial production) and the annualized real interest rates, both given on a monthly basis. To be concise, details are provided in Table B.1. Real interest rates are calculated following Uribe and Yue (2006). They are measured as the sum of JP Morgan's EMBI+ spread for each country and a measure of the world interest rate. The later is proxied by the interest rate on three-month US treasury bill minus an estimated US expected inflation, which is gathered from a simple AR(2) regression using the CPI data.

Let us briefly describes how we estimate the time-varying VAR with stochastic volatility. The procedure follows Primiceri (2005) using the following model for each country:

$$y_t = B_{0,t} + B_{1,t}y_{t-1} + \dots + B_{6,t}y_{t-6} + A_t^{-1}\Sigma_t\epsilon_t \quad (\text{B.2})$$

where y_t is a 2×1 vector ordered with GDP growth first and real interest rate second, B are time-varying coefficient matrices and A_t , and Σ_t are given by:

$$A_t = \begin{bmatrix} 1 & 0 \\ \alpha_{21,t} & 1 \end{bmatrix} \quad \text{and} \quad \Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 \\ 0 & \sigma_{2,t} \end{bmatrix}$$

Table B.1: Data Description

	Time Span	
ARG	1994Mo6	2015M10
BRA	1994M10	2016M11
CHL	1999Mo9	2016M11
CHI	1998Mo1	2016M11
ECU	1995Mo6	2016Mo3
MEX	1998Mo4	2016M11
PER	1997Mo7	2016M11
TUR	1996M10	2016M11
RUS	1998Mo4	2016M11

Notes: GDP growth proxied by monthly industrial production. Sources: Industrial production: GEM; EMBI+: GEM; US T-Bill: FRED. US-CPI: FRED.

The models are estimated with 6 lags using the algorithms provided in Koop and

Korobilis (2010). For each country, we make 80,000 draws from the posterior probability distribution. We set the size of the training sample equal to 40. The parameters $\sigma_{1,t}$ and $\sigma_{2,t}$ are the measures of uncertainty surrounding GDP growth and real interest rate, respectively. The results are plotted in Figure B.1.

Figure B.1: Time-varying volatilities for EMs. Blue line: posterior mean of the standard deviation of residuals in GDP equation. Red Line: posterior mean of the standard deviation of residuals in the interest rates equation

B.4 Implied Policy Functions

Figure B.2: Policy functions for pairs (b, k) .

Appendix C

Appendix to Chapter 3

C.1 Decentralized Equilibrium

From (3.9) under our assumed functional forms presented in section 3.4.1, we can get an expression relating l with τ and the model parameters, defined as $l(\tau)$. The FOCs to the government, (3.10), problem are:

$$u_g = \lambda^g \quad (\text{C.1a})$$

$$R' \beta \mathbb{E} V'_{d'} + \mu^g - \lambda^g \left(1 + \frac{\partial b'}{\partial d'} + R \frac{\partial c}{\partial d'} \right) + \mu^p \phi^p \left(\frac{\partial b'}{\partial d'} + \frac{\partial q}{\partial d'} k' \right) = 0 \quad (\text{C.1b})$$

plus the envelope condition:

$$\frac{\partial V}{\partial b} \equiv V_b = \lambda^g \quad (\text{C.1c})$$

where $\mu^g \geq 0$ and $\mu^p \geq 0$ are Lagrangian multipliers associated with government and private sector collateral constraints, respectively. Assuming that government takes prices as given, then the last term on the LHS of (C.4d) vanishes.

C.2 Constrained-Efficient Equilibrium: The Regulator Case

In the Constrained-Efficient Equilibrium, a planner —or a regulator— can take into account the effects of borrowing decisions on prices, internalizing that future prices

and borrowing capacities depend upon the household debt position. For simplicity and tractability, we assume that the regulator is an agent independent of the government. An equilibrium like this can be interpreted as the households committing to each other to follow decisions so as to maximize the social welfare, taking into account that their precautionary savings can reduce the systemic risk coming from debt deflation mechanism.

The planner takes the government choices as given, but accounts for the optimal choices of the private sector—as an implementability constraint—, taking into account the impacts of b' on q . The recursive problem for the planner is given by:

$$V^{sp}(d, b, k, \varepsilon) = \max_{c, l, d', k', q} \left\{ u(c, l, g^*) + \beta \mathbb{E}[V^{sp}(d', b^{*'}, k', \varepsilon')] \right\} \quad (\text{C.2})$$

subject to

$$\begin{aligned} b' &= R(b - c + (1 - \tau)F(z, k, l)) \\ b' &\geq -R\phi_p q(b, \varepsilon)k' \\ q(u_c - \mu\phi_p) &= \beta \mathbb{E}[V'_{k'}(d', b^{*'}, k', \varepsilon')] \\ -u_l &= (1 - \tau)F_l(z, k, l)u_c \end{aligned}$$

First order conditions plus the envelope conditions are:

$$\lambda^{sp} = u_c - \xi u_{cc}q \quad (\text{C.3a})$$

$$\lambda^{sp} = \beta R \mathbb{E} \left[V^{sp'}_{b'}(d', b^{*'}, k', \varepsilon') + \xi \frac{\partial V'_{k'}(d', b^{*'}, k', \varepsilon')}{\partial b'} \right] + \mu^{sp} \quad (\text{C.3b})$$

$$\mu^{sp}\phi^p q - \xi(u_c - \mu^{sp}\phi^p) = 0 \quad (\text{C.3c})$$

$$V_b = \lambda^{sp} \quad (\text{C.3d})$$

Condition for l is trivially satisfied (see Bianchi and Mendoza, 2015). The equilibrium condition for the planner's problem follows from the above system of equations, from where we can get:

$$u_c = \beta R \mathbb{E} \left[V^{sp'}_{b'}(d', b^{*'}, k', \varepsilon') + \xi \frac{\partial V'_{k'}(d', b^{*'}, k', \varepsilon')}{\partial b'} \right] + \xi u_{cc}q + \mu^{sp}$$

To get the expression for regulator's tax, we follow Bianchi and Mendoza (2015), defining tax as:

$$1 + \tau^{sp} = \frac{\beta R \mathbb{E} \left[V_{b'}^{sp'}(\cdot) + \xi \frac{\partial V_{k'}'(\cdot)}{\partial b'} \right] + u_{cc}q}{\beta R u_c}$$

The macro-prudential debt tax, which, by definition, will be in place when the constraint is not binding, can be obtained by replacing $V_{b'}^{sp'}(\cdot)$ using the envelope condition, and is given by:

$$\tau^{sp} = -\mathbb{E} \left[\frac{\xi' u_{cc}' q'}{u_c'} \right] \geq 0$$

C.3 Numerical Solution: The Envelope Condition Method with Occasionally Binding Constraints (ECM-OBC)

We illustrate the ECM-OBC method using the decentralized equilibrium (DE) as starting point. The DE is given by the system of Euler equations (3.9) and the private budget constraint for the private sector, the set of Euler equations (C.1) and the government budget constraint (GBC), plus the exogenous variables. For the private sector, given the Value Function (3.8), FOCs translate to:

$$\frac{\partial V}{\partial c} : \quad u_c - \lambda = 0 \quad (\text{C.4a})$$

$$\frac{\partial V}{\partial l} : \quad u_l + (1 - \tau)F_l(k, l)\lambda = 0 \quad (\text{C.4b})$$

$$\frac{\partial V}{\partial k'} : \quad \beta V_{k'}' - q(\lambda - \phi^p \mu) = 0 \quad (\text{C.4c})$$

$$\frac{\partial V}{\partial B'} : \quad -\lambda + R' \beta V_{B'}' + \mu = 0 \quad (\text{C.4d})$$

plus the envelope conditions:

$$\frac{\partial V}{\partial b} \equiv V_b = \lambda \quad (\text{C.4e})$$

$$\frac{\partial V}{\partial k} \equiv V_k = [(1 - \tau)F_k(k, l) + q] \lambda \quad (\text{C.4f})$$

where $V_{B'}'$ and $V_{k'}'$ are the expected discounted values of the derivatives of $\mathbb{E}[V(B', k', \varepsilon')]$

with respect to B' and k' , respectively. The first order conditions are derived using the fact that households take price of land $q(\bar{k}', \bar{k})$ and wage rate $w(\bar{l})$ as given, where variables with bars express ("exogenous") market averages, which equal the representative agent's choices at equilibrium. To find the equilibrium for the economy, we iterate over these conditions, as well as over the system (C.1), the occasionally binding constraints for both sectors, and for the budget constraints.

The main idea of the Envelope Condition Method (Arellano et al., 2016; Maliar and Maliar, 2013) is to explore the envelope conditions instead of future expected variables, since the derivatives of the value function conditioned on the state variables are fixed in every iteration. Moreover, under certain functional forms, no costly root-finding is needed —as is the case of the present model—, further increasing the gains of the method. To see this point, first note that the relevant state space is given by $\mathbf{s} = \{b, d, z, \tau\}$ for all models. The algorithm performs as follows:

1. Form a meshgrid from the tensor product $\mathcal{G}^{b,d,z,\tau} = \mathcal{G}^b \otimes \mathcal{G}^d \otimes \mathcal{G}^z \otimes \mathcal{G}^\tau$. We set 150 gridpoints for b , 30 for d , and 15 for each shocked variable.
2. Compute l from (C.4b).
3. Guess $\tilde{V}_b(\mathbf{s})$, $\tilde{V}_k(\mathbf{s})$ and $\tilde{V}_g(\mathbf{s})$.

(a) At the iteration i , use (C.4a), (C.4e), and (C.4f) to compute

$$c^i = \tilde{V}_b^{i-1}(\mathbf{s})^{-1/\sigma} + \frac{\theta}{\omega} l^\omega \quad \text{and} \quad q^i = \frac{\tilde{V}_k^{i-1}(\mathbf{s})}{\tilde{V}_b^{i-1}(\mathbf{s})} - (1 - \tau) F_k(k, l)$$

(b) Similarly, use (C.1a), (C.1b), and (C.1c) to compute

$$g^i = \tilde{V}_g^{i-1}(\mathbf{s})^{-1/\sigma}$$

(c) Use the economy budget constraint and the collateral constraints to compute $b'^i = \max\{R(b + (1 - \tau)y - c^i), R\phi^p q^i\}$ and $d'^i = \max\{R(d + \tau y - g^i), -\phi^g\}$

(d) Use the quartet $\mathbf{s}' = (b'^i, d'^i, z', \tau')$ to update $\tilde{V}_b^{i-1}(\mathbf{s})$, $\tilde{V}_k^{i-1}(\mathbf{s})$ and $\tilde{V}_d^{i-1}(\mathbf{s})$ and calculate $V_{b'}^{i,i}(\mathbf{s}')$, $V_{k'}^{i,i}(\mathbf{s}')$ and $V_{d'}^{i,i}(\mathbf{s}')$. We use a 4-dimensional piecewise linear interpolation/extrapolation scheme to approximate the future variables since it has been shown to be robust in problems with kinks.

To numerically integrate the expected variables, we use the parsimonious monomial rule M1 (with 2*2 nodes) as described in Judd (1998) and Judd et al. (2011).

- (e) Compute μ^i using (C.4a) and (C.4d). However, this step requires a simple trick to find $\mu > 0$ at the initial iterations: after computing b'^i , recompute $c^i = b + (1 - \tau)y - b'^i / R$ and use it to calculate u_c^i . Similarly, compute μ^g .
- (f) Update the current guesses for the derivatives of the value functions using the Envelop Conditions:

$$V_b^i = \beta R V_{b'}^i(\mathbf{s}') + \mu^i$$

$$V_k^i = \left[\beta V_{k'}^i(\mathbf{s}') + \theta^p q^i \mu^i \right] \left(\frac{(1 - \tau) F_k(k, l) + q^i}{q^i} \right)$$

$$V_g^i = \frac{\beta R V_{g'}^i(\mathbf{s}') + \mu^g}{\left(1 + \frac{\partial b'^i}{\partial d'} + R \frac{\partial c^i}{\partial d'} \right)}$$

Use damping parameters to slowly update the derivatives. This is necessary especially because of the dramatic changes in the initial iterations due to the presence of the kinks.

- (g) Iterate over the derivatives of the Value Function until a desired tolerance criterion is met (1e-7).

In the model with the optimal tax, we iterate over the planner's choices. When solving the models with endogenous rules, we replace $\mathbf{s}' = (b'^i, d'^i, z', \tau')$ in the step (3.d) by $\mathbf{s}' = (b'^i, d'^i, z', \tau'^i)$, where $\tau'^i \equiv \tau'(b'^i, d'^i, \tau, \varepsilon_\tau)$, iterating until convergence.

Finally, all simulations are based on a series of T=100,000. For the models with tax rules, we calculate τ' by guessing a starting value for b' and iterating through it until the changes in τ' become very small.

C.4 Policy Functions for pairs (b, d)

Figure C.1: Dynamics under Debt Rule 1.

Figure C.2: Dynamics under Debt Rule 5.

C.5 Ergodic Distributions

Figure C.3: Ergodic Distributions of Private Bonds Under Different Rules.

Figure C.4: Ergodic Distributions of Private Bonds Under Different Rules.

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